THE GEOGRAPHICAL INFORMATION SYSTEM (GIS): A TOOL FOR SUSTAINABLE FOREST MANAGEMENT

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Abstract

The use of Geographical Information System (GIS) and Global Positioning System (GPS) in forest management has become a major event in the forestry sector. Tin's paper gives an insight of the application of Information technology into forestry development. GIS is designed for the collection, storage, and analysis of objects, and phenomena where geographic location is an important characteristic or critical to the analysis. GIS is now accepted as a fundamental tool for the effective use of geographical information. Forestry involves the management of a broad range of natural resources within a forested area. In addition to timber, forests provide such resources as grazing land for animals, wildlife habitat, water resources and recreation areas. The use of GIS for analysis of timber harvesting, habitat protection and planning the location of scenic roads and forest fire all discuss in this paper.

Introduction

GIS technology helps in organizing data on problems, understanding the spatial relationship associations and provides a powerful means for analyzing and synthesizing information about the research carried out (Aronoff, 1989).

GIS technology is a device widely accepted by the public as well as private forestry agencies. It is the primary management tool for timber stock taking in forest inventory.

Forestry involves the management of a broad range of natural resources within a forested area. In addition to timber, forests provide such resources as grazing land for animals, wildlife habitat, water resources and recreation areas. The U. S. forest service, for example, is saddled with the responsibility of management of forest harvesting, grazing leases, recreational areas, wildlife habitat, mining activities as well as protection of endangered species. Balancing the competing resource conservation and resource use activities must be accommodated. Accessing the feasibility of these multiple uses is greatly enhanced by the use of GIS techniques.

For example, the GIS for Flathead National Forest in Montana includes digital terrain data, vegetation associations from Landsat satellite data, timber compartments, land types, precipitation, land ownership, administrative districts and the drainage network. The GIS has been utilized for such analyses as timber harvesting, habitat protection and planning the location of scenic roads (Aronoff, 1989)

Over the past eight years, GIS technology has been widely accepted by public as well as private forestry agencies. In most parts of the world this has been a result of the benefit of using GIS technology over current forest maps. The primary management tool for timber production in America is the forest inventory. It is used to access the existing forest resource and develop harvest schedules and treatment programs to project future timber supplies and for other operational planning activities. Forest inventory data are collected using remote sensing techniques.

The conventional forest inventory was done progressively with a small portion of the forest being inventoried each year. To update a forest cover map could take 20 years or more with expensive manual drafting. With GIS the forest cover maps can be updated on a constant basis and it provides the forest managers more current data than what was previously available.

With GIS technology, the average age of the information in the forest database could be reduced from 20 years to only a few weeks. The time factor alone has led to a wide acceptance and large demand for GIS applications in forestry.

In itself, the use of GIS to update the forest inventory maps is not much more than automated cartography but it is the analytical power of GIS that sets it apart from cartography. The GIS can store and analyse the forest information in ways that could not be previously done. It can be used to calculate the harvestable timber in the forest or model the spread of a forest fire.

Virtually Government Forest Management agencies in the world have acquired or are acquiring G1S, for instance the U.S forest service. In the mid 1980's three national forests were selected as GIS evaluation sites. They were: (i) George Washington National forest in Virginia. (ii) Tongass National Forest in Alaska and (iii) The Siuslaw National forest in Oregon.

At each of these sites, a GIS was installed and comprehensive data bases for these national forests were implemented. A cost/benefit analysis was kept on the GIS systems for a three-year period. The U.S. forest service has decided, after the three-year period, to implement a standardized GIS data base for the entire forest service. A $150 million procurement has been initialed for GIS hardware and software to be installed in 600 locations beginning in 1991 (Mead, 1994). The southern region of the forest service will receive GIS software on new UNIX workstations in 34 offices as part of the first phase of a region wide conversion of 120 of their southern offices. All of these units will have a complete GIS database. 'The ability to perform spatial analysis and complex database queries will be completely new to them. The new system will empower employees with new ways to acquire knowledge" (Mead, 1994).

The Uses of GIS in Forestry

The use of GIS in forestry is a welcome development and cannot be over-emphasized. GIS technology is used to balance delicate habitat and land - use policies in forested areas. Louisiana Pacific is an international company with $2.8 million dollars in annual sales with 25,000 shareholders and 1.6 million acres of timberland. The company harvested 10% of its forest holdings in California and leaves more than 90% unharvested as a future investment and habitat for animals. The decision of where and when to cut down trees needs to be based on scientific fact and the ability to foresee long-term protection of habitat. In order to better understand the impact of cutting down trees on habitat, the company has invested in GIS technology. The GIS technology has enabled Louisiana Pacific to model the effects of harvesting trees now and 120 years from now.

An added benefit of using GIS technology has been a communication avenue between leading environmental groups such as World Wildlife Fund (WWF), the Nature Conservancy, and World Bank. The GIS applications allow maps, graphs, and other planning tools to be shared instead of each side coming up with its own statistics, maps and graphs. The Smithsonian Institute and Nature Conservancy have applauded the efforts of GIS.

Louisiana Pacific had already been using ARC/INFO {GIS software) for forest inventory and realized the enormous benefits of GIS in its ability to analyse and overlay data. The company uses the program FREIGHTS which stands for Forest Resource Inventory Growth and Harvest Tracking System. It is a generic simulator that allows information to be collected and analysed about the conditions of .individual trees. The company spends nearly $3 million dollars implementing the GIS database and system but having the most accurate information available will save the company millions of dollars in the long-term. (Thompson, 1996).

