COMPUTER MAPPING FOR BIOMASS INVENTORIES

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ABSTRACT

The Northern Forest Research Centre is developing a computer mapping capability as part of a geographic information system for the western and northern region. The initial requirement was to develop a capability for converting forest inventory maps and supporting data to a biomass data base. The location-specific data manipulations for a test inventory map from Saskatchewan are described and evaluated. This is more than just a technical challenge, however, because while experts make maps, nonexperts use them to make policy. The cost-effectiveness of automated reinterpretation of existing data is discussed, as is the adequacy of such reinterpretation. Future requirements for remote sensing and other integrated inputs are also considered. Resource analysts and policy makers require that quantitative storage, classification, manipulation, and retrieval of location-specific results (as maps and tables) are reliable and available on demand. A complete resource analysis, mapping, and information system must be designed and developed for practical and continuing operations in a clear, timely, accurate, and economic manner. Further developments and operational applications are required.

INTRODUCTION

Combustion of forest biomass, a term that includes all forest vegetation, already accounts for about 4% of Canada's energy needs. The forests have great promise as a renewable energy source. National considerations, therefore, should immediately involve inventories of how much forest biomass is available and where it is located. This paper examines how the large quantities of existing forestry maps and supporting data can be transformed into reasonable biomass estimate inventories.

The development and operational applications of computer mapping systems are important bases for geographic information systems. Biomass inventories, or data bases, can become an integral part of such a system. A computer mapping system is basically an efficient map filing system whereby spatially referenced data can be efficiently stored, classified, updated, manipulated, and retrieved as custom maps and tables. This is a significant improvement over the traditional banks of map drawers, thematic overlay products, map redrawing, and tedious dot counting now necessary to obtain the required forestry data. As a practical example of computer mapping development, a system has been installed and a sample forest inventory map has been converted to a biomass data base at the Northern Forest Research Centre (NoFRC). This can be used to illustrate some of the practical advantages, potential limitations, and future developments of such a s tem.

The basic components and theoretical operations of the NoFRC mapping system were described previously (Kirby and Chow, 1982). Practical operations have more recently been evaluated using a sample forest inventory map and supporting data (i.e., stand and stock tables) provided by the Forestry Branch of the Saskatchewan Department of Tourism and Renewable Resources. The conversion of this material to a biomass data base was possible through the application of regional biomass equations to forest species volumes.* The renewable biomass of potentially overlapping peatland inventories might be an additional requirement in the future (Zoltai and Pollett, 1983). This would be another reinterpretation of existing data, but it would also be a feasible compromise between budgetry constraints and increasing information demands (Napton and Luther, 1981).

The utility of computerized mapping of summarized forestry statistics covering the whole country has been demonstrated using the considerable facilities of Statistics Canada (Cunningham, 1980). Canadian Forestry Service regional establishments, such as NoFRC, have research, assistance, and coordination responsibilities for more detailed operations and statistics in cooperation with provincial and other forest agencies. Thus, additional work is required to make the NoFRC mapping system compatible with a variety of map and remote sensing inputs that have been documented by others (Myers, 1981, and Brooner, 1981). This is a next step, because computerized systems also increase operational productivity and flexibility, particularly for multisource change mapping (Milazzo, 1981, and Wilson and Thomson, 1981). These developments provide new, practical capabilities. For example, cost-effective means of using Landsat data have already been demonstrated operationally in the revision of topographic maps (Fleming, 1982) and the monitoring of burned forest land in remote areas (Moore, 1983). In addition, forest mensuration with large-scale aerial photography has been developed to significantly enhance fieldwork (Kirby, 1980). Nevertheless, it is important to realize that while experts make maps, nonexperts use them for policy making. Great care is therefore required with manipulations of existing data, and with concise qualifications of the results (Napton and Luther, 1981).

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* from T. Singh, "Conversion of Tree Volume to Biomass in the Prairie Provinces", a proposed Forest Management Note, currently under review, NoFRC, Edmonton

METHODOLOGY

Mapping System

The complete Mapping and Analysis of Resources System (MARS) is organized according to Figure 1. In that flow chart, the hatched lines enclose the Systemhouse Limited* Resource Analysis and Mapping System (SHL-RAMS) that is central to MARS. Developments to the summer of 1983 have progressed to the biomass computations stage. In addition, the Gregory Geoscience** Procom-2 image transfer and mapping system for the change interpretation stage has been acquired separately. The numbers between the blocks, or stages, in Figure 1 refer to the operations that are briefly described in Table 1. The larger arrows to the right of the flow chart indicate the outputs of MARS. Future growth potential of the system is described later.

