FIGHTING BUDWORM WITH A GIS

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ABSTRACT

This paper outlines the current state of GIS application in the ongoing battle against spruce budworm in the province of New Brunswick, Canada. In particular, the paper concentrates on describing a new methodology for applying GIS capabilities in the planning of aerial spray block layout. The paper concludes that the methodology has merit and is further evidence that current GIS technology does indeed offer the capability to move beyond simple retrieval applications into complex planning situations. However, slow response times due to large data volumes and current vector overlay approaches need to be addressed.

INTRODUCTION

Protection planning is an integral part of forest management. Forest management involves scheduling a host of activities associated with silviculture and harvest of the timber resource but, significantly, it also involves protecting the timber resource from insects, disease and fire. In the province of New Brunswick, Canada, the provincial Department of Natural Resources and Energy (DNRE) is responsible for forest protection on Crown (public) land and small freehold (private woodlots) land while forest companies pay for protection on their limits. The principal insect pest in the province, the spruce budworm (Choristoneura fumiferana (Clem.)), is the focus of their attention.

The spruce budworm is a prevalent and persistent insect pest over large regions of Canada and the United States. Budworm larvae annually defoliate spruce (Picea sp.) and fir (Abies sp.) trees over extensive areas in Central and Eastern Canada and, in the Northeastern States (Kettela, 1983). Spruce and fir are the mainstay of the pulp, paper and lumber industries in these regions. In New Brunswick these industries are the very backbone of the economy (Watson, 1983)! Repeated annual defoliation of spruce and fir trees by budworm leads to significant tree volume losses through slowed growth (Kleinschmidt, 1980) and, if unchecked, death in 3 to 5 years (MacLean, 1980.). New Brunswick has attempted to minimize such losses with annual aerial spray of pesticides. Conducted since 1952 (Irving and Webb, 1984), the spray programme has aimed to limit timber volume losses and maintain established levels of softwood harvests on Crown and small freehold land. It does not aim to eliminate the spruce budworm (Kettela, 1975).

Conducting an aerial spray campaign over an area the size of New Brunswick (approximately 6 million hectares of productive forest) is not a task that is accomplished without considerable planning effort. Actual spray operations are conducted by Forest Protection Ltd. (FPL), a non-profit company jointly owned by the provincial government and forest companies owning freehold land and holding Crown land licenses in the province. However, it is the Timber Management Branch of DNRE that actually plans the protection programme each year with input from those company sponsors having forest areas involved. Protection programme planning requires the collection and manipulation of large amounts of data, much of it map-based, in an effort to identify those forested areas needing protection and to configure these areas into operable spray blocks. The actual amount of forest targeted for aerial spraying each year varies with fluctuations in budworm populations. In 1986 approximately 500,000 ha were sprayed (Forest Protection Limited, 1986), though operations covering several million hectares have been common in the past 10 years (Irving and Webb, 1984). Until recently all data and map manipulation was carried out manually.

In 1982 DNRE purchased a GIS (ARC/INFO) with the intent of using it to store and handle forest and base map data for the entire province, and began the process of building the database (Erdle and Jordan, 1984). This massive task, almost complete, involves digitizing 2,000 forest cover-type maps (each covering approximately 4,000 ha at a scale of 1:12,500) and entering forest inventory and silviculture data for hundreds of thousands of forest stands. Once the database is complete, numerous applications of the GIS, particularly as a planning aid, will be possible. Already the GIS is being employed as an aid in protection programme planning and harvest scheduling (Erdle and Jordan, 1984). This paper will outline the current state of GIS application in the ongoing battle against the spruce budworm in New Brunswick. In particular, the paper will concentrate on describing current research aimed at developing a computer-based planning procedure for spray block layout.

THE PROTECTION PLANNING PROCESS

A number of map products are generated and used by DNRE in protection planning, including: (1) infestation forecast maps; (2) forest cover-type maps; (3) susceptibility maps; (4) setback maps; and (5) hazard maps. In the past, this information was generated each year and employed to target forest areas for aerial treatment in the form of spray block layout maps. A significantly different approach is now being attempted for the first time. The approach will arrange spray blocks solely on the basis of the distribution of susceptible forest and setback zones. Since the distribution of susceptible forest changes slowly over time, spray blocks, once arranged, will become "permanent" — subject only to minor adjustments from year to year. For actual treatment, spray blocks will be included or excluded, each year, on the basis of their coincidence with areas identified as being at risk due to past defoliation and predicted infestation. The paragraphs that follow outline the procedure in more detail.

