DRAIN RA OWL HABITAT 2

Figure #5
DRAIN RA OWL HABITAT 3

Figure 38
granted for these sales. In order to present a credible set
of visual exhibits, the 44 exemption sales boundaries were
captured. Prior to this we had only the RTU boundaries
of these sales in the WODDB, which was a rough
approximation of the sale boundaries.

The Oregon Governor's Office identified 81
communities severely affected by the lack of timber.
These were captured from 1:160 000 scale USGS quads.
Other themes were created using the Spotted Owl
locations we had and buffering them by different widths
based on their locations within certain zones, again a
theme we already had in the system.

We initially provided the lawyers a plot showing
location of the 44 sales. They asked for a better spatial
perspective showing the sales, main state and federal
highways and severely affected timber dependent
communities.

Support for the witnesses required more analysis
and special representations of the data. We provided
plots at 1:40 000 scale that put the sales in perspective
with the lands around them. One of the repeated
questions from the USFWS is why we did not pick
other locations for these sales. Plots were created that
merged BLM ownership, the lands taken out of base by
the SOHA's, the Habitat Conservation Areas (HCA-1,
2, 3 & 4's) established by the Interagency Scientific
Committee, the additional lands identified under the
ISC report for dispersal habitat (50-11-40 rule), and
the recently raised requirement from the USFWS
Biological Opinion that we do not harvest timber
within 1.2 to 1.5 miles of any owl nest based on
geographic province (figure #7).

These plots show little land left available for timber
harvest. Beside the 1:500 000 scale original plots that will
be used in testimony, we also provided copies of the plots
as 11x17" versions that will be reproduced and made part
of the permanent record.

In order to fully examine the effect on BLM acreage
available for timber harvest, we also intersected the
expanded owl buffers with BLM defined habitat (figure
#8) to get the total number of acres in BLM ownership
and in each habitat type (category 1 = Nesting; category
2 = Roosting and Foraging; category 3 = Other). This
exercise was based on BLM biologists attributing every
timber stand by the above categories, rather than a
standard query such as 200 plus year old stands.

To show the relative timber age of the adjacent
non-BLM lands we provided plots of BLM ownership
and the Exemption sales at a scale of 2 inches to the mile
to fit 1991 aerial photography.

December/January 1992, Feather 8

The plot continues. The Spotted Owl Recovery Team is
due to release their report, which outlines management
of critical owl habitat. The Final Critical Habitat
designations are due to be published. One hopes that at
some point there will be an agreement on what is critical
habitat, where is it and how it should be managed.

Summary

Since April of 1990 we have computed the ASQ for
western Oregon nine variations of spotted owl habitat
proposals. Prior to WODDB this would have involved
dot grid compilation of acres on 65 000 timber stands,
nine times, dividing each stand into acres available and
not-available for timber harvest based on buffered owl
sites, buffered roads, buffered streams, SOHA's, HCA's,
CHA's, CHU's and land use allocations. This totals
around 3.5 million polygons. To say it couldn't be
accomplished by hand would not be true, as BLM had
to do it! However, these projects couldn't have been
accomplished by hand in the time frame allowed or to
the degree of accuracy required without WODDB. Our
investment in WODDB began to pay off in April 1990,
and continues today.

I have spent most of my time discussing how the
Bureau is responding to different physical and spatial
definitions of spotted owl habitat. The paper by Dippon
et. al. 1992, discusses the linking to the McKelvey model.
This model, HCA's, CHA's, CHU's, our biologist's
habitat calls, and the results of the analysis of the five
RMP alternatives, including a forest biodiversity analysis
(Nighbert 1991), will be utilized in developing the last
stage of our RMP process, the preferred alternative.

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Modelling Dall Sheep habitat in the northern Yukon

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Abstract

GIS is becoming a powerful tool for mapping, planning and research in the Yukon. The Yukon Department of Renewable Resources is using GIS technology to help determine the relationships between wildlife distributions and habitat parameters.

Winter ranges, lambing areas, rutting grounds, migration corridors and mineral licks are all key habitat for Dall Sheep. This study was limited to the analysis of lambing areas. In the first phase, spring sheep locations were related to slope, aspect, proximity to escape terrain and proximity to winter range. With the modelling capabilities of the GIS we then predicted, in the second phase, lambing sites for a test region using the relationships identified in the first phase. The accuracy of the model was finally verified by overlaying surveyed lambing locations in this test area with the predicted lambing areas.

The results could be used to assess impacts of development scenarios on wildlife and assist in land use decisions in the northern Yukon. Future work will continue to include other wildlife species in various regions of the Yukon.
GIS in information management

Mapping and establishing GIS for tropical rain forest in Indonesia
Herman Hidyat, PT Adikarto Printindo, Jakarta, Indonesia

Reliability of GIS for environmental assessment in data poor regions
Kevin Barthel, University of Wisconsin-Madison, WI, USA

Using GIS and image processing to prioritize cumulative effects analysis
Steven Bernath et al., Washington State Department of Natural Resources, Olympia, WA, USA

An examination of the role of GIS in the regulatory process: the Oslo project as an example
James Case et al., CASEBiomanagement, Calgary, AB, Canada

Monitoring and modelling transboundary air quality using a GIS
Anne Lucas, IBM - Bergen Scientific Centre, Bergen Norway
Mapping and establishing GIS for tropical rain forest in Indonesia

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Abstract

The total area of Indonesia is about 780 million hectares and consists of sea (587 million hectares) and land (193 million hectares). Seventy five percent of the land is covered by forest and fifty percent of that forest is so-called Production Forest. Wood products contribute up to 30% of the national income from exports.

In order to achieve sustainable development in the forest industry and maintain the forest as a renewable natural resource, PT. Mapindo Parama is now conducting a survey and mapping of Production Forest throughout Indonesia, a total of 70 million hectares. Forestry spatial and descriptive data are being collected and later on the Forest Resource Information System will be established. All activities are planned to be finished within 5 years.

In establishing the database, PT. Mapindo Parama employs not only aerial photos at a scale of 1:20 000 but also SPOT, Landsat Thematic Mapper and Synthetic Aperture Radar Imagery. All data are being compiled and stored in digital form.

This is a report on the mapping and establishment of the GIS Project for the richest tropical rain forest in the world.

Introduction

Indonesia has the third largest Tropical Rain Forest in the world, but probably the richest one. The Government of Indonesia (GOI) has determined the Forest Land uses as shown on the next page.

The Protection Forest, National Forest and Production Forest are determined as a Fixed Forest while the Converted Production Forest is an area of forest which can be converted into other land uses such as transmigration settlements, agriplantations, etc.

The Production Forest area spreads out in several islands throughout Indonesia: 15 million hectares in Sumaters, 30 million hectares in Kalimantan, 5 million hectares in Sulawesi, 3 million hectares in Maluku and 11 million hectares in Irian Jaya. The distance between Sumatera and Irian Jaya is almost the same with that between the west coast and east coast of the USA. Currently the GOI has given the right to manage 60 million hectares of production forest area, usually called forest concession rights, to 578 Concessionaires.

Those Forest Concessionaires established the Association of Forest Concessionaires which has worked hand in hand with the GOI, in this case, Ministry of Forestry, to develop the best...
- Protection Forest 30 million hectares
- National Forest/National Reserve 19 million hectares
- Production Forest 64 million hectares
- Converted Production Forest 30 million hectares

143 million hectares

systems for managing the Indonesian Tropical Rain Forest. Both parties realize that achieving sustainable development in the forest industry and maintaining the forest as productive contributes significantly to the Indonesian economy currently and in the future.

To support the above policy, the Ministry of Forestry and Association of Forest Concessionaires have begun to conduct a forest inventory, monitor and, later on, to establish a Forest Resource Information Systems.

**Contribution of forest products to the national revenue from export**

Before oil prices crashed in 1986, Indonesia was famous as one of the oil producing countries. Almost seventy percent of its national revenue from export was oil money. In 1985 non-oil exports contributed only 32% to the national revenue. But gradually, these non-oil exports have played a more and more important role. Currently oil money contributes only 40% while non-oil products contribute 60% to national revenue.

One of the components of non-oil products is wood product. While the income from wood product was US$ 1.3 billion in 1985, it tripled in 1990 and is projected to be US$ 8-10 billion every year in the next five years.

The forest industry absorbs almost 3.5 million people in various related industries from logging companies to woodworking factories. That means that the forest industry in Indonesia is a very labour-intensive industry. If one family consists of 4 people (husband, wife and 2 children), it means this forest industry sustains 14 million peoples' lives.

Realizing this situation, the Indonesian Forest Community has committed to achieve sustainable development in the forest industry and maintain the forest as a renewable natural resource.

**Sustainable development in forest management**

Forest Inventory plays an important role in obtaining better information regarding forest resources, such as merchantable, and lesser known species, their diameter distribution, topography, soil conditions and climate. To attain information on growth, inventories on primary forests and residual stands will be undertaken. Residual stand inventories will be done directly after logging operation, and will be repeated five year thereafter and one year prior to harvesting. Based on the characteristics and nature of each forest, which vary greatly from place to place and from type to type, the policy regarding the size of management unit areas, age cycle, cutting cycle and allowable annual cut can be formulated.

In order to maintain sustainable forest management, the MOF employs a progressive sustained yield principle. That is why the MOF imposes 3 silviculture systems which are:

1. TPTI which is Indonesian Selective Cutting and Replanting System, a version of the shelterwood system. The TPTI System is based on the amount and diameter of nucleus trees per hectare. The minimum diameter for allowable cutting tree is 50 cm, while residual stands should have a diameter of more than 20 cm and minimum 25 trees per hectare. The cutting cycle is 35 years.
2. THPA is a clear felling with natural regeneration.
3. THPB is a clear felling with artificial regeneration. One example of this system is HTI (Industrial Timber Plantation Forest).

Each system above has its specification criteria. Which system to be employed in a production forest area will be determined by the MOF after evaluating the inventory survey results carried out before. Currently, most of the Forest Concessionaires are using the TPTI system, but the MOF has also encouraged some of them to do HTI.

**Forest inventory and database**

Good forest management is impossible without good inventory data. In this case, forest inventory is considered to be synonymous with timber estimates. That is why forest inventory is an attempt to describe the quantity and quality of forest trees, especially the merchantable tree species, and many of the characteristics of the land area upon which the trees are growing. So, we can categorize this forest inventory as timber-oriented inventory.

The purpose of forest inventory is to establish a database of the entire Production Forest throughout Indonesia. In the first stage, some activities (following) have been done:

a. Aerial Photography at a scale of 1:20 000
b. Photogrammetric Mapping to produce form line map at a scale of 1:25 000.
c. Photo interpretation to produce Vegetation Map at a scale of 1:25 000.
Base maps and ground control points
The National Agency for Survey and Mapping - BAKOSURTANAL - is a government organization which is responsible for establishing ground control points networking and base maps in Indonesia. Unfortunately, they have not finished the work yet. The area in which Base Maps 1:50 000 and Ground Control Points are already finished are Java, Bali and Sumatera Islands and some areas along the coast in Kalimantan and Sulawesi. For the rest there are only JOG Maps at a scale of 1:250,000 available, which were published by the US Army Map Services.

Facing this problem, the Ground Control Points network will be established in the early stages by employing the Global Positioning Systems method for the area which have no base maps or Ground Control Points.

Improper base maps in certain areas also cause navigational problems in taking aerial photographs, that then result in abundant stereo models of photograph. In average one stereomodel 1:20 000 contains 300 hectares only.

Aerial Photography
Panchromatic B/W aerial photography at a scale of 1:20 000 is being done throughout Indonesia to cover the entire Production Forest of 64 million hectares. The company now operates 10 aircraft equipped with aerial survey cameras with focal length of 15.2 cm. The production rate of photography is about 2 million hectares per month. This seems to be a very low production rate, but this is actually quite a reasonable rate since Indonesia lies in the equator. So, one of the biggest problems is cloud cover. Every month approximately 6500 stereo models are produced.

Photogrammetric mapping
In order to produce Form-Line Maps with the scale of 1:25 000 some analytical and analog stereoplotters are used. Since all data are processed digitally, the analog stereoplotters are converted into semi-analytical ones. Using 5 Zeiss Planicomp and 6 Wild B8 Stereoplotters, almost 40% of the work is done in the company, while the rest of the job is to be subcontracted to other Indonesian mapping companies.

The size of the map is 55cm x 55cm; that means one sheet of map contains approximately 18 900 Ha. Maps editing, joining and sheet creation are done digitally. All systems are working in AutoCad environment-PC Version.

Vegetation mapping
Photo-interpretation is done in order to get information on vegetative cover type, crown density, stand height, Crown diameter and to derive categories such as volume classes. Stratification of the forest is done on aerial photographs with a forest class map as follows:

- Crown closure density (C)
  - C1 : 10 - 40%
  - C2 : 41 - 70%
  - C3 : 71 - 100%

- Stand height (H)
  - H1 : 10 - 20 m
  - H2 : 21 - 30 m
  - H3 : > 30 m

- Crown diameter (D)
  - D1 : < 10 m
  - D2 : 10 - 20 m
  - D3 : > 20 m

Forest photo interpretation is concerned with recognition of forest cover types, the delination of areas, the measurement of trees and stand and the estimation of timber volume afterward by combining them with ground sampling results using a regression analysis method.

The volume of forest stands can be estimated on aerial photographs to the extent that it is correlated with tree heights, Crown width, and Crown closure. Based on ground sampling, the stand aerial volume table predicts the average stand volume expected for a given stand height and crown closure. Crown width is sometimes also taken into consideration.

Using 6 Zeiss Stereocord and manual mirror stereoscopes almost 40% of the work is done in the company.

Spot and Landsat TM
For the areas which have not been covered yet by the aerial photos, SPOT and Landsat TM images are being used, especially those which were taken after 1988. As aerial photographs, the spaceborne images which are cloud free are difficult to get.

Based on the images, a general specification of forest cover type can be determined. This technique is usually applied to determine whether virgin or primary forest areas or Industrial Timber Plantation Forest Areas are to be established. Interpretations of the images are done in two ways, i.e. manually and digitally, through the image processing system method.

The company has been using 156 scenes of SPOT images covering approximately 20 million hectares owned by 344 Concessionaires and 7 scenes of Landsat TM image covering approximately 10 million hectares.
Synthetic aperture radar (SAR)

It has historically been very difficult to obtain airborne aerial photographs or optical satellite imagery of almost 20 million hectares of production forest areas as they have been obscured by cloud. Toward the area mentioned above and integrated multi-system approach of substitution Remote Sensing Technologies will be applied.

The company and Ministry of Forestry are now conducting a Pilot Study on the application of SAR for forest inventory and management in Tropical Rain Forest Areas, especially over mountainous or generally hilly areas.