ESRI (GIS Package) is already waving its green flag for GIS technology in Forestry. Jack Dangermond - a forester said, "1 am a longtime believer in using GIS technology to preserve the environment. With GIS, the corporate customer can find viable, sustainable and profitable solutions to managing resources. That's something I think we can all live with" (Thompson, 1996). The company, Lousiana Pacific has long-term plans and goals for its GIS including making it available to others in government, academia, and the forestry industry. "By sharing this system with those-who need it most, the company hopes to ensure the preservation of one the world's most precious resources; Its Forest" (Thompson, 1996).

In .Canada, almost, every forestry agency has either implemented GIS or is in the process of implementing GIS technology. Forestry is a huge industry in the provinces. British Columbia's forest cover is 50 million hectares which is about 40% of the Canadian timber supply (Aronoff, 1989). Before GIS, aerial photography, field sampling methods and manual drafting updated the forest database. Under the GIS program, the forest maps were digitized and a forestry inventory can be updated constantly. GIS provides a way for forestry agencies to manage and manipulate their database. Land set satellite is used to update the individual maps that need current information due to forest harvesting or forest fires.

GIS and Forest Fires

Forest fires have an important influence on the vegetation cover, animals, plants, soil, stream flow, air quality, microclimate, and even general climate. The loss of timber is obvious and so is the damage to life and property. The loss of recreation value of the forest and the destruction of wildlife habitat are also consequences of forest fires.

Researchers and scientists have long been trying to predict the behaviour of a forest fire. Computer modeling has been the effort of many scientists using high resolution remote - sensing satellite imagery, powerful software, and GIS. In order to model a forest fire, the techniques for obtaining, analyzing and displaying special information in a timely and cost effective manner are needed.

As forest fires are spatial, GIS is used as a tool for modeling. A fire simulation program called FIRE: has been developed using ARC/Infor. "The model puts the power of comprehensive fire behaviour prediction into the hands of qualified ground resources managers where it can be most effectively applied. (Weinstein *et al,* 1997).

Through the integration of fire behaviour models with GIS modes, new insights in the fire danger situation can be gained. One example is the damage potential that arises from fires starting at a certain point to sensitive objects and areas like buildings, railways lines, fire - sensitive ecosystems. Proximity is a concept which is used in a great many GIS related models.

The need for accurate and dependable tools for forest fires management has led to the demand for GIS in fighting forest fires. Every year people, equipment, and financial resources are spent trying to contain forest fires and extinguish wildfires. Millions of dollars are spent annually on protecting life and property, timber, recreational areas and valuable wildlife habitat. The need for accurate and timely formation is crucial for safety and resource protection.

In the past, the fire behaviour prediction tool used was BEHAVE. BEHAVE is a non-spatial tool that inputs fire fuel tupes, topography data, weather data, and initial fuel moisture data. While BEHAVE is useful for predicting fire characteristics in a given area, it cannot give spatial output. It is unable to predict spread rates, flame lengths, fire line intensities, and heat calculations when these parameters change and they do constantly during a fire. Whenever there is a change, the entire BEHAVE model must be recalculated. Obviously, this is a very inefficient way to model the behaviour of a forest fire. However, with the use of GIS technology, the prediction of fire behaviour has not only become possible, but incredibly efficient and effective in forestry development. (Weinstein, *et al,* 1997).

The GIS - based forest fire model "puts the power of sound, accurate and efficient information into the hands of forest fire management personnel charged with coordinating the containment and extinguishing of wildfires. The model can now become one of the most effective tools for managing personnel, financial and equipment resources for battling one of our most destructive and dangerous forces of nature". (Weinstein *et al,* 1997).

Timber Harvesting

The availability of reliable logging records, inventory and growth data makes timber production a sustainability of timber harvesting.

An area estimates are an essential component of the resource forecast, and due account must be taken of unproductive land such as rock outcrops, stream buffers, and other areas which cannot be logged. The present calculation employs data derived from a Geographical Information System (GIS), which is compiled to assist in planning and management of the forest. The GIS is a Vector Based System (ESRI) Arc/Info and includes both anthropogenenic and environmental information, mostly captured at 1:50000 scales (Anonymous, 1989).

Harvesting Mode!

Prior to logging, trees thought capable of producing a merchantable log are marked for removal in accordance with forest service guidelines (Perston and Vanclay, 1988). The havesting model therefore comprises three essential components: the logging rule which indicates stems to be removed in logging, an allowance to predict the compulsory production of the logged stems, and a damage function which predicts mortality caused by felling and extraction operations.

GIS enabled better stratification and more precise area estimates; additional inventory data and a more objective method of site assessment; the revised growth model retained the species identities of all trees; a dynamic harvesting model enabled better predictions of removals of defect and logging damage (Doyel, 1981).

Planning the Location of Scenic Roads

The GIS and GPS support plays a very important role and support to forest management in the following areas:-

Road layout design and road network analysis, Road classification, Road acreage estimate, Road engineering, building, maintenance and upgrade, Access and delivery information for forest management, recreation and other on - site business (Doyel, 198 1)

Habitat Protection

GIS has a role to play in a detailed vegetation analysis planned for the future. Analysis of remotely sensed multispectoral/hyperspectoral imagery is being considered. In a rugged terrain, where accessibility is limited, GIS staff members can use high rcsokition aerial imagery and a Hue -- foot DEM to provide planners with data and maps to aid day --- to - day planning activities in protection of habitat and games (Doyel, 1981).

Conclusion

In conclusion, GIS is very much part of the information technology (IT) infrastructure for any organization, not a separate or niche technology. Stakeholders should plan on training all their employees on the new GIS software by training and monitoring program. It is the intention of the present study to illustrate the integration and practical application of GIS, field inventory data and dynamic growth model to estimate short and long - term timber yields and to indicate management alternatives for sustainability.

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