The process of targeting specific forest areas for spraying begins with the identification of susceptible forest stands, i.e. those stands with characteristics that make them susceptible to budworm attack. Cover-type information, stored in DNRE's geo-referenced forest database, is used to produce 1:50,000 susceptibility maps. Each map, like the map illustrated in Figure 1, represents approximately 100,000 ha of ground area. The production of susceptibility maps is a relatively simple but time consuming undertaking involving the reclassification of basic stand information, such as species composition, into susceptible or non-susceptible categories on the basis of a specific set of rules.

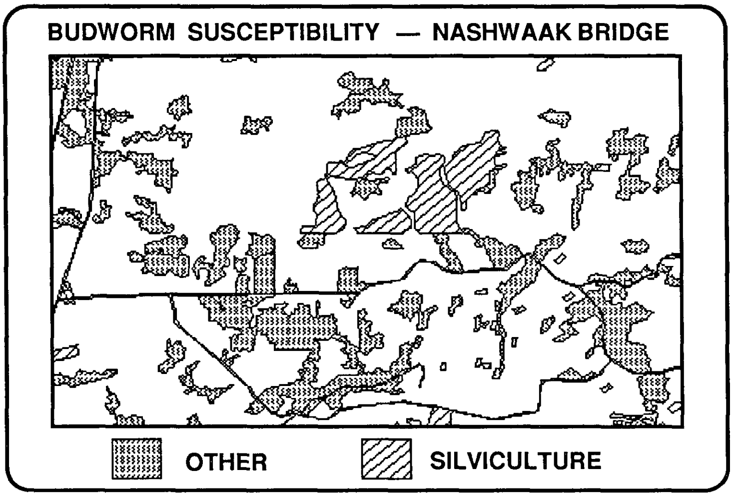

Figure 1. A 1:50,000 Map Showing Distribution of Budworm Susceptible Forest.

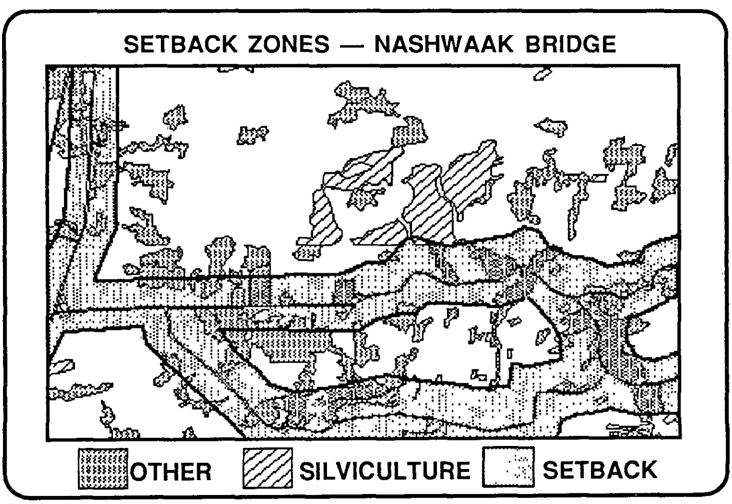

Figure 2. Budworm Susceptibility Map with Setback Zones Delineated.

The next step in the planning process involves identifying setback zones. Setback zones are buffers around habitation and ecologically sensitive areas which require special planning consideration in that they limit, or exclude altogether, aerial spray operations within their boundaries. Presently the delineation of setback zones is carried out entirely with manual mapping methods and results in a map typified by that shown in Figure 2. Although the GIS at DNRE has the ability to generate buffers around map features, the existing forest database does not contain the source information, for example the location of dwellings, fox farms or blueberry fields that would be necessary to generate setback zones. This situation is unlikely to change in the foreseeable future, since the cost to gather, digitally encode, maintain and process such information in a spatial database would be high and the payoff, versus current manual methods, apparently limited.