The overall concept for the Pilot Study Program is as follows: the first phase of the program would be to collect Synthetic Aperture Radar (SAR) image data over the study area in Kalimantan to provide guaranteed, high-resolution, cloud-free imagery. The high resolution SAR Mode provides resolution of 6 x 6 m using a swath of 23 km. SAR data collection is carried out in side-looking mode with a nominal 70% overlap between adjacent swaths. In the second phase of the program, helicopter mounted low-altitude photography (heliboom) would be collected to provide sample plot information within this study areas. The third phase of the program would possibly be collecting laser profile data in grid over the study area, including the sample plot areas.

The SAR data are used to provide complete broad area coverage, to generate topographic contour and forest cover types information, and to select sites for heliboom photography sampling. The heliboom photography will be used to provide the density and crown diameter information as well as species mix data. The laser profile information will provide tree height information and be used to tightly register the topographic contours. The sample plot and field sample data will be extrapolated to cover the entire study area using the interpreted SAR data as a guide. Further field visits will be made to the study areas to assess the accuracy of the extrapolation. Recommendations will be made to optimize the operational use of the technologies demonstrated.

Monitoring systems

In general, reinventory of forest will be done every 5 years to update the established data base and for monitoring purposes. For general and broad view spaceborne images (SPOT, Landsat TM, Radarsat, etc.) will be employed, but toward specific areas which are identified from spaceborne images are needed to get more detailed data will be photographed using fixed wing aircraft and heliboom. An integrated image processing system will be established.

Annual field reports provided by Forest Concessionaires will also be used as a tool for monitoring and updating of data base purposes.

Forest resource information systems support forest management

Geographic Information Systems will be established in the company to serve the Association of Forest Concessionaires, Forest Concessionaires Companies and also the National Forest Inventory Program done by the Ministry of Forestry.

The Association and Ministry of Forestry need the information for strategic policy and Forest Management purposes, while Forest concessionaires companies need the information for operational and forest management purposes. A system design of GIS and prototype was finished last month. It is planned that the GIS activity will be started in July this year.

Conclusion

Establishment of a database of Forest Inventory and Forest Resources Information Systems (FRIS) in Indonesia as the Third Largest Tropical Rain Forest in the world needs big efforts and strong commitments to accomplish the task. Mapping, Forest Inventory data and FRIS are very important tools to support management of forest as a renewable natural resource.

The physical well-being of people everywhere depends upon the way they use their natural resources

B. Husch — FAO
Reliability of geographic information systems for environmental assessment in data poor regions

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Abstract

The intent of this paper is to advocate the use of GIS in environmental assessments with cognizance of limitations inherent in GIS processes and data. The implication of these limitations are discussed in the context of environmental assessment and natural resource planning in 'data poor' developing countries.

GIS analyses are constrained primarily by limitations inherent in the source material used to create the data base, such as base maps and imagery, and to a lesser degree by the errors introduced in the computerization of these data. Limitations in data quality degrade the reliability of GIS results, and consequently restrict their value in the decision-making process. The analytic power of GIS can also be used inappropriately. Like statistics, GIS is based on core concepts and assumptions that, when ignored, can lead to erroneous or misleading results. These issues are especially significant when GIS is used to study areas where data simply do not exist or where existing data are of poor quality. Such is frequently the case in many developing countries.

The authors conclude that GIS can fulfill an immediate need in the environmental assessment of development projects. However, in order for project decision-makers to use GIS results to make better assessments, and more financially and environmentally certain decisions regarding project areas, they must have an understanding of the constraints inherent in the information provided by GIS. Because data are often incomplete, out-of-date or inaccurate in data poor regions, GIS should be used to encourage local and international interaction in the project planning process, and to determine problem areas for further in depth study, rather than as a definitive planning tool.
Introduction

The importance of striking a balance between economic growth and the impact of this growth on the natural resource base and natural environment of a country, is becoming increasingly apparent. However, in many developing countries seeking economic development, natural resource reserves constitute a significant, if not the major component of national capital endowments (Bromley, 1986) needed to promote economic development. Concern regarding the use of these resources, combined with the possible degradation of the natural environment has lead to increased public and environmental organization scrutiny of development projects. This scrutiny has also increased awareness by lender and borrowing countries as to the local and global environmental effects of development projects.

Natural resource based development projects that appear economically feasible, can be detrimental to the long term sustainable development of the area without informed decisions based on reliable information. In the case of one multinational development lending agency, the World Bank, the requirement of an environmental assessment (EA) for any project having the potential of causing adverse environmental impacts has been initiated. Results from the EA seek to provide project decision-makers with information on ways of improving projects environmentally, and minimizing or compensating for adverse impacts early in the project planning process (World Bank Operational Directive 4.00).

While the EA requirement is relevant, and it is apparent that EA's will become increasingly important in supporting development project decisions, to be effective, each EA will require diverse information on the natural resource base as well as the existing ecology and infrastructure of the project area. Responding to the requirement for EA's, project managers are now realizing the need for information and the necessity of new tools to help in gathering it, analyzing it, and identifying actual impacts in practice.

Need for geographic information to support development projects

Economic development policy has frequently been formulated without adequate information pertaining to the countries natural resource base, the existing environmental condition or the environmental impact of proposed development projects. Typically, physical barriers, cultural differences and political impediments combine with the 'datapoor' conditions commonly found in developing countries to make performing an EA a costly, time-consuming and complicated task. As a result of the EA requirement and the difficulty in performing them, there is concern that without new approaches, project managers and decision-makers may rely on existing, possibly out-of-date assessments and unreliable information in their decision process.

Land information is particularly important to developing nations in order to prevent wastage of scarce resources (Dale and McLaughlin, 1988), and to provide a basis for rationally derived, environmentally aware, economic development policy. In many developing countries, accurate land information is not readily available, and that which is available is commonly incomplete or out of date (Morgan, 1990). This deficiency has become apparent, and is well recognized throughout the development field. According to a 1986 internal World Bank study, development projects requiring large and small scale map data, accounting for nearly $800 Million (US), were delayed due to lack of adequate land records and land information. This figure will undoubtedly rise as more lending is targeted for environmentally oriented programs, (Morgan, 1989).

Several geographic data collection programs are now established. Examples of these are, the African Remote Sensing Program (Hassan, et.al., 1991), and the Famine Early Warning System (USAID) in Africa, the Regional Remote Sensing Program in Asia and the Pacific funded by the United Nations Development Program (UNDP) (Changchui, et.al., 1991, Brooner, 1988), and the UNDP Global Environment Monitoring System (GEMS). Many developing countries, however, have either no collection program, or no effective strategy of managing and analyzing these data for use in an integrated development plan. An integrated approach seeking to coordinate individual country efforts and needs, with development agency data acquisitions has been proposed by the World Bank (Hassan, et.al., 1991).

The importance of natural resource data and lack thereof, is recognized throughout the development community. A 1988 United States Agency for International Development (USAID) report states, the principal need in the developing countries is for information which will support the production of food, specifically natural resource information. The report expressed the need for increased use of remote sensing and geographic information systems (GIS) technologies to provide this information.

USAID's involvement with GIS is similar to the World Bank's approach. The intent of these agencies is to encourage the use of GIS in projects where the benefits are compelling. This is done by preparing and disseminating reports describing GIS applications in development projects, determining and reporting on the costs/benefit of GIS, and providing technical support to project planners in preparing technical specifications for the use of GIS/Remote Sensing/Surveying and Mapping technology in development projects (Brooner, et.al. 1988). (Author's note: cost/benefit reports, which significantly influence the use and value of GIS, are lacking. A research proposal examining this issue has been proposed to the World Bank (Jagannathan, et.al., 1990)).
Currently there is no commonly accepted method of analysis used in the EA process to alert policy makers to the environmental consequences of their actions. However, with much of the potential impact of development projects being spatial in nature, the geographic framework and spatial data handling capabilities of GIS seem well suited to provide the needed approach to integrate environmental, natural resource, cultural, and economic data in order to analyze possible impacts.

**Geographic information systems: their use and constraints**

Baseline studies of the natural resources within a project area, including land use surveys, soil surveys, vegetation studies, and forestry studies, are typical requirements of an environmental assessment of an economic development project area. Primary data on these resources can be acquired by combining various map and imagery sources, if available, through GIS functions. GIS provides its user with the means to integrate data and examine interrelations between natural resources and human activities. GIS also provides the ability to develop "what if" scenarios. Experimentation with various development scenarios can help determine the impact of a development project on the existing condition. These GIS functionalities appear well suited to aid the environmental assessment process.

GIS has been used successfully, and increasingly, by individuals and agencies in wide ranging disciplines to provide information in support of various environmental policy decisions. With success, GIS and the analytical capabilities it provides finds its way into the work places of the non-geographer or mapping scientist. These users may have little understanding of the intricacies of analyses GIS makes possible, nor how the inherent limitations of source data used in these analyses will effect the reliability of the resulting information.

Unwary use of GIS, and particularly the unwary use of unreliable information resulting from analysis of poor quality data, is a significant concern. These concerns increase when the consequences of decisions based on GIS information are so potentially costly, environmentally, socially and economically.

Considerable research has been done on the spatial data quality and GIS error propagation issues referred to in this report. Results of these studies seek to raise awareness to the issues, and commonly, and appropriately call for additional research to develop error models (Verenin, 1990) and methods for assessing data quality (Mead, 1982). Research at NCGIA/Maine on the visualization of spatial data quality (Clapham and Beard, 1991), and the 'fitness for use' studies at the University of Washington (Chrisman and Lester, 1991) are current examples of these efforts. Nevertheless, the statement made by Goodchild in 1990 still holds, "the GIS systems currently available have basically ignored the fact that most spatial data used in these precise computerized analyses are not always perfectly accurate". Nor will they ever be. However, today's GIS systems allow users to stretch data beyond its original intent (Goodchild 1991), and violate fundamental mapping conventions with no consideration of the limitations inherent in most source data used in the processes.

Continual technological advancements and constant market force necessitate studies that reach beyond data quality and error propagation issues. Indisputably, the effects of inadequate spatial data, and the error introduced by computerization of these data are not to be ignored. However, research examining the effects of these limitations on the reliability and usability of information derived from the GIS analysis of these data, and its use in the decision process is noticeably lacking.

**Difficulties associated with GIS analysis**

The fundamental limitations to GIS analysis are essentially fourfold. They are: the operational limitations which result from the computerization and analysis of geographic information, the inherent limitations in the source material used in analysis (Vitek et al. 1984), the possibility that the user is unaware of these limitations, and the inability of current GIS software to inform users if appropriate suppress potential misuses.

**Inherent Limitations**

Cartographic generalization on maps used as GIS source data represent one limitation to GIS analyses. Maps produced at all scales are abstractions of reality. When producing maps at small scales cartographers are restricted in the amount of detail that can be portrayed. As a result of scale limitations, the cartographer begins to systematically (and sometimes unsystematically; referred to as cartographic license) omit detail from the source document when compiling the small scale map document. Enlarging the scale of the small scale map only produces an enlarged portrayal of generalized data. Detail and information omitted during the generalization process is not, and can not be recreated by simple enlargement.

The scale of the map used as GIS source should be consistent with the scale of the decision being made. For example, it is apparently inappropriate to use a 1:1,000,000 generalized vegetation map to determine vegetation cover at the town level. This warning may be elementary, but it was done in a recent World Bank pilot study because no other vegetation cover data was available. The point here is not whether this operation can be done with GIS, it can be. But, that it should be done with understanding of its affect on the resulting information. In the example mentioned, the vegetation data was used to demonstrate the capabilities of GIS, to show the need for larger scale data, and to promote discussion in the project planning process.
Other limitations in source material result from positional and attribute error, map projection distortions, the "fuzzy boundary" problems associated with mapping physical features (e.g., soils, vegetation, geology), and the inability to determine the distribution of data within a thematic area.

**Operational Constraints**

The inherent limitations found in maps used as source material for GIS databases and analysis can be increased through data manipulation (Vitek, et al., 1984). Operational limitations include errors introduced during digitizing, the numeric errors resulting from performing mathematical computations performed on single precision computers, the problems that arise when representing vector and polygon data in a raster format due to grid resolution constraints (Burrough, 1986), and the problems associated with polygon overlay, namely the creation, and miscoding of "spurious" polygons that can result (Goodchild, 1978).

One of the major strengths, and commonly used purposes of GIS is to combine digitized map data from various sources, regardless of scale. Ironically, this function may also be one of its most problematic. The map overlay process allows users to integrate various types of spatial data into one data file and then perform queries on, or portray results from the newly created combined data. While the use of map overlay enables more extensive and more efficient analysis, the user must be aware of the problems associated with it.

Regarding the digital map overlay process Abler (in Goodchild, 1987) states:

"Two GIS capabilities that excite enthusiasm among potential users are the ability to change map scales and the ability to overlay maps at random. Both capabilities are indeed exceedingly useful: they constitute much of the comparative advantage GIS holds over spatial analysis based on analogue maps. Both capabilities may also mislead decision makers who are unaware of the imprecision inherent in all cartography and who are unversed in the ways errors compound when map scales are changed or when maps are merged".

To strengthen Abler’s assertion, Dahlberg (1986) warns that integration and relation of map data from various unrelated sources using GIS is a uncertain proposition unless the data base has been assembled from sources of high quality. Unfortunately, most developing countries fall into the 'data poor' category.

Functionally, map “overlay uses position information (geometry) to construct new zones which share parentage from the separate layers” (Chrisman, 1990). The primary concern with overlaying polygon 'coverages' is that false sliver polygons with erroneous attributes are unintentionally created. These slivers result primarily from the generalized boundaries portrayed on maps, and also from variations in individual used to digitize maps used as source material.

Because of these inherent data and operational limitations, the user of GIS for environmental assessment in 'data poor' regions faces a dilemma. While GIS provides a tool to effectively derive information, the reliability of decision ready information is directly related to the original quality of the data.

Acquisition of quality primary data (i.e., from field surveys tied to accurate survey measurements (GPS), or differentially rectified aerial photography) require time and money. These resources are at best scarce when developing countries are paying the bill and waiting for the project to begin. These constraints to GIS analysis can be controlled however, by acknowledging and understanding data and computerization limitations, and carefully planning data acquisition strategies.

Unfortunately, it is more common that data quality issues are ignored or unconsiously overlooked in the project planning and data acquisition stage; due to time constraints, or lack of knowledge.

The issue here is not whether errors or inaccuracies in spatial data exist; they do. Rather the issue is to make non-technical GIS users aware of these limitations. Analysis and use of poor quality data suggests uncertainty in the results of GIS. This uncertainty increases the risk associated with decisions made from these results. GIS has been used effectively and successfully in applications where source data is available and of traceable lineage and quality. There must be however, concern regarding the reliability and even the validity of GIS analysis performed on data of poor quality.

**Information Reliability and Decisions**

To further complicate the situation, and to suggest a more significant limitation of today's GIS systems - they do not provide the means for determining the reliability of information they produce. Unfortunately, the computerization of spatial analysis with its rapid response may imply, to the unaware, an unfounded belief of unquestioned reliability in the output of these systems.