Biomass Mapping

The whole 1 : 12 500 scale (i.e., for provincial field operations) Bittern Lake forest inventory mapsheet (UTM Z13 E45 N597) was processed to form a biomass data base. Volumes by tree species and cover type (i.e., dominant, subdominant, and understory) from the stand and stock tables were converted directly to biomass per hectare by forest inventory polygon. The result was a biomass inventory map. A portion of that map (i.e., a 4 km^2 test area) is reproduced, with principal tree species annotations, in Figure 2.

The volume data in the stand and stock tables, however, was for merchantable volumes only. Some assumptions had to be made for unmerchantable stands. In this case, therfore, the biomass estimates might be a little high. Mean stem heights and diameters were also available in the tables, but were not used for data processing and consistency reasons. Appropriate equations also exist for biomass conversions using mean heights and diameters for this region (Singh, 1982) and might be used in supplementary sampling later.

The data for the Bittern Lake mapsheet was manipulated as follows:

1. After digitizing and correcting for map errors, the polygons were sorted by species association, height class, density class, and the three cover types. The polygon identification numbers and areas were stored for future use. Applicable portions of the stand and stock tables were also entered as a volume table.

2. The data was printed and stored on the PDP 11/60 computer.

3. Volume estimates were calculated using the data in the stand and stock tables. This was done by matching map attribute listings to the volume table variables as follows:

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Ottawa, Ontario K1V 0C4

** Gregory Geoscience Limited
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Mapping & Analysis of Resources System (MARS)