After setback zones have been outlined on susceptibility maps, the planning process enters one of its most difficult stages. This stage involves the layout of aerial spray blocks in such a way that areas needing protection are targeted in a configuration that will allow safe and cost-effective spraying. As might be guessed in looking at the map in Figure 2 this is not an easy undertaking, and in fact, it is not practical to target all parcels of susceptible forest. The process of laying out or modifying existing spray block configuration requires the integration of a host of considerations. For example, knowledge about aircraft types and associated load capacities, spray swath widths and relative operating costs, must be combined with visual impressions of spatial arrangements of parcels of susceptible forest and occurrence of setback zones and topographic features. The decision to locate and arrange a spray block in a certain way is subjective. The planner may readily see groupings of susceptible stands and configure a spray block accordingly; however, without a quantitative basis for evaluating a proposed spray block layout, the planner will always wonder whether a better configuration might exist. Figure 3 isolates a geographic area on a 1:50,000 susceptibility map and depicts two spray block proposals for the indicated analysis area. Each proposal appears, on the surface at least, to be as good as the other. Currently the quantitative basis for comparing alternatives does not exist. However, if a quantitative basis can be established, it would seem logical to use GIS technology as the basis of a planning tool for spray block layout, given the map-based nature of the problem and the existence of the geo-referenced forest database. The next section of this paper describes such an approach, currently being researched at the University of New Brunswick's (UNB) Faculty of Forestry.

The final step in targeting forest areas for spraying involves eliminating those spray blocks that are not coincident with forest areas at hazard. Hazard maps, presently produced manually by combining information on the location of forest areas subjected to repeated defoliation in recent years and predicted budworm population distribution for the coming year, are overlayed on spray block maps to isolate those spray blocks not containing areas at risk. (This last step would certainly be amenable to GIS application; however, this is beyond the scope of the project described in this paper.)

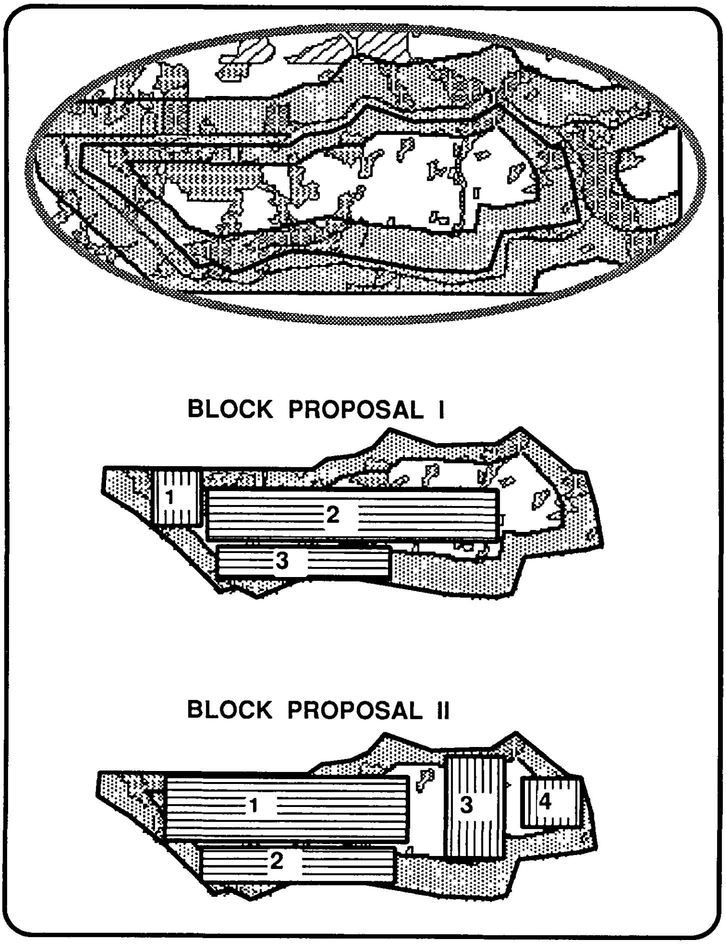

Figure 3. Ilustration of Alternative Spray Block Proposals for an Analysis Area.

A GIS-BASED APPROACH TO SPRAY BLOCK PLANNING

A prototype spray block layout procedure has been researched and programmed at UNB, with the support of both DNRE and FPL. The objective was to develop an iterative planning approach which would see the planner design alternative spray block configurations, communicate these to a computer for analysis, evaluate resulting quantitative feedback, and make further refinement to spray block layout as necessary. Thus the process was designed to be user-driven, taking advantage of the planner's ability to visually integrate spatial information from a map base, while using the computer for computation-intensive analyses.

The proposed spray block planning procedure described in the following paragraphs was developed and tested using the ODYSSEY GIS running under

TSO on UNB's IBM 3090 mainframe computer. A test database was constructed by extracting the forest cover-type data for 21 adjacent map sheets (approximately 90,000 ha) from DNRE's ARC/INFO-maintained forest database. This meant writing the data to magnetic tape in ASCII format on DNRE's PRIME 550 minicomputer and subsequently reformatting it on UNB's mainframe to create an ODYSSEY-compatible database. Applying actual DNRE rules for budworm susceptibility classification to maps in the test database permitted the creation of susceptibility maps, in digital form, for use in testing the proposed procedure.