Because of these characteristics, a real problem occurs when trying to determine the ultimate value of GIS information in the decision process. GIS Geography/mapping science professionals have been unable to convince the typical GIS users as to the importance of data quality and operational limitations, and how these factors can constrain the GIS process. There are at least three reasons for this inability. We are unable to keep up with the rapid increase in GIS users from non-mapping backgrounds, the issues of data quality and information reliability are seen by many users as a negative response to the overwhelmingly positive accounts of GIS application, and despite the quality and abundance of papers dealing with these issues, we have been unable to express their significance in terminology that is familiar to users with different disciplinary backgrounds.
Discussion

GIS can be used to collect, integrate, and analyze diverse spatial data to provide information on a variety of development issues; whether they be evaluating the regional impact on natural resources of economic development projects (Jagannathan, et al., 1990), assisting land use mapping in the Philippines (Luscombe, 1990), supporting coastal resource planning and management in the Mediterranean (World Bank/European Investment Bank, 1990), facilitating land titling in Thailand (Williamson, 1986), or providing information to assist environmental assessments of development projects. However, a viable solution to decreasing the environmental impacts of development projects will only result from meaningful, responsible, and defensible policy, which GIS can merely influence. What GIS provides is a new view of existing geographic data, including imperfections. It is the GIS analyst’s responsibility to understand the limitations of the information resulting from GIS, and to apprise the decision-maker as to its reliability so that it is used in an appropriate, responsible and defensible manner.

While more complete and reliable information seems to be important, another question arises. Does better information really provide for better natural resource, environmental, land use and development policy decisions? Reflecting on what is still the ultimate question, Zwart (1986) refutes the contention that better information will automatically result in better environmental decisions due to the complexity and multifaceted nature of these issues. In response, Niemann (1987) called for broad institutional change, and efforts towards technology transfer and departmental cooperation in data sharing as the key to better use of the information which GIS can provide.

These views come from the developed world. In the context of developing countries, the words multifaceted and complex do not begin to define the difficulties confronting economic and environmental policy making. And the social, economic, and political obstacles to institutional change, and departmental cooperation may be beyond definition. It is in these conditions that the use and value of GIS will encounter a staunch test.

The real concern in developing countries is upgrading human life. The authors question whether GIS can have an immediate and direct affect on these concerns without extreme institutional changes. However, we feel if used appropriately, GIS can provide far more information on project areas than previously available, as well as information regarding the potential impact of development projects. The issue is not simply the use of GIS for technology sake, but the use and value of the information provided by GIS technology in making decisions. We believe that if used with an understanding of its limitations and if the ‘right’ questions are asked, GIS can provide information to illuminate illogical and indefensible decisions. And perhaps, the information that results will provoke the necessary institutional changes.

The task ahead for GIS advocates is to continue fostering interest in GIS. We should continue demonstrating the potential uses of GIS and related technology to a variety of disciplines. Concurrently we must educate ourselves, and prospective GIS users to the existence of limitations in source material, as well as the operational constraints of GIS. If we are successful in understanding and fostering awareness to these issues in the ultimate user, the decision-maker, then together we can discuss and determine conditions for information use. The decision-makers themselves may have the ultimate knowledge as to the required level of information reliability. They are presumably more aware of the gravity of the decision being made, the degree of defensibility and responsibly required, and the amount of risk they are willing to assume.

These are not easy tasks. To be successful, it will require continued effort on the part of GIS professionals to cross disciplinary lines as advocates of the technology. It will require GIS professionals to understand the constraints and to explain these constraints in an understandable manner to a variety of scientists and policy makers. Ultimately the success of GIS will depend on the success of the decisions themselves.

Conclusion

Dr. David Simmonett suggested several years ago that development decisions in developing countries are made in a atmosphere of great uncertainty due to the weaker information base found there (in Morgan, 1990). As a consequence of this data poor condition, sometimes undesirable economic, cultural and environmental decisions occur. Yet, regardless of this lack of information, development projects continue to be identified, prepared, and implemented (Luscombe, 1986).

The much heralded advancements in GIS technology and its influence in changing the world has yet to do much to change the situation in developing countries. As tersely stated by a GIS software distributor from Sri Lanka, “developed countries are using GIS to organize what is already organized, it will prove more difficult to use GIS where things have yet to be organized”.

Using GIS for analysis and development project impact modeling can be an effective instrument for providing information to aid the environmental assessment process. While the extent of technology used is ultimately dependent on the specific project, the utility of GIS is undeniable. However, due to the ‘data poor’ conditions commonly found in developing countries, the results and reliability of GIS analysis may be limited. Constraints arising from this condition make results of these analyses less valuable and possibly misleading if used as a definitive planning tool. Therefore, the authors believe the results of GIS analysis of ‘data-poor’ regions

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should be used primarily as a means to raise awareness, encourage discussion, and facilitate expert interaction in the project planning and environmental assessment process of development projects.

References


1 The term "reliable information" is used in this report to describe the result, or product of analyzing quality data with GIS. The reliability of information is a direct result of the quality of data used in analysis, and has a direct impact on how the information can, and will be used in the decision process.

2 The term "data poor" is used to describe a general "data environment" condition where a lack of quality data exists.

3 Realizing the word "better" is subjective, the authors use it to mean improved, logical and equitable. It should be noted that the authors believe one of the primary motivations for using GIS is to help reveal illogical and/or self-justifying (primarily land use) decisions.
Using GIS and image processing to prioritize cumulative effects assessment

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Abstract

Concern for the potential cumulative effects of forest practices on wildlife, hydrology, fish, and erosion/sedimentation has become critical throughout the West. In an effort to analyze the cumulative effects of forest practices in Washington, the state's Department of Natural Resources has initiated a project to assess the potential for cumulative impacts for each forested basin across the state. Because detailed assessments in basins or across the landscape cannot occur simultaneously state-wide, a system of priorities for identifying basins that are most susceptible to cumulative effects has been developed using GIS and image processing technologies.

For example, harvest in the rain-on-snow zone of the Pacific Northwest can change the runoff characteristics of a basin affecting channel morphology, water quality, and fish habitat. The water available for runoff can be calculated from (1) NOAA 10-year 24 hour precipitation data, (2) rain-on-snow information, and (3) classification of the size and crown closure of forest stands based on interpretation of Landsat imagery. Such data can be used to prioritize basins as to the risk of sustaining adverse cumulative effects. Management and/or regulatory strategies for harvest can be formulated to avoid significant environmental impacts.
Background

Definition — Cumulative effects (in the forest) are the changes to the environment caused by the spatial and temporal interaction of natural ecosystem processes with the effects of two or more forest practices.

Washington’s State Forest Practices Board2 (FPB) has recognized concerns regarding cumulative effects (CE) for more than 10 years. In 1982, in an effort to begin to address CE, Ecosystems, Inc. was hired by the FPB to prepare a document that presented current knowledge of CE with respect to forest practices (Geppert et al., 1984). A second task in the original request for proposal was to conduct basin examinations in Washington relative to CE; this activity never began.

In the following three years pressure mounted for further regulation of forest practices. The pressure manifested itself in legislative power struggles between the interested parties, wars between experts in front of the FPB, and litigation. In an effort to curtail these divisive activities, the Timber-Fish-Wildlife (TFW) agreement (1987) was negotiated by four interest groups: Indian tribes, state agencies, forest landowners, and environmental organizations. This agreement ultimately changed the Forest Practices Act3, the forest practices regulations4, and inspired cooperative efforts, including joint research and a commitment to work together on the ground. However, the agreement and subsequent changes in the regulation of forest practices did not result in a process or method for dealing with CE.

In 1989, the TFW cooperators approved an issue paper (Golde et al., 1989) recognizing that CE should be addressed comprehensively. That effort resulted in asking TFW’s Cooperative Monitoring, Evaluation and Research (CMER) committee to focus more of its energy into research that would fill the holes in our knowledge regarding CE. In addition, the FPB had not addressed CE specifically in the regulations. This limited the conditioning of forest practice applications for CE (Olson, 1989) by the Department of Natural Resources5 (DNR).

Two events occurred in 1989 prompting action in addressing issues that had not been resolved in TFW. The first was a lawsuit concerning CE as a result of proposed harvest around Lake Roesiger. The other was a second round of negotiations, known as the Sustainable Forestry Roundtable (SFR).

During the SFR negotiations, the same parties that participated in the TFW Agreement plus a new interest group, local governments, asked CMER: “Given current knowledge, what kind of technical approach could be used to begin dealing with cumulative effects?” CMER responded to the request with an initial report to SFR regarding how CE might be addressed (1990). While SFR incorporated this information into their proposal (1990), the negotiations ultimately failed. Several attempts were made during the 1991 legislative session to codify some of the concepts contained in the SFR proposal, including analysis of CE, but these, too, were unsuccessful. What the Legislature did provide was incentive. If the FPB would, by July 1, 1992, adopt regulations that address CE, wetlands, wildlife, rate of harvest, and clearcut size and timing, then dollars for implementation of the new rules would be made available.

To identify a methodology for approaching CE, the DNR, in consultation with CMER, was directed to complete the work originally initiated by SFR and to provide a scientifically-based tool for the FPB by March 1, 1992 (WAC 222-16-046). This effort has culminated in a proposed framework for dealing technically with CE on a watershed basis for state-regulated forest lands in Washington (12 million acres).

Cumulative effects assessment6

Currently, regulatory decisions on forest practices rely mostly on professional knowledge and evaluations regarding local conditions, i.e., the state of the forest-practice unit and areas directly adjacent to it. The ecosystem- and basin-wide perspectives are typically absent. Similarly, the resource information necessary for assessing existing or potential cumulative problems, the methods of analyzing the information, and standardized means of communicating the results among interested parties are generally inadequate or nonexistent.

A basic premise behind CE assessment is that landscapes differ in their sensitivities to forestry activities. Hydrologic and geomorphic processes vary spatially with differences in climate, geologic materials, structure, and terrain; vegetation and habitat conditions are partly controlled by these processes and by the history of natural and human-caused events in the forest. Furthermore, the broad class of activities encompassed in ‘forest practices’ has an equally broad spectrum of potential effects on the environment.

Because of the diversity of operations and conditions, all areas are not equally sensitive to any particular forest practice, and probably no area is sensitive to all possible negative effects. Consequently, the risks to water quality, fish and wildlife habitat, and public improvements associated with the range of management activities vary from place to place.

The essence of our approach is to develop a more explicit and objective procedure for performing and displaying basin-scale environmental evaluations. The results will be used by managers to design local strategies to address identified CE problems.

The design

The CE assessment examines basins for existing ecosystem conditions, actual and/or potential vegetation
changes, accelerated erosion, increased flooding, deterioration of water quality, and changes in stream morphology. Many of these factors are evaluated with respect to fish and wildlife habitat needs. Resource impacts resulting from both natural background conditions and past human activities are considered.

The assessment of basin-wide hazards and the forestry activities likely to affect them can assist managers in minimizing both local and cumulative problems by aiding in the design of watershed-specific harvest plans. Subsequent operations may incorporate best management practices specified in the forest practices regulations, or alternative measures where appropriate.

Evaluation of risk to public resources helps in establishing appropriate decision criteria based on water and habitat-quality standards. Appropriate conditioning of forest practices to minimize the potential for significant adverse effects is the result. In addition, the assessment can be used to identify opportunities for monitoring to determine the effectiveness of management and regulatory actions in meeting public-resource objectives.

It is intended that CE assessment will eventually take place in all basins containing state and private forest land. However, staff and funds are not available to perform all work on all basins in a short time. Therefore, the CE assessment has been organized into two phases of analysis. Level 1 analysis is intended to be performed over approximately six months. Existing information, regional staff, and local expertise will be used to look at all the basins of the state containing forest lands. Level 2 analysis will be performed using "certified" watershed analysis teams, funded by the legislature or provided by others (such as landowners or tribes). This analysis will deal more intensively with basins of concern, gather more information, and identify critical decision criteria.

Watershed screening will determine the order in which the basins will be examined, regionally for Level 1 analysis and state-wide for Level 2 analysis, by prioritizing them on the basis of broad-scale environmental factors. The prioritization will not preclude others from performing Level 2 watershed analysis in watersheds of concern when desired. Neither will the initial prioritization prevent potential adjustments to the state-wide priorities as Level 1 is performed. Watershed screening will provide some information, not previously available, to the CE assessment in each basin.

**Designation of basins**

The first step was to delineate basins for the purpose of screening and analysis. It was presupposed that the basins should be contained within the water resource inventory areas (WRIAs), and be fourth- to fifth-order in size. Adjustments were made to the latter criterion based on physiography, land use, and ownership. Using these criteria, 204 basins were designated, with one to seven basins in each WRIA. (Designation of these basins does not preclude further subdivision for detailed analysis.) Approximately 30 of the basins will be excluded from screening because they do not contain significant tracts of commercial forest. The boundaries of these basins have been digitized and are reproducible from DNR's GIS.

**Prioritization of basins**

The remainder of this paper is focused on how GIS and remote sensing are being used to prioritize basins for CE assessment across the state. To prioritize basins on a regional and state-wide basis in a timely fashion, information had to be easily obtained from maps, GIS, or satellite imagery. The following screens were identified for key categories of hazard and risk.

**Slope instability screen**

The assumptions underlying the slope-hazard screen included that it be based on physical factors relevant to slope stability, that it use available information, and that the information is in forms that can be incorporated into a general instability rating.

Existing slope-hazard ratings are available for state and private commercial forest lands in the soils layer stored on the DNR GIS; the ratings for national forest lands are being obtained from the US Forest Service. Information on slope gradients is being obtained by purchasing sets of digital elevation data from the US Geological Survey and processing them to produce slope maps.

A storm-input layer is being developed to reflect the role that storm precipitation plays in triggering landslides. The isohyetal map of 10-year 24-hour precipitation (from NOAA) has been digitized, and a precipitation zones map has been developed. These will be combined into a model rating of potential storm-water input (see Hydrologic Screen section below).

The combination of the slope-hazard ratings and slope gradient information will show where steep and unstable areas are located. The storm-input layer will overlay the soils-slope layer to show where storms could be most effective in causing slides. The resultant combinations will be given numerical slope-hazard ratings.

To validate the ratings and add information regarding potentially unstable rock types, landforms, and known problem areas (information not otherwise contained in the slope-hazard ratings), teams of geologists and soil scientists familiar with different areas of the state will be brought together. These experts will use aerial photography, geologic maps, reports on historic slides, and personal experience to check the designations. This will provide verification.
that the identified 'unstable' zones are appropriate, and allow for modification of ratings with additional information.

**Fisheries screen**

The two criteria recommended for the state-wide fish screen recognize the importance of (1) streams that supply water to fish hatcheries, and (2) streams that support the state's natural/wild fish populations.

The value of including waters supplying fish cultural facilities is self-evident, since production is fully dependent on reliable, high-quality water. The inclusion of the proportion of utilized habitat, indicated by the presence of fish species in the basin by river mile, will identify where the habitat is being used.

The Washington Rivers Information System (WARIS), a GIS data base maintained by the Washington Department of Wildlife, contains site-specific information on state, tribal, and federal hatchery facilities and the presence and absence of fish species. These data have been further updated and verified, and currently resides on the DNR GIS.