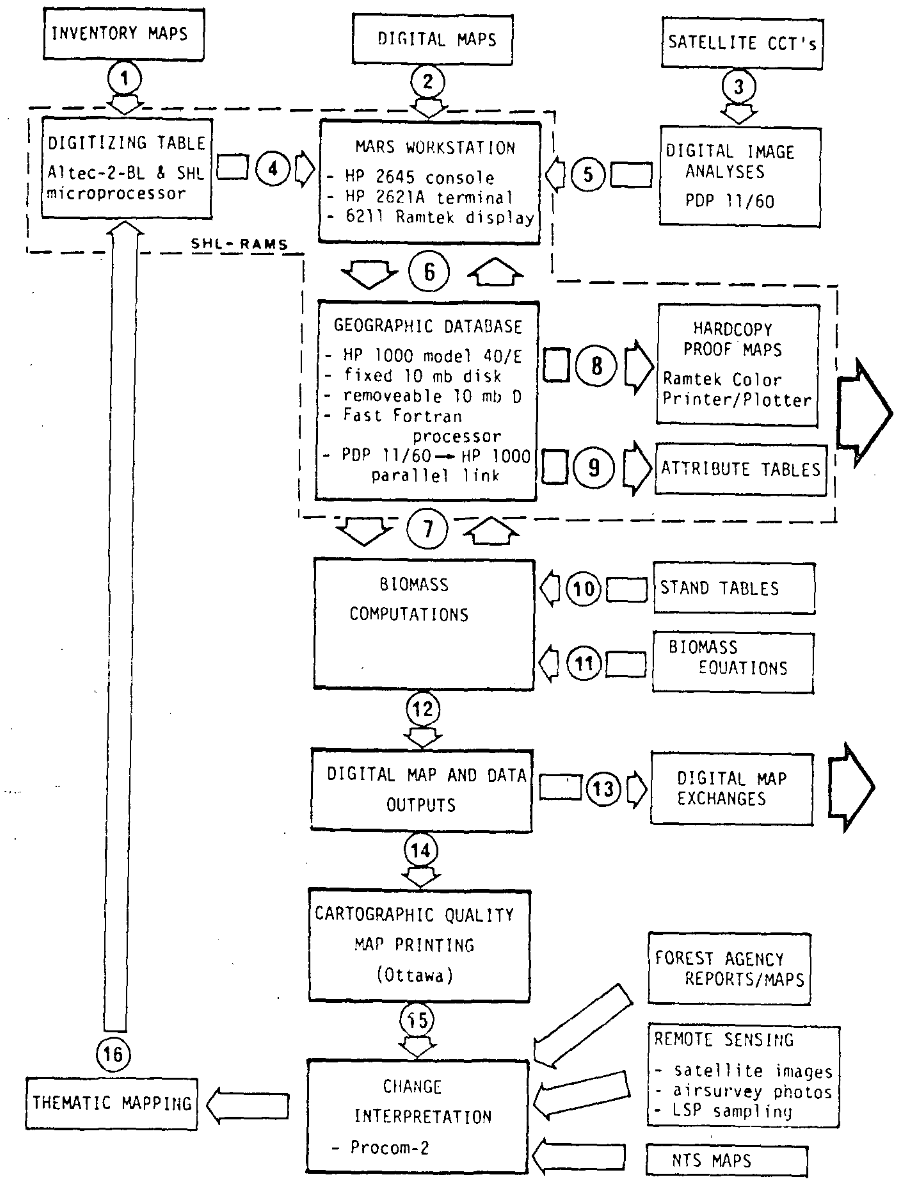

Figure 1. NoFRC Computerized Mapping System
Abbreviations are as follows:
CCT's - computer compatible tapes (i.e., Landsat)
LSP - large-scale photography (aerial)
NTS - National Topographic Series
GIMMS - Geographic Information Manipulation and Mapping System (Cunningham, 1980)

MARS Operations

1	A high-quality (preferably mylar) line map transparency is required, and geographically referenced attributes, or data definition files (DDF), are to be designed.
2	OPEN map file - digital map ready for display on screen.
3	Earth satellite image data is received as CCT's by user.
4	SHL-RAMS commands on digitizer to enter line segments.
5	Unsupervised classifications have been used with parts of CCT image and converted to RAMS-compatible display.
6	RAMS commands to PAINT or DRAW required for Ramteck display. Other commands to display tables or generate reports. Can be transfered to PDP 11/60 for printing.
7	Biomass variables computed and entered as part of DDF.
8	RAMS PRINT command will produce map hard-copy of the Ramtek display on the Ramtek plotter.
9	LEGEND command produces attribute classes on display, and PRINT command will produce a hard-copy reproduction.
10	Stand tables required with digitized maps for sufficient data for biomass prediction equations (e.g., volumes).
11	Biomass/hectare computed by polygon and entered in DDF.
12	Each attribute can be displayed independently or combined with other attributes for plotting thematic maps.
13	RAMS ⟺ GIMMS provided with the system for compatibilities with other computer mapping systems.
14	GIMMS-formated tape can be sent out for production of a cartographic-quality line map.
15	A cartogrpahic-quality map can be a base map for overlaying new map themes to form new polygons. Procom-2 now available for updating maps for burned or cut-over forest lands from Landsat or integrating other data.
16	Existing DDF can be upgraded by digitizing change maps on cartographic-quality map of existing DDF. Entire map would not have to be redigitized because of a new polygon overlay capability of SHL-RAMS.

Table 1. Itemized Operations in the Figure 1 Flow Chart

(i) Where map attributes matched volume table variables, the biomass equations for the species were applied. These were summed to determine the total estimated biomass weight per hectare for that polygon, which was then multiplied by the area of the polygon to tabulate the total biomass estimate for the polygon.