The first step in the proposed spray block layout procedure is the definition of a "planning area" . Under present circumstances the planner works from a 1:50,000 map sheet base (91 maps in total) on which susceptible forest cover is highlighted over cultural as well as topographic features and elevation contours. Setback zones are also highlighted on these maps. Using the GIS-based planning procedure proposed, the planner will still work from the same 1:50,000 map base. Indeed, the planner will use this map base for all digitizing work as well. The planner must, however, identify those "digital" map sheets that define the planning area and then run a GIS procedure that digitally appends the identified maps to create one digital base map coverage of budworm susceptible forest.

The next step in the proposed planning procedure subdivides the planning area into component "analysis areas". These are non-overlapping areas which can be logically treated as separate entities for spray blocking purposes due to the presence of setback zones or vast areas of non-susceptible forest which form absolute or logical boundaries. Each analysis area is handled individually. The analysis area boundaries are digitized, and each analysis area in turn is extracted (via GIS overlay) from the underlying planning area. This allows quicker spray block proposal overlay in the next planning step.

The third step in the proposed procedure involves planning spray block layout, one analysis area at a time. Once the planner has designed a potential spray block configuration for an analysis area, it is communicated to the computer via digitizing of block corners. A digital overlay of these blocks (polygons) on the analysis area allows the generation of area statistics. For example, treatment costs can be calculated, based on spray aircraft type and area covered. Table 1 presents one possible cost summary for the two spray block proposals depicted in Figure 3. Note, that although average treatment cost per hectare of susceptible forest is slightly higher with proposal II, considerably more susceptible forest is targeted. In looking at Table 1, it is important to keep in mind that treatment costs using large aircraft (designated TBM) are considerably less, per hectare, than smaller agricultural-type aircraft; however, TBM aircraft are not allowed to spray chemical pesticides within the 1600 metre (1 mile) habitation setback zone, whereas small aircraft may operate within 300 metres of habitation. Other forest stand data, such as wood volume yields, could also be combined with costing data and incorporated in a tabular display. In any case, the statistics generated for one spray block configuration can be compared against alternative configurations or against a standard, indicating to the planner whether refinement of the configuration is desirable. The planner repeats the process with subsequent analysis areas until the current planning area is complete.

BLOCK PROPOSALS	AIRCRAFT TYPE	TOTAL AREA (ha)	SUSCEPTIBLE AREA (ha)	COST
PROPOSAL I				
BLOCK1	AG	825	512	$ 9,751
BLOCK2	TBM	5,000	1,550	$ 36,150
BLOCK3	AG	1,800	864	$ 21,276
TOTAL		7,625	2,926	$ 67,177
COST / HA SUSCEPTIBLE FOREST SPRAYED = $ 22.96				
PROPOSAL II				
BLOCK1	AG	5,100	2,550	$ 60,282
BLOCK2	AG	2,210	1,017	$ 26,122
BLOCK3	AG	1,860	744	$ 21,985
BLOCK4	AG	990	436	$ 11,702
TOTAL		10,160	4,747	$ 120,091
COST / HA SUSCEPTIBLE FOREST SPRAYED = $ 25.30				

Table 1. Quantitative Comparison of Alternative Spray Block Proposals.

Other planning areas are identified and are processed as described until the entire province has been analyzed.

CONCLUSION

The spray block layout planning procedure outlined has been implemented as a prototype and tested using the ODYSSEY GIS at UNB. Work with the prototype indicates that GIS procedures can be usefully applied to the spray block layout problem. In particular, the prototype has shown that current GIS technology, programmed to capture and analyze spray block layout alternatives, has the potential to be a valuable tool in the complex process of protection planning. However, testing to date has raised concerns about implementation on a production basis. The concern stems from the fact that while both quick response and simplicity of use are deemed important, vector overlays are computation intensive and would certainly be slow to complete on DNRE's present computer system, assuming realistic data volumes. For example, using DNRE's PRIME 550 minicomputer (0.7 MIPS) the overlay of a spray block proposal involving a realistic analysis area of approximately 10,000 hectares (432 polygons, 773 arcs and 26,000 vertices), required in excess of 30 minutes of CPU time to complete. This response, although perhaps not surprising, is unacceptable. At the time of writing, means to improve response time, aside from hardware upgrading, were being researched.

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