**Wildlife screen**

The wildlife screen will score each WRIA for five factors: (1) the proportion of the forested area in late-successional habitat, (2) the proportion in functional (60-acre patches) late-successional habitat, (3) the proportion in large patches (640 acres) of late-successional habitat, (4) the distribution of 60-acre patches, and (5) the proportion of vegetative cover in mid-successional forest.

The use of late-successional forest in the wildlife screen focuses on providing diversity of habitat for species not found in earlier successional stages. The criteria regarding size and distribution of patches are incorporated because these factors influence the dispersal of wildlife. The consideration of the mid-successional stage reflects the need for preserving natural diversity in a basin by identifying the habitat that is between early and late successional stages.

The classification of vegetation for wildlife habitat types is a result of processing Landsat images, as explained below. The evaluation of the classifications for wildlife will be performed using the ERDAS (Atlanta, Georgia) Clump and Sieve algorithm.

**Hydrologic screen**

The primary hydrologic problem related to forest management in Washington is the impact of timber harvest on runoff during rain-on-snow events. In the Pacific Northwest, the heaviest rains generally occur when cyclonic-frontal winter storms bring warm, moist air from the southwest. Since there is likely to be some snow on the ground at middle and higher elevations when these storms occur, snowmelt can combine with rainfall to aggravate floods and trigger landslides. The distribution of forest stands with varying degrees of hydrologic maturity (i.e., their ability to function like mature forests with respect to snow accumulation and melt processes), and their similarity to stands with natural runoff characteristics, will be used to rate the basins for the potential to alter peak flows and channel morphology.

To perform this exercise, several GIS layers are being adapted or developed for an analysis that is based on modeling of hypothetical rain-on-snow storms. The 10-year 24-hour storm isohyets were digitized from the NOAA atlas (Miller et al., 1973). Using data from the National Weather Service and cooperative snow surveys, a map of five precipitation zones was created to delineate areas likely to have various amounts of snow on the ground (in early January). The peak rain-on-snow zone was defined as the area in which the amount of snow available is approximately the same as could be melted by the 10-year 24-hour rainstorm (assuming reasonable temperature and winds). Below this peak rain-on-snow zone are the lowlands (little snow on the ground) and rain-dominated (some snow, but rain is the primary source of water input) zones; above are the highlands (too cold, so little liquid water generated) and snow-dominated (some snowmelt, but delay during percolation through the snowpack) zones. Although the distribution of these zones is controlled primarily by elevation, other climatic and geographic factors (e.g., latitude, aspect, storm tracks, mountain ranges) also affect their locations. These were reflected in the mapping.

The hydrologic maturity of forest vegetation is being identified through processing of Landsat imagery (as identified below). Recovery of a young forest to hydrologic maturity occurs when the properties controlling snow accumulation and melt, such as canopy closure, match those of a mature forest. These characteristics, adjusted for region, species, etc., can be used as standards of maturity.

Using these data layers, an approximation of the amount of water available for runoff from a hypothetical rain-on-snow storm can be generated using ERDAS GISMO. The 10-year 24-hour precipitation amounts are combined with the amounts of snowmelt appropriate for each zone (none in the highlands and lowlands, a maximum amount in the peak R/S zone) and each vegetation type (more snow available and faster melting in hydrologically immature stands and nonforested areas). The GIS calculates the areally-weighted averages of storm precipitation plus snowmelt for each basin under two sets of assumptions: (1) all forest lands support hydrologically mature vegetation (i.e., fully-forested conditions); and (2) the pattern of vegetation is as interpreted from the Landsat imagery (i.e., current conditions). The difference between these calculated values for a given basin represents the change in water...
available for runoff that could occur in a storm like the one modeled, as a result of timber harvest: the greater the difference (say, over 2-3 in. of increased water over a whole basin), the greater the potential for increased peak flows and damaging effects downstream.

Thus, the hydrologic screen will score each basin by calculating the change in water available for runoff from a mature forested condition to current conditions, for a model 24-hour rain-on-snow storm.

Vegetation classification

The vegetation classifications for both the wildlife and hydrologic screens are being performed under contract by Pacific Meridian Resources. The classes include: (1) late-successional conifer stands, (2) mid-successional conifer stands, (3) early-successional conifer stands, (4) other forest lands, and (5) water. These classifications have been processed through the use of geocoded and terrain-corrected 1988 Landsat TM imagery (EOSAT, Lanham, Maryland) and ERDAS image-processing software.

Six national forests and three national parks have already been mapped using more detailed vegetation classification of 16 and 31 categories, respectively (Teply and Green, 1991); these public lands have been recoded to fit the five-class scheme. The remaining forested areas are being classified using an unsupervised classification in combination with aerial photo interpretation, field reconnaissance, and the expertise of DNR regional foresters. The resulting classification is filtered and polygons less than five acres eliminated. The wildlife and hydrologic analyses are then carried out for each WRIA.

The wildlife screen will utilize the late-successional and mid-successional vegetation types of the forested areas of Washington. The hydrologic screen will consider mid- and late-successional vegetation classes to be hydrologically mature.

Summary

Attempts at evaluating cumulative effects have been continuing in Washington for over ten years. In response to concerns before the FPB and litigation, DNR, in consultation with its TFW partners, has constructed a framework for performing CE assessment on state and private forest lands. Such assessments could take from five to ten years state-wide. In order to prioritize where cumulative effects assessment should take place first, a watershed screening process is being utilized. GIS and remote-sensing techniques are being employed to gather and analyze broad-scale environmental data to prioritize basins. This exercise serves as an example of how data that are already resident on a GIS system, or that are easily obtainable, can be used in a timely fashion to identify where a CE assessment might be focused.

References


Footnotes

1 The opinions, findings, conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of any participant in, or committee of, the Timber/Fish/Wildlife agreement, the Washington State Forest Practices Board, or the Washington State Department of Natural Resources; nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

2 The Washington Forest Practices Board was created in 1974 under the Forest Practices Act to promulgate forest practices regulations.

3 The Forest Practices Act was passed by the state legislature in 1974 establishing a policy of protecting the public resources of the state coincident with the maintenance of a viable forest products industry.

4 Best management practices and rules for administering the Forest Practices Act.

5 The state agency responsible for administering the Forest Practices Act.
6 Parts of the information in the following sections were taken from a report to the Forest Practices Board by DNR and TFW (1991).

7 Water resource inventory areas (WRIAs) are the hydrologic administrative units of Washington adopted by the Washington Department of Ecology.

8 Screening, as used here, is the process of focusing where CE of a particular type may be of concern.

9 The forested area in Washington has been determined through the use of USGS digitized land-use
The future of GIS in the regulatory process: The OSLO case study

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Abstract

The regulatory process for approving proposed industrial developments, which involves the preparation of an Environmental Impact Assessment (EIA), can require the analysis of large amounts of spatial data.

A GIS was used in the preparation of the draft EIA of the proposed $3.4 billion OSLO project; an oil sand extraction upgrading facility in Alberta. GIS technology was considered vital to the analysis and presentation of the enormous amounts of data gathered for the EIA. It became apparent that in addition to improving the traditional manual EIA process, use of the GIS could improve data management, analysis and presentation, resulting in a better assessment and improved environmental protection. The GIS application could subsequently be used for on-going planning and management of environmental information.

Suggestions are also presented that the GIS could be used more extensively in the regulatory process.

A public "library" of digital environmental information could be built up over the years in much the way the ERGB well log data was accumulated. The availability of this information would reduce the cost of environmental studies and facilitate on-going monitoring and research by private and public agencies. The place of GIS in EIA and subsequent monitoring in developing countries is discussed.

Introduction

The OSLO Project is a proposed oil sands development in northeast Alberta. It will include a surface mine and extraction plant, which produces bitumen, located on a portion of OSLO Lease 31 near Kearn Lake, about 60 km north of Fort McMurray. In addition, an upgrader, which produces synthetic crude oil from the bitumen extracted from the oil sand, will be located in an area about 7 km from Redwater, within ready access of the city of Edmonton. The mine and extraction plant will be connected with the upgrader by pipelines, one to bring diluted bitumen to the upgrader, and another to return the diluent to the mine and extraction plant.

The project cost about $4.5 billion and is being undertaken as a joint venture by the owners of six oil sands leases in the Fort McMurray area; hence the name OSLO; an acronym of "Other Six Lease Operators". In terms of both geographic extent and database size, OSLO is one of the largest natural resource projects in the private sector.
As part of the regulatory requirements for the project, an environmental impact assessment (EIA) must be completed before approval can be given. An EIA is a study done to determine the effects a proposed project might have on the environment. It is done to ensure that the proponent of the proposed project will satisfy and evaluate all potentially significant environmental effects of the development. In addition, the proponent is required to give due consideration to means of avoiding or mitigating any adverse potential environmental effects.

In North America, the EIA process usually involves an approving agency listening to three concerned parties: the proponents of the project, the general public and the special interest groups. The proponent must prepare an EIA outlining all aspects of the project, the potential for impact on the environment, and the measures, if any, that will be taken to mitigate effects. It is common practice in Canada, U.S.A. and Mexico, for an EIA to be prepared for the proponent by a third party (i.e., consultants).

Over the past few years, some developers have been required to prepare environmental assessments that meet the requirements of more than one piece of legislation, and undergo joint reviews by more than one government body. This confusion arises because both the provincial and federal governments have responsibility for environmental resources in Canada. Had the OSLO project proceeded (it was postponed in June 1991), it would have undergone a joint provincial/federal hearing, because the project was provided federal financial support and would have affected resources that fall under federal jurisdiction (i.e., fisheries, migratory birds and navigable rivers).

The EIA process

In Canada, the influence of environmental issues on project approval, and the process used to prepare EIAs are expected to increase in complexity over the next few years. There is also an increasing amount of confusion about which government body has the authority to review EIAs and authorize proponents of a project to proceed with its development.

The current EIA process can be unwieldy and impede development of some projects, while allowing other projects to proceed without a proper review of environmental effects. In addition, due to jurisdictional debates between governments, several developers have recently faced increased costs and time delays in project implementation.

The Canadian EIA process is also consultative in nature, and federal and provincial Ministers, acting in a discretionary capacity, are entitled to disregard the recommendations of appointed review boards (Ross 1991). In the past, behind-the-scene political decisions based on socio-economic issues have often taken precedence over environmental concerns in the project approval process. However, over the past 2 to 3 years, environmental concerns have more and more been treated as real issues, and the passage of the Alberta Environmental Protection and Enhancement Act (AEPEA) and the Canadian Environmental Assessment Act (CEAA) will legislate a more structured EIA review process that will encourage greater public involvement. Greater public participation will remove some of the weaknesses, such as political intervention, in the process, but this will mean that greater amounts of data will have to be processed and the presentation requirements will be more complex.

One of the major tasks in this process, with its many participants is managing the collection, correlation and analysis of the information generated by the EIA. This information must also be presented in a format that is meaningful and expressive to the participants and decision makers. There are many types of data required to perform an EIA. In most instances, field surveys are required to collect current information about wildlife, vegetation, fisheries, soil chemistry, terrain, historical resources, land use, etc. in the project study area. The extent of the field surveys depend on the availability of accurate, relevant, and contemporary information from existing sources.

Some of the obvious sources of information for an EIA are: municipal maps, government digital basemaps, air photo libraries, satellite imagery, and remote sensing. However, remote sensing information such as satellite surveillance data are usually under utilized. There are literally hundreds of other data sources available too. The difficulty rapidly becomes not one of too little information, but rather, which information to include in the analysis. For example, some databases may contain historically important but out-of-date information.

Two GIS technologies (Nucor on IBM PC and MapGrafix on Macintosh) were chosen to aid in the preparation of OSLO Project EIA. GIS technology, with its ability to manage, analyze and present spatial data in graphic and textual forms (i.e., maps and tables) has great potential as a tool in the EIA process. The analytical capabilities of a modern GIS, fully loaded with detailed information, make it feasible to make predictions and explore at least some of the consequences of particular kinds of projects on particular environmental issues.

The implementation of the GIS for the OSLO Project had four objectives:

- To assess the use of GIS technology to support of planning, design, construction, operation and decommissioning of the OSLO project.
- To bring all the environmental information into one manageable place.
- To facilitate objective assessment of impact hypotheses by means of data analysis.
- To produce illustrative figures for the impact assessment.
It was anticipated that the results of this exercise would provide a guide-line for the future use of a GIS in support of EIA.

In addition to allowing the rapid update of maps, the GIS would allow the complex analyses of spatial data sets that would be unfeasible using manual methods or CAD systems. It would be possible to combine many kinds of "maps", including existing paper maps, engineering drawings, architectural plans, digital maps, airphotos, and satellite images. It would also be possible to create new georeferenced information on the basis of data combinations and transformations.

The GIS-supported environmental EIA commenced in 1989 with extensive baseline inventories covering a region of nearly 1000 km². Environmental specialists conducted extensive field surveys to map existing resources (land use, vegetation, soils, terrain, wildlife habitat, historic resources, etc.) within a broad region surrounding the components of the proposed project. On the basis of their field surveys they produced detailed baseline maps. These baseline resource inventory maps were provided to us as paper maps, airphoto mosaics with polygons drawn on them, or as digital files from a variety of GIS and CAD systems.

Another component of the baseline database were the engineering drawings of proposed project facilities; for Lease 31 mine/extraction facilities and for the Red Water upgrader facilities. The engineering and mining groups within OSLO used AutoCAD and EAGLES to produce their facility plans.

Our endeavours quickly revealed that many people did not have a good understanding of what a GIS is and what its capabilities are. One of first tasks quickly became one of education so that realistic expectations were held by other team members. It was possible to take advantage of the GIS analytical capabilities, however, because a specialist with extensive experience in both ecological disciplines and GIS was available to act as an "interpreter" between the various environmental specialists and the GIS technician. This was important as pointed out earlier, because the GIS is a new technology and while there may be a general understanding of GIS, the environmental specialists would have required considerable education, training and practice in order to use the system effectively on their own. The tight time constraints set by industry for the preparation of EIAs have traditionally not included budgets to educate the consulting team members in GIS concepts or to train them in the use of the particular GIS selected for use in the project. The procedure permitted them to get the analysis results they required within in the short time available and the format of the various products requested was consistent for all individuals requesting maps or analyses.

Production of analytical and map products was accomplished by following a procedure that evolved during the implementation of the GIS. The procedure involved carefully defining the end products, the data needed and the analysis procedures to be used to generate the product.

The end product required was defined jointly by the EIA specialist and the GIS specialist together. This insured that the proper product was generated and that the correct analyses were performed. The description included a rough sketch of the required map, the approximate extent, and major details, along with information to prepare a legend. The product description request also included the title, scale, name of the person requesting the map along with their address and phone number. Next, the data required was identified. If derived data were required, the source factor data sets were first identified. A step by step procedure is then developed with the technician, to produce the product using the various software modules and their associated functions.