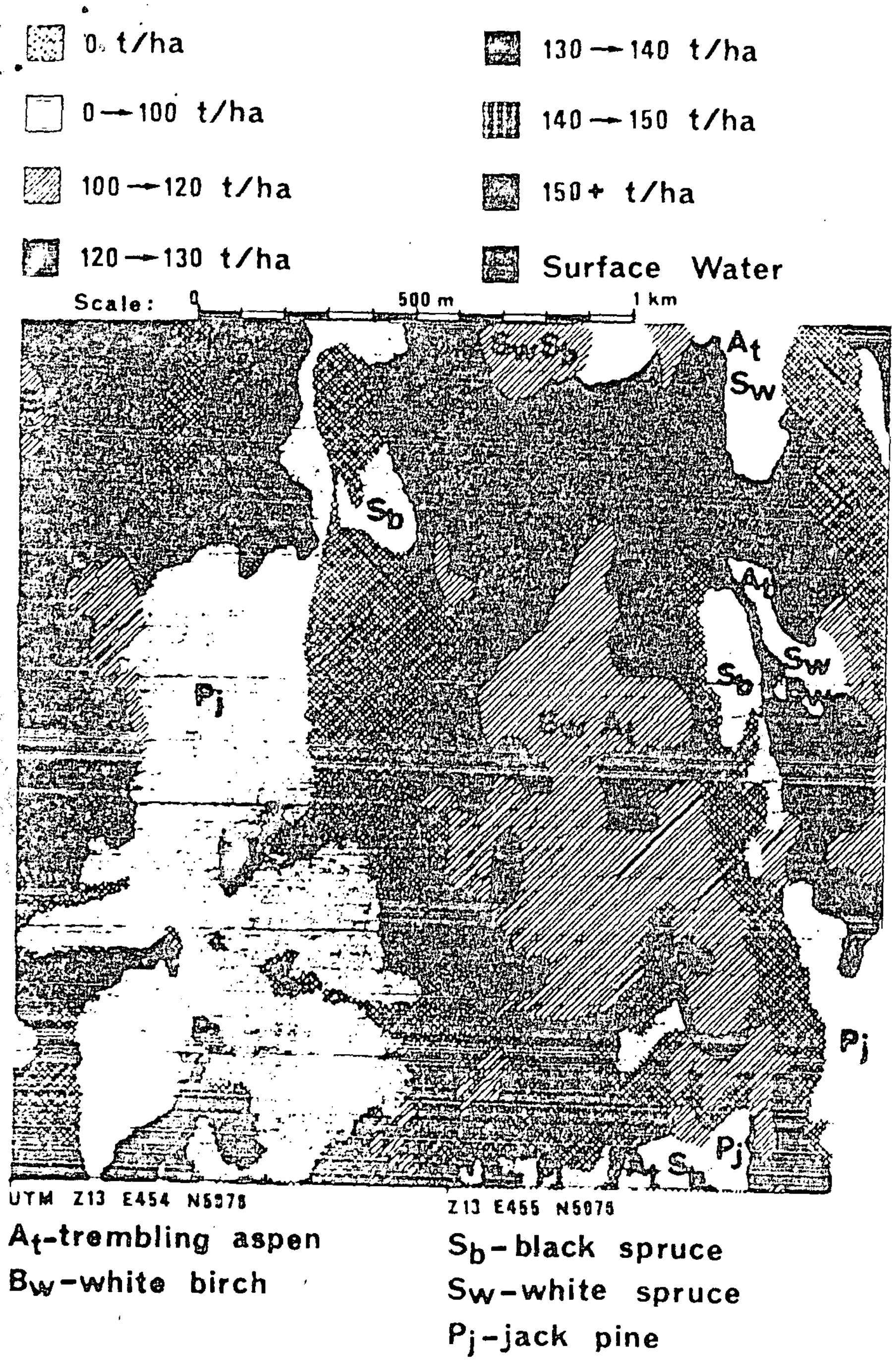

Figure 2. Biomass Inventory Map

(ii) When an exact match was not found, the cover types were reversed and the search was rerun. If there was then a match, the procedure in (i) was followed.

(iii) If there was still no match, the second cover type was deleted and the search was rerun on the first cover type. If there was then a match with the volume table, the procedure in (i) was followed.

(iv) The last resort was to print out the polygon information, compare it to the original map, and make whatever corrections were necessary. When there was still no match, a species was substituted (i.e., one that was similar), and the calculations were done manually.

4. The estimated biomass weight per hectare and total biomass weight per polygon variables were defined and entered in a data definition file (DDF) on SHL-RAMS. This was used to produce Figure 2.

Programs could be written on the NoFRC PDP 11/60 minicomputer to sort and print various selections of location-specific data from the data base, but this was not deemed appropriate. Instead, computing the biomass before the map is digitized appears to be a better idea for the future. The DDF could then be established to accommodate these values, and all the sorting required would be done on SHL-RAMS.

DISCUSSION

The size of the area of forested land in the western and northern region of Canada might at first appear to be overwhelming. Over 10 000 forest inventory maps similar to the Bittern Lake example from Saskatchewan are required to cover the forested land on the prairies. As many again are required for the forested land of the Northwest Territories. Forestry agencies in the provinces of Alberta, Manitoba, and Saskatchewan, however, are placing considerable emphasis on compiling and updating their forest inventories. In addition, these provinces are in various stages of establishing computer mapping facilities of their own. Forest management in the Northwest Territories is at present the responsibility of the federal Deparment of Indian Affairs and Northern Development, which is not nearly as advanced in forest inventory mapping and sampling as are the prairie provinces. There is great potential for more cooperation among all these forestry agencies for assessments of such a huge area, and biomass computations are a natural follow-up to forest inventory surveys.