The OSLO EIA GIS has now been archived so that it can be "taken out of the box and turned back on" when the OSLO Project is resurrected. At the time of the GIS archival, it contained 54 maps, 4 forestry data files, 1 habitat data file and the engineering drawings of all mining, extraction and upgrader facilities. The GIS archive contains files in the proprietary format of the GIS. In addition, the archive contains all the "raw" data import files so that the information can be transferred to another GIS if necessary.

Our experience with the use of GIS in the preparation of an EIA for a major project leads us to believe that GIS has great potential in enhancing the EIA process. However, this will require that GIS become an integral part of the EIA process rather than an "add on" to the existing traditional methodologies. The EIA process is going through an evolutionary change and now is the ideal time to develop the concept of GIS-based environmental management information systems.

In the remainder of this paper we will discuss the feasibility of using GIS technology to address the changing expectations for EIAs. It will address some of the ways we have used GIS in the environmental impact assessment of a very large project and ways it might be used in the future. The topics to be addressed are:

- Public involvement in the impact evaluation process.
- The scope and content of an EIA.
- Preparing a focused, comprehensive, technically-defensible and effective EIA.
- When should an EIA be required and who will review the EIA?
Public involvement in the OSLO EIA process

OSLO initiated a new process for the assessment of the environmental impact. It was a scoping process and involved the following steps:

Description

In this step, a clear understanding and description of the project developed. This was required to assess potential environmental issues.

Issues Scoping

This step involved identifying the issues, assessing their impact and defining impact mitigation and monitoring.

EIA Preparation

Preparation of the Impact Statements and the successful resolution of the issues identified were documented for review.

Key to the success of the issue scoping process was the involvement of key stakeholders (including federal and provincial government agencies, municipal governments and non-governmental organizations), as well as the public. In the case of the OSLO Project, substantial changes in the project description coupled with intensive stakeholder and public consultation resulted in a need to be able to quickly revise and regenerate maps and impact analyses based on new information or new wrinkles added to old information. It was believed that this could best be handled by the development of a GIS (Figure 1). We cannot stress enough the importance of establishing a procedure for routinely obtaining and incorporating updates to project plans and the environmental data base. This permits changes in the project engineering to be reflected quickly in the GIS. In what follows, the OSLO GIS is described in terms of its component parts and an overview is given of the various themes which have been used in the construction of the GIS.

Much of the information required for the EIA was developed as the result of issue scoping and hypothesis generation. The disturbance categories typically include, but are not limited to:

Atmospheric disturbances — disturbances to local and regional air quality.

Ground disturbances — disturbances to land resources caused by land clearing.

Waterbody disturbance — disturbance to water resources caused by diversions, flooding, siltation, etc.

Public access — increased access by the public to areas as a result of new roads, resulting in more traffic accidents, increased maintenance costs, increased pressure on sensitive resources, etc.

Visual impact — aesthetic degradation ("eye sores") resulting from project construction and operation.

The ability of the GIS to overlay several layers of georeferenced data makes it potentially valuable as a display tool for illustrating and analyzing impacts. The GIS can also be used to evaluate mitigation practices.

Once maps have been prepared for spatially oriented impacts, it is necessary to examine how each type of disturbances would affect the natural resource included in the database. Prior to the use of GIS, manual methods were used to compile these data on paper or film maps. These data were "coded" using symbols, patterns, and colours that were explained in a map legend or accompanying text. Survey data were presented in accompanying tables. Updating or expanding a survey required that all maps and tables be reconstructed from scratch. The ability to explore the effect of a different project configuration and produce a map of the results was often cost prohibitive or, in some cases, technically impossible.

Who should be involved in the impact evaluation process?

Based on our experience in the OSLO Project and other large projects, we can put forward the following comments regarding the advantage of using GIS technology in the EIA process. We have found that a GIS as a central component of the EIA process can [or could] lead to:

- the establishment of improved communication and understanding between the proponent team members, the regulatory agencies, and members of the public;
- the production of a more complete EIA, including a more complete, objective identification of all impacts and environmental safeguards, and the creation of innovative solutions to difficult problems. One of the most effective ways to be creative would be to assemble all the key stakeholders and use the GIS to devise solutions that will keep environmental impacts and economic feasibility of the proposed project within acceptable limits. The availability of an GIS at such meetings would permit the consequences of different scenarios to be examined. The requires that the GIS be designed and implemented at the start of the project and not, as has been the case in many projects in the past, concurrent with preparation of the EIA document. This will also help define the extent of the region to be studied and identify what and how to gather the data.
- The use of GIS could also result in the minimisation of project costs (intervention costs) and time delays. By having maps and facility plans in a GIS, areas can be measured and maps updated much
more quickly than by manual methods. The potential also exists to improve the way in which the intervenors get involved. By making available all the environmental data in digital format, the redundancy of data and duplication of effort could be greatly reduced, as would the waste of funds. Each party could still conduct their own analysis but everyone would be starting with a more complete database than they could economically assemble by themselves. In addition, the use of GIS would require a change in the level of sophistication of the intervenors, which should result in better understanding of the project and higher quality interventions.

- If approved, the project would have in place, at the end of the process the basis for an environmental management information system which could help the company be diligent in enforcing their environmental code of practice by integrating the management of permits and licences, hazardous materials,

Figure 1: The role of GIS in the Environmental Impact Assessment Process.
toxic waste, environmental research, personnel training information, emergency response plans, compliance reporting, planning, etc.

- The assurance that environmental issues will receive appropriate review in relation to socio-economic issues, and that behind-the-scene political agreements do not determine whether a development is approved or disapproved.

A structured environmental management information system, with defined data manipulation procedures and reporting mechanisms, could also be audited. This presupposes the development of an “industry standard” defining the minimum requirements for data and recommended structure for the GIS. Each project would be subjected to a comprehensive systematic examination of its content to determine their individual environmental influence. Data submitted to public hearings needs to be stored in a library in a digital georeferenced format. Excellent models for such systems are the ERCB in Alberta which stores all well log data generated in Alberta or the Nature Conservancy GIS. The NRCB would seem to be an obvious candidate to develop and maintain such a “fee for use” environmental data library for Alberta; industry and government do not qualify as unbiased candidates. The digital information could be combined with existing data so that it would be possible to evaluate the influence of the proposed project on cumulative impact. The use of such an environmental information management system (EIMS) would have several positive effects:

- There would be an standard environmental management system which could be audited.
- Deficiencies would be much less likely and would be easier to detect and remedy. This would be especially useful in developing countries where experienced environmental impact assessment experts are not always available to conduct comprehensive and objective assessments.
- Data would be available in a more standardized format. This would make possible the concept of a public environmental data library.
- The development of a library of environmental data over the years would also address the problem of who pays for the off site environmental data collection if cumulative regional environmental impacts of a project are going to be required.
- Each project would be subjected to a comprehensive examination
- The EIMS provides the company with the basis with which to diligently carry out their environmental management strategy. It would also help them develop an environmental management strategy if they do not already have one.
- Each EIMS would augment the public environmental database without the shameful waste of mountains of paper; instead, the data would be truly “recyclable”.

The scope and content of an EIA

A frustrating aspect of the EIA process that each proponent faces is the confusion over how broad a scope and what issues the assessment should cover. In the past, only project components that were operated by one proponent were addressed in an EIA; other proponents were responsible for preparing separate and independent assessments. In the case of the Oslo project, the pipelines, power-lines, and municipal roads were not included in the EIA because they were being built by other companies or government departments. This is clearly unsatisfactory if we wish to integrate environmental information to monitor and plan for cumulative effects.

Recently, this fragmentary approach has been changing and, it is likely that in the future, all components of a project that are inextricably intertwined will be addressed in a single comprehensive document and review process. The proponents of the various components of such projects will either need to cooperate and work jointly to prepare one comprehensive EIA, or they will have to co-ordinate and conduct several EIAs so that they are completed within the same time frame using similar approaches. Standardized GIS procedures and design plans are seen as one means by which proponents could combine their efforts and resources to jointly accomplish this. The GIS would also facilitate analysis, systematic data collection, analysis, and presentation. This is particularly important because it would permit the cumulative effects of all components of a project to be evaluated.

Use of common or compatible GISs would allow proponents of all project components to submit their EIA information for incorporation into a “master” project EIA. This would permit the impact of the entire project to be assessed. In turn, making the project data available to a centralized data library would facilitate quantitative analysis of cumulative effects of the project in a timely manner by regulating agencies. All of this presupposes the rapid acquisition of GIS expertise by such agencies.

Recent and anticipated changes to environmental legislation has also initiated a broadening of the scope of environmental impact assessments as well as the type of projects which require assessment:

- Under the AEPBA and the CEA, the definition of environment has been broadened to include not only air, land and water (as under the current Alberta Environmental Impact Assessment Guide-lines), but all layers of the atmosphere, and all organic and inorganic matter and living organisms, and the interacting natural system that includes all these components. Under the new AEPEA, the potential impacts of a development from the environmental, social, economic and cultural perspectives must also be evaluated. Proponents could face delays in the review process
and consequent in project development if all relevant issues are not addressed in the assessment document.

- The AEPEA, CEAA and Canada’s Green Plan recommend EIAs take the ecosystem approach to resource impact evaluation where the interrelationships of biophysical components, as well as the biophysical components the themselves are discussed. This type of approach to environmental assessment preparation requires the integration of data from all disciplines and intense interaction of technical experts to delineate ecosystem relationships and subsequently define impacts.

- The CEAA requests that environmental effects of malfunctions or accidents associated with a project be reviewed. This requirement could have major implications for industry as potential events such as the failure of a tailings dyke, or a natural gas fire at a sour gas plant would need to be described.

- The AEPEA requires the evaluation of project effects on health and safety.

The complexity of EIAs is anticipated to increase as we start to include biophysical, socio-economic, health and safety risk issues, aesthetics, ecosystem effects, off-site effects, atmospheric effects, and the interactions of living organisms with organic and inorganic matter. The routine application of risk assessments will likely expand beyond examining the effects of water and soil contamination or sour gas blowouts on human health, to the examination of health effects on wildlife, livestock and forest resources. Under the new AEPEA and CEAA, the EIA must also address the effects of alternatives to the proposal, including the no go option, with respect to social, biophysical, economic and cultural issues.

Preparation of an EIA for a large or medium project is currently almost impossible to accomplish by traditional manual means. In the future, as the number of required EIAs increases and their complexity also increases, the preparation of a single environmental assessment, in a reasonable amount of time and at a reasonable cost, which adequately addresses, integrates and analyses all information and interactions of biological and physical, as well as social, health and economic consequences of development is going to severely stress the availability of experienced environmental impact experts. Something like a standardized EIA/GIS packaged will have to be used. And the requirement for contingency planning could be handled dealt with by developing the emergency response plans on top of the GIS-based information management system. Such a system would incorporate relevant predictive models to handle emissions of contaminants into the atmosphere, water or onto soil. It is also likely that the “look” of the EIA document will change, as large documents with bulky pockets for fold out maps are replaced by streamlined summary documents and references to digital maps in the GIS.

Properly designed, a GIS loaded with the baseline data can model interrelationships of biophysical components more quickly and reliably than if technical experts have to rely on traditional manual interaction.

**Off-site effects**

A very important question, that has received greater attention over the past few years and has astronomical implications for the content of EIAs, is “Should off-site project effects be evaluated?” For example, if we are assessing the development of a sour gas processing plant or an oil sands project that will draw electricity from the Alberta grid, should the SO2 emissions produced off-site from coal-fired facilities be addressed? Should sulphur dust deposited in Japan from solid sulphur transported from Alberta be addressed in the EIA?

In part, the question of whether to evaluate off site effects is moot. The evolution is definitely towards the discussion of environmental impacts on regional, national and even global scales. Recent involvement of the authors in public meetings related to major projects (e.g., the Caroline gas field and the OSLO project) clearly demonstrated that key stakeholders are concerned about not only their own backyards, but also those of their neighbours. Under the Land Surface Conservation and Reclamation Act (LSCRA) and Alberta Environment’s Impact Assessment Guidelines, the Minister of Environment can request this information.

The implications, for industry, of this expansion in the scope and content of EIAs in addition to the increase in the number of types of projects which require them, will be an increase in the amount of effort and costs required to stay current on environmental issues, maintain up to date environmental databases and to objectively analyze that information in the preparation of assessment documents.

If we are going to develop sophisticated information management systems, national and international environmental data standards will have to be developed immediately; even, if to the chagrin of academics, they are de facto industry standards. Such information could be made available in public data libraries similar to the ones like the Nature Conservancy. We recognize that this is not a perfect solution but it is better than navel gazing until the “ultimate” format is developed.

**Preparing a focused, comprehensive and technically defensible EIA**

Progress is accelerating towards the perfection of focused, comprehensive and technically-defensible evaluations of project impacts. An EIA that is incomplete or unreadable does not provide regulators or members of the public with the facts and analyses that are required for the project approval process. A satisfactory EIA should be succinct, well organized and clear (Ross 1987).
It must also be based on reliable, accurate, precise data assembled through the application of scientifically defensible (i.e., repeatable) methodologies.

The trend in the approach to EIAs is to prepare a focused assessment that addresses only key impacts to key environmental, social, economic and cultural resources, and to thoroughly document the analytical methods and decision-making process used to evaluate project effects through impact hypotheses. The AEPEA and ERCB support an environmental issues scoping process in Alberta, and at the federal levels, CEARC strongly advocates this process. In order to prepare a comprehensive and technically-defensible EIA, adequate baseline information on biophysical resources that could be affected by the project must be collected and a well-defined methodology to identify impacts and their significance, to quantify impacts and to model cumulative impacts must be utilized.

Many environmental assessments do not provide adequate information on the methods and assumptions used to evaluate impacts. Such "scientifically" incompetent studies limit the ability of public reviewers or regulators to assess the accuracy, reliability and comprehensiveness of impact predictions; that is, the decision-making process has not been thoroughly documented or justified. In some cases, these assumptions have accidently been left unidentified or due to the inexperience of the author. In some cases there is inadequate baseline information upon which to make an assessment, and in still other cases, the proponents have strategically failed to document the information.

The use of a GIS application built according to a standardized design plan would provide something to audit. A review of such a GIS would quickly reveal whether the baseline information was complete and/or adequate. Deficiencies could be detected early.

**Regional biophysical baseline information**

To effectively identify impacts, a thorough knowledge of biophysical resources, not only in the development area, but in the region being affected by project-induced impacts, is required. Baseline information used in assessments is usually inadequate for regional studies because it has not been collected over a broad enough region or over a long enough time period, or it has not been collected for all the biophysical resources or ecological components that should be examined in the EIA.

A confrontational question that needs to be resolved soon, particularly in areas where several developments are being proposed (e.g., Bow Valley Corridor, Kananaskis Country, the Rocky Mountain House/Caroline area), is who should be responsible for collecting the regional baseline information that is required to satisfactorily evaluate project-induced impacts? One proponent is usually unable or unwilling to provide the money, time or effort necessary to collect baseline information outside their immediate project area. Unfortunately the provincial government, which is the steward and manager of most biophysical resources, also lacks funding for these regional programs. The most feasible approach appears to be the establishment of a collective of the developers, which is chaired by the government, and jointly designs and funds regional baseline inventories. In the Alberta Oil Sands Environmental Research Program (AOSERP) area in northeastern Alberta, information on biophysical resources was collected by the provincial government and made available to multiple users in the region. The AOSERP data, however, lacked a consistent format. A public "fee for service" environmental data bank of GIS compatible digital information could be a solution.

Use of a GIS encourages data collection and sharing. It would also provide a framework in which to use them. Data would be gathered according to selected criteria using objectively selected areal extents, density of sampling, etc. Such a request by a regulatory body is not so far fetched. Consider the fact that all the pages presented at this conference were submitted on diskette using a technology (desktop publishing) that was not recognized in business 10 years ago.

**Quantifying impacts and addressing cumulative impacts**

A trend in impact assessment that will continue has been the attempt to quantify the effects of project activities on biophysical resources, and move away from subjective and qualitative impacts evaluations. GIS analysis has enormous potential to provide objective and defensible methods of quantifying spatial impacts.

Although advances have been made towards quantifying the magnitude, duration and spatial extent of impacts, these tasks have suffered from insufficient baseline information on biophysical resources. Progress in modelling research, and technical monitoring, have resulted in improved capabilities for predicting potential environmental impacts particularly in the area of water quality, hydrology, air and wildlife habitat. However, up to the present, the use of remote sensing information from airborne or satellite surveillance has been largely ignored in the preparation of EIAs. Major advances are still needed in the case of modelling effects of emissions, soil, vegetation, water, etc.

The evaluation of cumulative project-induced effects in EIAs will be required under both the AEPEA and CEAA. It is difficult to imagine how evaluation of cumulative effect would be possible without the use of GIS or something like it to facilitate modelling and quantification of impacts on the basis of remote sensing data and public libraries of digital environmental information.
Long-term monitoring and research programs provide information by which to verify the accuracy of predicted impacts and the effectiveness of proposed measures to mitigate adverse environmental effects, and thereby improve the ability to predict real impacts. GIS offers the mechanism by which research and monitoring data could be systematically and routinely compared with baseline conditions or predictions. It is likely that discussion will finally determine that data reported to the public regulatory agencies will be made available to the public on a discretionary basis. Research data, however, are likely to remain proprietary.

**The future**

Under the proposed provincial and federal acts, both the mandatory and discretionary approach will be taken in determining whether an activity will require an environmental assessment. The new AEPEA will include a list of projects for which an EIA will be mandatory, and the Director and Minister of Environment will have the discretionary powers to request an assessment if the activity has significant adverse impacts, the impacts of the project are unknown, or there is major public concern.

In the future, we anticipate that significant changes in the EIA process, as such assessments become more common and more objective. Historically, EIAs have been prepared by the project proponent and technical experts, under government guidance and recommendations, and public involvement has been restricted to hearings. However, this approach may change in the future because proponents can lack objectivity and may be biased. And are government officials are independent of political influence? The Environmental Legislation Review Panel to Alberta Environment on AEPEA recommended that “a third party prepare an EIA report in circumstances where legitimacy and public acceptance of a proponent-prepared report might be in doubt”. A committee, appointed by the Saskatchewan Minister of Environment and Public Safety to review the province’s environmental assessment legislation and practice, presented its recommendations in February 1991. The committee stated that “those responsible for the EIA must be objective, unbiased and independent of political influence”. We suggest that professional environmental experts who are controlled by an enforced code of ethics and practice (e.g., A.S.P.B.) using GIS according to strict protocols will provide an environmental impact assessment that is the objective, unbiased and free of political influence. The protocols are expected to be set by a regulatory agency similar to the NRCB in Alberta.

It must be obvious that the days of experts working in isolation are disappearing. The use of a interdisciplinary networked GIS-based information systems are starting to provide models of the real world. This should improve the understanding and reliability of predicted impact assessments, and at the same time resulting in cost reductions by eliminating (or at least reducing) the collection of redundant, incompatible or contradictory data.

In summary, these changes are going to result in an increase in the number of EIAs being prepared. In order to facilitate the prepared preparation and review of EIAs in a timely manner, it would be beneficial if they were implemented on competent and compatible GIS platforms according to carefully defined designed considerations. It is anticipated that regulatory agencies will soon begin issuing recommended (or required) GIS design considerations to be followed in the preparation of an EIA.

It is apparent to us that the GIS has the potential to streamline and standardize the process. Geographical units can be mapped and ranked values assigned for important criteria. Also, the criteria can be weighted to reflect their perceived importance. Boolean algebra can then be used to identify the key issues. One area where this type of quantitative and objective approach is very important is in site and route selection. The use predictive models (integrated into GISs) is another area which could contribute greatly to the conservation of time, money and paper by identifying those “significant” impacts so they could be incorporated into an environmental information system.

Remote sensing (LandSat, SPOT, radar, microwave, airborne multispectral, etc.) needs to be taken advantage of to provide the regional background information necessary to allow off-site and cumulative impact evaluation.

Design of GIS-based environmental management information systems needs to be researched with the view of developing a practical industrial design for such an application. We believe that this will and should be an evolutionary process leading to the refinement of a minimal GIS-based system which facilitate environmental management throughout all phases of a project; planning, approval, operation, emergency response, decommissioning and reclamation. Such a system would be eminently suitable for adaptation for use in developing countries. It is vital that the evolutionary process maintain upward data compatibility.

Public libraries of digital environmental information generated by EIAs need to be planned and implemented by an unbiased party. A good model is the ERCB well data library in Alberta. A good candidate to operate the library for Alberta, is the NRCB.
References and other background materials


Monitoring and modelling transboundary air quality using GIS

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Abstract

A GIS is used to integrate geographical, meteorological and chemical data with model results furnished by a number of long-range atmospheric transport models. By combining the results from a series of model simulations, new insight into the spatial and temporal variability of predicted air quality can be gained. Several pollutants, including arsenic grid established by EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe), covering Europe at a 150 km interval.

Overlays are created for individual and combined model input parameters (winds, precipitations, mixing height, scavenging ratio). Monthly and annual patterns of emission, deposition (set/dry) and concentration are described for single chemicals and chemical combinations. These are further combined with geographic variables such as soil characteristics (slope, texture, cultivation index), vegetation and topography, for impact assessment.
C4 GIS in information analysis

Fast access to fisheries information with low-cost desktop mapping software
Peter Lewis et al., Ministry of Environment, Lands and Parks, Victoria, BC, Canada

The conceptual determination of carrying capacity analysis using GIS technology. Case study: the upper Komering sub-watershed, South Sumatera, Indonesia
Nanna Suryana et al., The Wageningen Agricultural University, Wageningen, Netherlands

Setting global and regional priorities for coastal temperate rain forest conservation
Andrew Mitchell, Conservation International, Washington, DC, USA

Evaluating alternative land management policies from a water quality perspective: an automated land information systems approach
Lucy Buchan et al., University of Wisconsin, Madison, WI, USA
Fast access to fisheries information with low-cost desktop mapping software

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Abstract

The most urgent problem currently facing agencies like ours is our inability to rapidly locate existing information, some digital, but most still hard copy in files, map cabinets, etc. Information about the aquatic resources of streams and lakes in British Columbia has been collected for more than 40 years but it is scattered in various offices throughout the Province and many potential users are not even aware of its existence. The challenge is to provide easy low-cost access to that information, including access by geographic location.

This paper will illustrate the system that was developed to enter, store, map, query and retrieve geo-referenced information on the fisheries resources of B.C. The approach taken was incremental rather than all encompassing and it described in detail. Design and development were carried out by existing staff (biologists and technicians) using QUIKMap, a locally developed desktop mapping package that retails for less than $1,000. Internal data are integrated with other relevant digital data provided at many different scales and from many different sources. Screen and printed reports include maps, tables and text. The Ministry of Environment's 1:30,000 digital Stream Atlas for the Province is used as the base.

Introduction

What's This All About? For the past two years, provincial (Fisheries Branch, B.C. Ministry of Environment, Lands and Parks) and federal (Habitat Management Division, Dept. of Fisheries and Oceans, Pacific Region) fisheries organizations have been experimenting with desktop mapping, called "simple" or "non-analytical" GIS by some, as a practical means of providing fast, low-cost access by geographic location to existing fish, fish habitat and related administrative data.

In many operational situations, fisheries field staff function not only with little hard information about their resource but with inefficient and incomplete access to that information which does exist. This paper describes our experiences with simple GIS as one potential remedy for the data access problem and includes:

• reasons for beginning with desktop mapping — the bite-size approach;
• the process for defining and marketing the system;
• administrative and resource themes for fisheries management;
• options and problems in selecting a digital base;
• capabilities and limitations of the desktop mapping software package, QUIKMap by Asys Software Ltd. of Sidney, B.C. (formerly ESL Environmental Sciences Ltd.); and
• where we think we're at and where we're going.
Choking on GIS — is a seven-course meal the only way to go?

Conventional wisdom suggests that the adoption of GIS technology by an organization can be successful only if carefully planned and fully resourced. Design and implementation should be top-down, preferably driven by a broad range of applications, controlled by a fully specified systems development process, and carefully piloted (Campbell, 1989; Prior, 1991 etc.). This is seven-course GIS. The proceedings of GIS conferences like this are awash with examples: Bell (1991); Johnstone et al. (1991); Zillmer (1991) to list a few. We note with some suspicion, however, that all too commonly, presentations focus on system specification and design and, all too rarely, include testimonials from line managers and staff about the ongoing effectiveness of GIS in their daily work.

Fisheries Branch and DFO Habitat have discussed GIS ad nauseam for at least the last 10 years, even before many knew what the letters stood for. Meetings, workshops and JAD’s seem to occur monthly; memos and notes circulate back and forth, filling both file drawers and hard disks; strategic implementation plans have been started and even finished; budget proposals are prepared and submitted and revised and resubmitted; broader government initiatives have been supported and depended upon — and, for all this, we are not much closer today to making effective use of our georeferenced information than we were 10 years ago.

By traditional criteria, our organizations are not ready for GIS. Corporate sponsorship has been soft, potential in-house project managers and trained staff are almost non-existent, the limited number of digital data bases that we do have are not properly georeferenced, operational staff are frequently not computer-literate much less GIS-literate, and funds have been in very short supply. But the demand exists and is growing rapidly, fueled more by need and propaganda than by rational expectation. Both senior management and field staff have been infected but remain suspicious. The few individuals who do have more than an introductory understanding of GIS and of database management, both users and systems professionals, have been trapped in the middle.

Within this context, a few of us have sought an approach to fisheries GIS implementation that would:

- be incremental rather than all encompassing,
- be practical given our resources and expertise,
- permit initial focus on database creation, and
- both seduce and educate staff with simple applications of immediate use.

We like to call it bite-size GIS (more a wish than an expectation) and our hope for it springs both from the apparent failure, at least in the short term, of seven-course GIS in many organizations far more able than ours, and from the bottom-line fact that we are simply not capable of any more at the present time.

Grab the ball and run with it

Bite-size or not bite-size, we would have felt more comfortable following an explicit and accepted systems development process for this initiative. This was just not possible, except in an overview sense. We did not have either the funding or the organizational support. We had to create products and demonstrate their value for unsophisticated users before GIS of any sort could expect the support and resources necessary for success in our organizations. Everyone was tired of talking about GIS. If we were going to do anything (and we accept that we probably shouldn’t have), we had to grab the ball and run with it and we had to use our own staff to do so.

Our approach was to rely initially on the expertise and insight of a few individuals, both in-house and associated with our software vendor, and to assume that the technology we could afford was the technology we needed (fortunately, we really believed that it was). The dangers in this are well known — adoption of dead-end technology, creation of databases that don’t meet broad standards and must be abandoned or expensively modified, inability to meet user needs leading to frustration and abandonment, closing off of future options, etc. The horror stories are never ending. We were aware of these but hoped that the awareness itself, together with the narrow focus of what we were trying to do, would minimize the risk to both ourselves and our organizations.

The entire effort would not have been possible without a fortunate combination of circumstances and capabilities that included:

- an existing 1:50 000 digital Stream Atlas for the entire province, created internally and available free of charge, that could be used as a base;
- a piece of desktop mapping software that was affordable and well supported by a company that was willing to work very closely with its customers;
- a computerized Stream Information Summary System (SISS) (Pontus and Komori, 1990) whose use was severely limited by reliance on associated manually-generated maps that could not be easily updated;
- several very experienced staff and an excellent Fish Habitat Inventory and Information Program User Needs Analysis (Mathers et al, 1985) that gave us initial confidence in the value of what we were trying to do; and
- last, and critically, a temporary position that we were able to fill with an inventory biologist who had gone back to school to learn about computers.
We began by creating a computerized version of a single SISS map, enhanced to include lake as well as stream data, using the Stream Atlas file for a local 1:50 000 map sheet area on Vancouver Island (NTS 92F/14: Oyster River). The SISS data were selectively augmented with information from other digital base maps, digitized administrative boundaries, and data imported from existing fisheries databases. The process was painful. Even our internal databases were not compatible with each other; rainbow trout, for example, were coded RB in one database and RT in another; local names were used in one and official names in another; values for an attribute in one that directly contradicted those in another; and so on. Special symbols had to be designed and procedures developed for placing those symbols in cartographically appropriate ways on the map. Despite our focus on data access and display rather than analysis, we continually pushed the software to and beyond its limits. However we found that we could usually do what we wanted, either by breaking rules or by convincing the vendor to modify the software. In the end, we were able to display and plot both map and tabular products that we believed would be of value and interest to our operational staff.

We didn’t forget our audience

The next step was to see if anyone agreed with us. We took our computer to several internal meetings involving both headquarters and field staff, discussed our efforts, and showed them the products for the Oyster River map sheet. For many people, this was the first time they had actually seen GIS, either simple or full-featured, using real data that was of relevance to fisheries management. The reaction was enthusiastic, not just for the products, but for the fact that we had done them in-house, using software that seemed affordable and relatively easy to use. At the same time, we started to get the feedback that was essential if we were to improve the product set.

This need for feedback, coupled with our hidden agenda of using staff familiarization and involvement to generate demand for GIS within our organizations, led to a much more ambitious “pilot” initiative. We duplicated the Oyster River product for one 1:50 000 map sheet area in each of the 10 B.C. Fisheries sub-regions, covering all DFO Divisions in the process, and hauled our computer by road (we didn’t trust air transport) to each office in order to present and discuss both the local map sheet and regional data. Our presentations were directed primarily at Fisheries and Habitat staff but the audience included interested personnel from other programs and agencies. In all, 149 people attended the regional demonstrations and many more from a broad spectrum of organizations requested and received demonstrations in Victoria — and continue to do so.