The forests of the region lie principally in the boreal and transitional forest regions — parklands and foothills to the south and tundra to the north. The forest cover is largely heterogeneous. The significance of the extensive peatlands in the forested areas as an energy source is a separate question entirely, but location-specific peatland classifications might one day be defined and included in a biomass data base. As has been shown, the forest inventory emphasis on merchantable timber can also be a problem for complete biomass computations. Nevertheless, the forest inventory maps and supporting data provide the best information available for the creation of data bases and calculations of biomass estimates. They currently include data on the bulk of the aboveground biomass. There might be further improvement with supplementary sampling in the future. Independent biomass surveys do not appear to be cost-effective for such a complex and extensive forested region.

Remote sensing offers considerable information on the dynamics of such large forested areas (e.g., clear-cutting, burned, insect/disease mortality, flooding). This can provide valuable information for updating forest, and subsequently biomass, inventories — particularly when forest surveys are completed on 10-, 20-, or 30-year cycles. Normal forest inventory sample plot procedures might also be enhanced to include more total biomass measurements to improve estimates. In addition, the national Forest Insect and Disease Survey has a requirement for a multitude of thematic maps that might be included in a computer mapping system. Efficient computer mapping is necessary to integrate the multiple sources of relevant information in a cost-effective manner.

A comparison between a computer mapping system and a word processor might be useful for gaining an appreciation of the technology involved. Word processors operate on the basis of creating and manipulating computer data files. These files contain words, numbers, symbols, sentences, paragraphs and tables that can be used to form a text. This text can then be revised and adjusted quite efficiently, and it can be automatically printed in a variety of selected formats. A computer mapping system goes beyond the well-developed word processor technology application to involve the creation, storage, and retrieval of geometrically referenced data files for points, lines, polygons and texts. In addition, the data files are often further processed within the system to create new, geographically referenced files such as biomass estimates for polygons. Systematic revision, adjustment, or updating of files in the considerably less-developed computer mapping technology is somewhat more complex and time consuming than similar operations in most word processors. Nevertheless, the NoFRC system is useful for experimental and training purposes, and it has the potential for great improvements in operating capabilities at comparatively low cost. It also has the potential of interfacing with provincial systems as they become operational, thereby enhancing developments in remote sensing applications and sampling designs at NoFRC.

The SHL-RAMS portion of MARS might be considered a modular component that can be modified or replaced with little or no effect on other components. RAMS was a prototype development of Systemhouse Limited. Improvements have been made to the system, but it is still too slow for operational requirements. Over 40 hours were required to digitize the approximately 2000 polygons of the example Bittern Lake map. Improvements in the technology need to be implemented, and several options are being considered to update the SHL-RAMS.

CONCLUSIONS

1. Computer mapping has an immediate potential for functionally upgrading geographic information systems. The technology is evolving at a high rate, and such systems should approach the efficiency and utility of modern word processors in the near future. In practical terms, these developments should provide the required productivity increases to meet the increasing environmental information requirements within constrained budgets.

2. Data definition files in the current NoFRC SHL-RAMS should be defined and established before maps are digitized. Technology improvements are also required to ease the current bottleneck in digitizing.

3. Caution is required in manipulating existing location-specific classifications and supporting data to produce maps and tables for which the original field survey was not necessarily intended — particularly for a very large area that is as heterogeneous and dynamic as the boreal forest region.

4. Supplementary sampling for biomass (i.e., all forest vegetation) might be required for more complete tabulations. In practical terms, however, quantitative biomass samples pertaining to lesser vegetation and regeneration areas might have to be systematically included with normal forest plot measurements to be economically feasible. Overlapping peatland sampling should be another consideration as an additional renewable biomass source. Various types of remote sensing applications might also be developed to provide supplementary biomass estimates in a location-specific geographic format.

5. Functional digital map exchanges and remote sensing integration for monitoring significant changes to the ground cover have yet to be tested with the NoFRC mapping system.

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