In each case, the system was not presented as a fait accompli. Our visit was advertised as an opportunity to use real products as the basis for consideration of regional needs and priorities for geographic information, particularly as they related to the objectives of the Fisheries program but also from the general point of view of the umbrella organizations. Discussion focused on a set of questions distributed at the beginning of each presentation and encompassed:

- general regional issues and concerns;
- relative priority of new inventory versus improved access to existing information;
- simple data display versus complex spatial analysis;
- digital base map requirements;
- overall GIS strategy, action plan and resourcing;
- additional data displays that would be of use;
- issues related to the creation and management of digital databases; and
- the role of headquarters versus regions.

As a result, we not only received productive feedback about specific themes and capabilities that would be of value in the management of fish and fish habitat, but were able to brainstorm about directions that would be most appropriate for broad GIS implementation in the longer term within our organizations.

Themes for fisheries management

The hardcopy Stream Information Summary Map that we began with contains information about:

- hierarchical watershed codes;
- fish distributions and spawning areas;
- the locations and nature of blockages and barriers;
- the locations of other “points of interest”, e.g. hatcheries, spawning channels, flow gauging stations.

We also knew, from a provincial government point-of-view at least, that lakes were as important as streams. At a minimum, field staff need to know which lakes have been surveyed and when, what data is available, where and in what form. Beyond this, our travels confirmed that administrative themes are as important to habitat and fisheries managers as information about the natural resource itself. Management unit boundaries, stocking information, waterbodies with special angling regulations, guide territories, angler use survey locations — all were included in the many types of georeferenced information that staff believe they need to access.

The QUIKMap products that we prepared to address these requirements are listed in Table 1. Four of the demonstration screens, showing both administrative and resource data, are reproduced in Figure 1. Figure 1a identifies lakes that have been completely or partially
Figure 1. Fisheries Summary Information: Sample Screen Plots
Table 1. QUIKMap Product Set for Fisheries Management.

a. Provincial

- 1:2,000,000 overview: coastline, islands, major water features, NTS 1:250,000 grid, local map areas.

b. Regional

- sample base maps at scales of 1:20,000 to 1:525,000 combined on screen: TRIM, forest cover, federal 1:250,000, hydrographic.
- watershed boundaries for major systems.
- administrative boundaries: MOELP Sub-regions and Management Units (MU's), DFO Sub-districts.
- data displays tied to administrative areas: angling regulations notes, stocking records.

c. Local 1:50,000 Map Areas

- fish distribution and spawning areas: summary and by individual species.
- blockages and barriers.
- points of interest: hatchery, counting fence, etc.
- point and reach survey sites; summary of available information.
- water quantity and quality sample sites.
- critical habitat areas.
- surveyed lakes; summary of available information.
- stocked streams and lakes; accompanying data tables.
- angling guide territories.
- aerial surveys of angler use of lakes.
- watershed codes.
- watershed boundaries for individual streams.
- biogeoclimatic zones.

surveyed. Clicking (with a mouse) on a surveyed lake will bring up a summary and description of the survey data. A scanned bathymetric map can also be imported. Figure 1b displays reach breaks and point sample sites from detailed aquatic biophysical surveys, together with the locations of obstructions to fish passage. Angling regulations notes can be listed by clicking on a management unit in Figure 1c and Figure 1d shows both fish distribution by species and stocking locations. Major legend groupings are colour-coded so that multiple themes can more effectively be reproduced on one map — all obstructions are in red and all fish species codes in green, for example.

For the most part, this is overview-level information. Potential management applications include:

- identification of high value and threatened wild fish stocks;
- location of critical habitats and controls;
- broad estimates of productive capacity;
- summary assessment of existing and potential impacts.
- selection of sites for enhancement or restoration activities; and
- development and modification of regulations.
And, even at this level, an average of four staff days was required to add the available thematic information to each 1:50 000 base. Stream Information Summary (SISW) data sets are not properly georeferenced and couldn't be migrated directly. Other digital data are stored on a variety of hardware/software platforms, usually in a manner that makes sharing difficult or impossible, this in addition to the inconsistencies in content already discussed. And most data is hardcopy scattered throughout various regional and headquarters offices, much of it unknown to the staff that need it most. The collation process was a graphic illustration of the difficulties that field staff must have in attempting to gather information in order to respond to operational demands.

**Base wars — streams are different!**

The MOELP digital Stream Atlas has been essential to this initiative. The Atlas is a data base of the complete British Columbia stream network ("bluelines") shown on 1:50 000 NTS maps except for some high gradient/low fisheries value 1st order tributaries. It was created to provincial standards on a VAX minicomputer using Intergraph IGDS/DMRS and custom software developed by PAMAP Technologies. Most importantly, the Atlas is not simply a base map upon which data can be overlain. All streams are uniquely identified by a computer-generated watershed code that locates it in the watershed's tributary hierarchy and to which any data can be tied. Associated attribute data include:

- gazetted stream/lake names;
- 1:50 000 NTS sheet number for watershed mouth or lake outlet;
- UTM grid reference of mouth or outlet;
- distance upstream from trunk mouth (in m);
- lake sequence number; and
- lake inlet and outlet locations.

At the present time, the Stream Atlas is, in the view of both provincial Fisheries and DFO, the only province-wide base with sufficient — but not excessive — detail and structuring to be effectively used with watershed-level fisheries data, the highest immediate priority for our inventory programs and, as we have seen, the level toward which this pilot initiative was focussed. Other possibilities are listed in Table 2, along with the advantages and disadvantages of each from our point-of-view. All, including the Stream Atlas, have significant shortcomings, either in content, in quality or in coverage. Even the Atlas, while essential, was not viewed by operational staff as enough in itself. Background topography, toponymy, transportation routes and settlement locations, at a minimum, were also seen as important for convenience and effectiveness of use. This could be accomplished in QUIKMap by combining the Atlas with selected themes (layers) from the federal 1:250 000 digital coverage — also immediately available for the entire province.

Unfortunately, the Stream Atlas has been temporarily mothballed because of disagreement over whether it should or should not be part of a supported provincial base. The Provincial Digital Atlas is based on three distinct data sets with levels of detail appropriate for display at 1:2 000 000, 1:250 000 and the TRIM product at 1:20 000. Some individuals see the Stream Atlas as competitive with TRIM, the future for detailed applications, but, for our immediate overview purposes, we see the Atlas only as a necessary enhancement to the provincial 1:250 000 base (itself an extension of the existing federal product; see Table 2). For aquatic information, streams are different. The streamline — or segment of it — is not merely a backdrop against which data is overlain; streamline segments are the fundamental spatial units to which that data is tied. Either we have a base that includes the level of detail and the features of the Stream Atlas or we must "turn off" the existing streamlines on that base and overlay the Atlas.

Streamlines on the provincial 1:250 000 base are unacceptable because of highly varying density and quality from map sheet to map sheet (because of different data sources) and because of insufficient structuring — no watershed code or equivalent. As well, lake outlines are too generalized, even for overview aquatic requirements, and smaller lakes are not captured at all. Watershed codes are very important in our work, primarily for external communication. The code provides a standard identifier for tying attribute data to stream graphics, a convenient and unique label for hardcopy filing systems, and a way of ensuring that all parties are talking about the same piece of landscape in planning or problem-solving exercises. The system is described in detail in "A Guide to the Hierarchical Watershed Coding System for British Columbia" (British Columbia, Ministry of Environment and Parks, 1988).

So the digital Stream Atlas remains in IGDS/DMRS format, a format that is no longer supported in MOELP. Fortunately, both for this initiative and for the rapidly increasing number of other users, within and outside government, it is usable. We can convert to QUIKMap and other GIS formats. We do not, however, have the ability, in-house, to edit it or to add new streams and watershed codes. Nor can we properly enhance it with lake outlines and watershed boundaries, the two highest priorities for the future, although both were added for the map sheets used in this project.
### Table 2. Digital Base Maps for B.C. Streams and Lakes

<table>
<thead>
<tr>
<th>Base</th>
<th>Advantages/Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOELP Stream Atlas 1:50,000</td>
<td>Advantages: complete provincial coverage; consistent standards to provincial level including edge matching; unique stream identifiers provide intelligence. Disadvantages: streamlines only; lake inlet/outlet locations but no outlines; no cultural or topographic information; presently archived; cannot be maintained or updated.</td>
</tr>
<tr>
<td>MOF Forest Inventory 1:20,000</td>
<td>Advantages: includes lake outlines, lake and stream names, road network, other cultural and resource data. Disadvantages: doesn't cover non-forest areas (parks, alpine, urban centres); streamlines break at bridges, map boundaries; CAD format; no network intelligence; quality control problems.</td>
</tr>
<tr>
<td>Surveys &amp; Mapping DEMR, Ottawa 1:250,000</td>
<td>Advantages: complete provincial coverage; includes lake outlines, generalized cultural and topographic information including toponymy. Disadvantages: inconsistent level of detail for streamlines; lake outlines generalized and smaller lakes not captured; no intelligence; quality control problems.</td>
</tr>
<tr>
<td>MOELP, Surveys &amp; Resource Mapping 1:250,000 (enhanced)</td>
<td>Advantages: as for federal coverage above except coverage not complete until 1993; format consistent with TRIM; additional editing; digital elevation model. Disadvantages: as for federal coverage above except much improved quality control.</td>
</tr>
<tr>
<td>MOELP TRIM 1:20,000</td>
<td>Advantages: includes lake outlines; detailed cultural information including toponymy; detailed DEM; high quality; meets all federal and provincial specifications. Disadvantages: only 1/3rd of the province has coverage; completion presently scheduled for 1998; excessive detail and file size for overview applications.</td>
</tr>
</tbody>
</table>
Desktop mapping — is it enough?

The short answer is no, but for many immediate purposes in fisheries management simple GIS will do, at least for display if not for data entry, until something better comes along. The highest priority demand in most offices was for quick and easy access to up-to-date basic information in order to reduce the burden of responding to routine questions and issues that are largely administrative. The need for complex spatial analysis was recognized but many staff felt that simple map/data display on many desks in each office would meet 80-90 per cent of their needs. Direct public access to menu-driven read-only workstations was suggested. An absolute requirement that software be easy to learn and operate was repeatedly emphasized. There is no faith at the working level in our organizations that full-scale GIS implementation with adequate technology and technical support will take place in the foreseeable future.

This feedback reinforced our belief that QUIKMap, or at least a QUIKMap-type product, would be a productive platform upon which to tie our initial forays into the hazardous world of GIS. QUIKMap's features are summarized in Table 3. The critical points to note are:

- the ability to display and plot anything on any base;
- low cost and limited hardware requirements for both QUIKMap and its associated database management software;
- the absence of analytical capability;
- the ability to import from a variety of full-featured GIS and CAD software; and
- the relatively easy learning curve.

A disadvantage for us, although not a fatal one, is that only a PC version of the software exists; Mac hardware is not supported.

A much more serious "fly in the ointment" and one that we remain very seriously concerned about is the use of any simple GIS package for digitizing line and polygon data. Problems with data display are one thing, software-generated limitations or errors in data acquisition quite another. QUIKMap, for example, does not by default store digitized data in a way that supports topological intelligence. This was not a significant factor for our pilot work but could be for full provincial implementation. A sudden plunge into an extensive data entry program without a full understanding of this issue would be a classic example of the danger in being technology-driven.

Where did we get with all this? What next?

The most realistic perspective is probably the statement, "12 down, 1162 to go!" There are 1174 1:50 000 NTS map sheets for British Columbia. We have created a product set for fish and fish habitat management that is valuable in the view of both line managers and staff but we are not much closer to full implementation than most of the seven-course meal GIS projects. On the other hand, we have spent a lot less money and haven't made any mistakes that we can't easily afford to back away from. Bite-size GIS does have its advantages.

We have been forced to face up to some fundamental truths because of this exercise. The most basic one is that, no matter how you begin, GIS implementation is going to be data-controlled. The data itself will quickly become the main focus and the main investment in building a system. Yes, this statement is obligatory in any GIS paper: it is a truism and it is fast becoming trite. But it's one thing to read it and another to live it.

As organizations, we do not have vast amounts of data at hand: our operational staff spend as much time or more complaining about not having information as they do about not having access to the information we do have. Even for an overview-level GIS system as discussed here, though, we are looking at about 20 person-years of work to create properly georeferenced data sets for the Province. And this is on top of the 12 or so person years it took to create the digital Stream Atlas and the additional 5 plus person years that will be required to add lake outlines and watershed boundaries. From our point of view, this is "big business".

Still, this initiative has shown that there is a role for simple, inexpensive map display software in GIS for fisheries management. The concerns about data entry are real and must be taken seriously, but for data display and given their ease of use, products like QUIKMap can be extremely effective. We note with interest that the B.C. Ministry of Forests has backed away from reliance on full-featured GIS in its district offices, at least for the short term, largely because of data quality problems and lack of qualified staff. Instead, they have used QUIKMap and FoxGraph to create a Forest Inventory Reporting System (FIR) that provides access from districts to their central timber, range and recreation inventory database. Products are user-defined statistical tables, coloured charts and colour-themed maps. This is a bite-size approach by an organization that does have a large volume of digital data in place.

And we have created a monster! We now have a more informed and a more demanding clientele. Staff, even senior management, have been seduced and are looking for solutions, both short and long term. Increased high level support ensures that our own seven-course meal is coming — someday. We can look forward to LAN/WAN client-server UNIX based technology, data administrators and GIS technicians, properly specified databases full of quality data, the Land Information Infrastructure, TRIM and a host of other goodies. But our staff have already had a taste of the turkey and our history indicates that no one is going to resist snacking until the meal is served. Ease of use alone will generate use. We don't think that's a bad thing.
Table 3. An Overview of QUIKMap.

- a simple but effective desktop mapping package that is very good at producing high quality output screens and plots.
- maps can be displayed in any of 6 different projections and the map display can be manipulated by windowing and enlarging specific areas (zooming).
- provides a scale bar which automatically re-sizes after zooming and the ability to display cursor coordinates in UTM or Lat-/Long.
- at any time, the active display can be printed, plotted, saved as a screen image or exported in .DXF format.
- not a true GIS by most definitions because of limited internal analytical capability: areas, line lengths, some neighbourhood operations and not much else.
- costs less than $1,000 at this writing, and can be used effectively on a standard VGA colour PC workstation (preferably 386SX or better) with a math coprocessor.
- present version uses dBASE III Plus (or a compatible like FoxBASE+) or Excel, and the next release will support dBASE IV.
- differs from most GIS systems in that data objects -- points, lines and polygons (areas) -- are not fundamentally linked to the base maps on which they are displayed; instead, objects are stored in data files and may be displayed (overlaid) on any base map.
- custom base maps can be created by combining bases, regardless of initial scale, and by turning layers on or off as desired.
- information about an object is stored as a database record which can be displayed by pointing to it on the map or extracted by performing one of a number of possible queries in dBASE.
- includes a digitizing module which automatically calculates line length and polygon circumference and area.
- translators are available to permit conversion of spatial data captured in other common formats (including Autocad .DXF, Intergraph .DGN, CARIS .NTX, and TRIM).
- computer-literate staff can be functional in QUIKMap with only a few days training and do not have to work continuously with it in order to retain operational familiarity.
So what are the next bites? Briefly,

- Field offices are buying QUIKMap. A small angling guide database is already in place in one MOELP region. We intend to encourage and support limited initiatives like this.

- Many of our habitat staff think that the Forest Inventory Reporting System (FIR) would be extremely valuable for their own work. MOF have offered to install and train. We're going to take advantage of that offer.

- In headquarters, we are moving toward an accepted systems development approach and are concentrating on the specification and development of province-wide databases, both spatial and attribute, and on database management processes. At a minimum, we want to provide systems and standards for the collection and storage of stream and lake data that will be broadly used throughout the province. We realize that outside agencies (native organizations and B.C. Hydro, for example) are collecting more information than we are and we want to be able to make full use of that information and to be able to easily provide ours to them.

- Further implementation of the product set developed in this initiative — a Fisheries Information Summary System — depends on the existence of a functioning digital Stream/Lake Atlas. This is our highest priority and, because of our efforts and rising external demand, we finally have management support. Revised specifications for the Atlas, including conversion to an arc-node, 3-D network topology, are near completion and will be implemented on a full-featured GIS workstation by spring of this year. We have also begun to add lake outlines for priority areas and are looking at how we are going to link to the 1:20 000 TRIM base for our detailed reach-level data.

- Our biggest problem is to remain nearsighted enough to achieve concrete results — i.e. not to be seduced ourselves by the seven-course approach. At the same time, however, we have to avoid the dangers of being nearsighted — choosing dead-end directions and letting broader initiatives proceed by default along routes that conflict with our interests. For these reasons, we remain involved in and informed about the plans for seven-course technologies in our organizations. To the greatest extent possible, though, we are letting others worry about the details.

References


The conceptual determination of carrying capacity analysis using GIS technology. Case study: the upper Komering sub-watershed, South Sumatera, Indonesia

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Abstract

The paper discusses the use and role of GIS-ILWIS software in determining conceptually the carrying capacity of the Upper Komering Sub Watershed for rice and coffee cultivation.

The carrying capacity was viewed and determined by the attractiveness of the land for cultivation. The attractiveness of the land was identified as a push factor of the farmer to expand and cultivate their land. Therefore, it determines the trend of the supply and demand for land ratio. The attractiveness was considered as the function of the supply of land and it was obtained by combining the physical suitability and socio-economic aspects i.e. the availability of physical infrastructure of the area and projected into different scenarios. The identification of the present and future demand of land was done by analysing the dynamic characteristics of the existing farming system i.e. farm size and change in farm size over time and population in the study area.

Accordingly, the GIS technology was employed to define and map out areas reflecting their carrying capacity. GIS has effectively handled the complexities of determining the carrying capacity based on user defined criteria, in this case, environmental or physical factors as well as socio-economic. The study yielded conclusive results that indeed GIS comes in handy to be employed in watershed management and development.

Introduction

This paper was written primarily to give a general descriptive analysis on carrying capacity in Upper Komering Sub Watershed, South Sumatera, Indonesia. The references used for this paper were mainly based on relevant reading materials on Resources Management and combined with those data collected and processed during the implementation of The Integrated Land and Watershed Management Information System (ILWIS) Project in Indonesia.

The paper will attempt to define carrying capacity by looking into the limiting environmental factors such as soil depth, nutrient contents, slope and
climate. It affects the suitability of land for both coffee and rice production within the watershed. It will also attempt to put an added dimension by taking socio-economic factors such as land availability which has been determined as a function of actual land supply and demand as well as the accessibility of land, two other principal factors to be used to define carrying capacity of the watershed.

The authors of this paper would like to therefore explore the possibilities of using GIS technology as supported by ILWIS software, as an effective tool has been employed as an effective tool with using criteria to define land suitability, availability and accessibility and further using these themes to determine the carrying capacity of the watershed through spatial data manipulation and analysis.

II. Background and problems definition

Land ownership has been identified as one of problems in upper watershed development. It means that most of the farmers have limited access to the land, especially to the productive suitable and available land. In some regions, especially in Java, this phenomenon is much worse than the situation in Sumatera (Ramsay and Mulyadhi, 1984). Because of these factors population pressure on the land is so tremendous and pushed the landless or nearly landless farmers to expand their agricultural practices to very steep and mountainous areas which are not suitable for agricultural cultivation. Therefore, it is not surprising that some symptoms or negative impacts such as landslides, sedimentation, siltation of dams, drought and flood frequently occur in most of these regions. According to the Ramsay and Mulyadhi (1984), the erosion rate (2-3 mm/year) and natural soil formation capability (1 mm/year) in the study area are not comparable. These problems strongly indicate that the critical level of land resources exploitation or carrying capacity has been reached (Sumarwoto, 1985).

The upland agricultural land in upper watersheds is addressed mainly to hilly and mountainous areas that can be grouped and recommended generally into four types categories I to IV and restriction for all types of cultivation is given to the land with category IV (Ramsay and Mulyadhi, 1984).

Based on this consideration the question about how far the available land can support and provide the basic needs of the people has arisen. Therefore the analysis of carrying capacity of watershed is very important aspect in order to give better insight in the situation of scarce land resources and in the formulation policy measures and other development interventions.

III. General description of the study area

Location and area extent

The largest part of the Upper Komering Watershed is located in Ogan Komering Ulu Regency, South Sumatera, Indonesia and lies approximately between lines of latitude 4° 12 and 5° 00 south and between line of longitude 103° 35 and 104° 27 east.

The study area covers 5 districts namely: (1) Banding Agung; (2) Muaradua; (3) Muaradua Kism; (4) Pulau Beringin, and (5) Simpang. It is a typical humid tropical upper catchment with the annual rainfall range from 1780 mm to 3081 mm. The total area is approximately 400,000 hectare. Among the five districts only Banding Agung, Muaradua, and Simpang are well accessible by asphalt road.

Land use and population in the study area

According to the Land Use and Vegetation Survey conducted by Suryana (1987), there are eight general vegetation-land use types: (1) rice/paddy field; (2) coffee plantation; (3) rubber plantation; (4) pepper plantation; (5) bushland; (6) grassland; (7) savannah; and (8) forest.

The dominant land use-land cover is coffee (73% of the total area has been cultivated) as part of either shifting cultivation or permanent cultivation. The main food crop is rice and covers about 16 percent of the total area. It is usually cultivated in the valley bottoms while upland rice is grown in the hill, often in combination with young coffee plants.

Furthermore, based on the role of cultivated crops (main or additional crops) Suryana (1987) has classified the agricultural land into type of cultivation that represents the existence of farming systems in the study area which consists of coffee monoculture system (CMS) and coffee plus wetland rice (CWR).

According to Official Statistical Data (1984) the total population in this study area is 240,000 persons with average family size is 5 persons/household and growth rate 5 percent/year. This is relatively very high in comparison to the Indonesia annual population growth (2.1% per year). This figure indicates high substantial immigration rate especially in Simpang, Muaradua and Banding Agung District with high population growth rates. These districts also have a relatively dense road network. The population density is varies between 27 persons and 67 persons/km. The subsistence of the people is mainly dependent on the agricultural sectors (89% of the population).
IV. Conceptual framework

Carrying capacity defined

The term carrying capacity has been defined in different manners as viewed by various authors. According to Fearnside (1985) the human carrying capacity is the number of people that can be supported indefinitely in an area at a given standard of living, without environmental degradation taking place, given appropriate assumption concerning technology and consumptive habits. The foregoing definition of carrying capacity could be taken to include the concept of conservation, sustainability and productivity of the land to support the consumption needs and/or consumption patterns of a given population on an area over period of time. In other words, it implies the optimum and inherent capability of the land to produce various outputs to support and feed population within permissible level.

Geographers utilize carrying capacity as the maximum theoretical population that can be supported, given a resources base (Ricci, 1976). The approach employed in this case mostly consists of calculating the available agricultural land undergoing cultivation. Determination of the maximum population that an area can support is done by assuming a minimum acreage necessary to ensure survival of producing farmer.

EPA (1974) defines the term as the level of human activity (including population dynamics and economic activity) which a region can sustain as acceptable quality of life in the long term.

Geerling and de Bie (1986) define carrying capacity as a level of equilibrium between the availability of an element in an ecosystem (e.g. pastures) and the level of exploitation of that element (e.g. by herbivores). Clearly this definition of carrying capacity is basically related to the physical environment capacity.

Based on this perception, it is therefore possible for human carrying capacity to be analyzed through different approaches. As such the balance or imbalance between actual supply and demand for land could be considered as a basic indication for human carrying capacity analysis.

On the other hand, carrying capacity as a concept is often applied to indicate and estimate the level of permitted exploitation. Thus, in a sense, carrying capacity conveys an idea of limitation on the use of something.

Carrying capacity analysis: an overview

The conceptual framework for this paper largely evolves on carrying capacity as previously defined. For the purpose of determining therefore the carrying capacity of the watershed, the term carrying capacity is defined in two aspects: as a direct function of the physical environment, i.e. physical environment capacity, and the other aspect as a related function of socio-economic factors such as land availability as indicated by actual land supply and demand together with accessibility factors affecting land such as nearness to existing infrastructures.

Thus in this particular case, the following has been defined as a prerequisite in determining the carrying capacity: the watershed and the setting up of the optimum level of exploitation: the area concerned is the whole watershed in general, and the terrain mapping unit in particular; the exploited element is land itself; while the object of exploitation in this particular case is the growing of either coffee monoculture or coffee plus wetland rice.

Hence, it could be assumed that the suitability of the land for combined growing of coffee and wetland rice would serve as framework of determining the physical carrying capacity. Therefore, all factors affecting land suitability will be classified as limiting.

Determination of land suitability was carried out by using FAO's guidelines and criteria which was combined with Land Evaluation Computer System (LECS) at the same time the spatial mapping of suitable and non suitable areas can be mapped out and was undertaken with the use of a GIS software called ILWIS.

This paper will also attempt to look at another equally important aspect of determining carrying capacity—that of identifying limit of exploitation as determined by socio-economic factors. In this case, socio-economic factors affecting land availability and land accessibility. Land availability has been defined as the total agricultural land available for cultivation. As such, factors that would affect land availability is basically the actual supply and demand for land, with demand being determined as direct function of farm household population, size of farm holding and change of farm size over time. Land supply is largely determined by the total area of the whole watershed less the already occupied areas.

Looking at farm household population, it could be also viewed as a limiting factor both as it affect demand as well as its effect on land productivity. Obviously, the higher the population, the higher would be the demand for land. On the other hand, diminished land productivity is also tied up to high population. The more the number of people there are, the higher would be the demand for food. Consequently, agricultural practices or farming system become intensive in order to satisfy and meet population demand for food. As farming system becomes intensive and without proper compensation for additional inputs to the land, the soil becomes prone in terms of depletion of soil nutrient available.

With regards to demand for land, this will be taken as indicative factor of the consumption pattern of the population. The premise would be that increase in population will mean an increase in the demand for agricultural land.
With these lead as framework, the study will yield 2 results of determining carrying capacity, that is, from purely ecological point of view which will make use of the land suitability factors and from a socio-economic point of view which will focus on factors affecting land availability and land accessibility.

V. Method and techniques used

1. For the carrying capacity analysis purposes the data which has been collected by the ILWIS project especially farming systems data were used. All data manipulation was done using GIS-ILWIS commercial software.

2. Various criteria were formulated based on approved guidelines and FAO guidelines to be able to carry out suitability, availability, accessibility and attractiveness determination.

3. The attractiveness rating of the land has been done through procedures as stated as follows:
   (a) Define land Suitability map for coffee
       The land suitability map for coffee was derived by combining or overlaying two different maps i.e. the potential erosion under coffee and the ecological suitability for coffee map. By overlaying these maps five classes of suitability rating i.e. very suitable, suitable, moderately suitable, low suitable and non suitable were resulted.
   (b) Define land accessibility map
       The land accessibility map was derived by assigning classes of distance i.e. 0—2 km; 2—4 km; 4—5 km and >=5km to the road map. The increasing distance per class represents the degree of accessibility.
   (c) Define land availability map
       The land availability map was derived from the landuse and landcover map through subtraction of the agriculture land (i.e. coffee or rice area) per terrain mapping unit by areas which have been occupied. By doing so, five classes of land availability i.e. 10 — 30%; 30 —50%; 50 — 70%; 70 — 90%; 90 - 100% were derived.
   (d) Define land attractiveness
       The land attractiveness map depicting land which are suitable, accessible and still available was resulted by overlaying three different maps i.e. land suitability, land availability and land accessibility map. The land attractiveness is consisted of five classes i.e. highly attractive, attractive, moderately attractive, low attractive and non attractive.

VI. Results and carrying capacity analysis

Results

Using GIS technology, an attractiveness map containing area labelled as "attractive in physical and economical context" were clearly defined. In coming up with this particular map, 3 (three) factors were largely considered, which were: suitability, availability, and accessibility. Based on these factors, a piece of land was determined as an attractive land if this land in general is suitable, available and accessible for cultivation and for growing coffee in particular. All of these 3 (three) factors involved in defining the attractiveness of land were duly considered as a function of land supply.

Erosion hazard and land suitability map

For the factor suitability, the main criteria used focused mainly around agro-ecological suitability, that is taking into account the agricultural as well as ecological aspects of the land. For ecological related parameters, due consideration was given to soil depth, steepness of slope, and erosion hazard within the area. By large, the soil formation rate within the watershed has been characterized as 1 mm/year while the soil depletion or degradation rate as function of erosion hazard, soil erodibility and steepness has been pegged at 3 mm/year (Ramsay and Mulyadhi, 1984). Clearly from the standpoint of carrying capacity, the critical point has been over reached. Soil depth was therefore considered a major limiting factor within the watershed and would largely dictate and influence agricultural cultivation. Steepness of slope was also a major consideration in the determination of land suitability. The higher the slope, the greater is the erosion hazard and risk. Thus, areas found at highest or steepest slopes (> 50 %) were considered suitable only as conservation area (protected forest). In other words, all land with steeper slope are less suitable for annual crops and require a lot of improvement. Inversely, areas at lower slopes are said to have lower erosion hazard and risk. They are generally with deeper soil, thus having higher suitability rating.

The resulting erosion hazard map and individual land suitability assessment for growing coffee and wetland rice in the study area are presented in the Table 1, and Table 2.

<table>
<thead>
<tr>
<th>No</th>
<th>Erosion Hazard Class (ton/ha/year)</th>
<th>Description</th>
<th>Area (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>2.5</td>
<td>Very low</td>
<td>173,616</td>
</tr>
<tr>
<td>2.</td>
<td>5.0</td>
<td>Low</td>
<td>108,294</td>
</tr>
<tr>
<td>3.</td>
<td>10.0</td>
<td>Moderate</td>
<td>76,890</td>
</tr>
<tr>
<td>4.</td>
<td>20.0</td>
<td>High</td>
<td>43,683</td>
</tr>
<tr>
<td>5.</td>
<td>50.0</td>
<td>Very high</td>
<td>5,355</td>
</tr>
</tbody>
</table>

Total  407,838