SPATIALLY CHARACTERIZING EFFECTIVE TIMBER SUPPLY

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ABSTRACT

The structure of a computer-oriented cartographic model for assessing roundwood supply for generation of base load electricity is discussed. The model provides an analytical procedure for coupling spatial information of harvesting economics and owner willingness to sell stumpage. Supply is characterized in terms of standing timber; of accessibility considering various harvesting and hauling factors; and of availability as affected by ownership and residential patterns. Factors governing accessibility to timber include effective harvesting distance to haul roads as modified by barriers and slopes. Haul distance is expressed in units that take into account the relative ease of travel along various road types to a central processing facility. Areas of accessible timber are grouped into spatial units, termed "timbersheds," of common access to particular haul road segments that belong to unique "transport zones." Timber availability considerations include size of ownership parcels, housing density and excluded areas. The analysis techniques are demonstrated for a cartographic data base in western Massachusetts.

INTRODUCTION

The demand for wood chips throughout the United States has been increasing in recent years. This increased demand has stimulated new technologies such as whole tree chipping and special chip recovery operations during milling. The significant growth of the pulp and particleboard industries have accounted for most of the increased demand for wood chips. The potential use of chips to generate base load electricity, however, may cause the demand to even more dramatically accelerate over the next decade.

The average price of energy from coal is about fifty percent lower than that from wood. On a national basis it is generally not economical to substitute wood for coal under current economic conditions. On the other hand, some extensively forested regions, such as New England, experience delivered coal and oil prices significantly higher than the national average. In these areas, wood-fired power generation may be economical. In addition, the potential for lower transportation costs and stimulation of local employment, coupled with the lower toxic emissions of wood-fired plants have combined to generate considerable interest in these projects.

The less stringent requirements of species mix for wood-fired power plants and proposed new harvesting techniques necessitate the development of a new methodology for assessing roundwood supply. Most currently used methods treat chip supply as a by-product of milling-oriented operations or as self-sufficient pulping operations on large ownership tracts. Rarely is consideration given to whole tree chipping on diverse ownerships, as will likely be required if wood chips are used in the production of electricity. A complete analysis must integrate consideration of the spatial distribution of timber inventory, harvesting costs, and owners' willingness to sell stumpage.

This paper describes the preliminary structure of a computer-oriented model for assessing effective timber supply. The model spatially characterizes supply in terms of:

* inventory of standing timber;
* accessibility considering various harvesting and hauling factors; and,
* availability as affected by patterns of ownership and development of timber lands.

The emphasis of this study has been on the development of the analytical components of the model, rather than on the calibration of the model. Refinement of model parameters for various physical and economic conditions will be left to subsequent research. Several other papers by the authors have reported on various aspects of this model (Berry and Mansbach, 1981; Berry and Tomlin, 1981; Berry and Sailor, 1981).

FUNDAMENTAL CONSIDERATIONS

Information on the extent and location of timber resources serves as primary input. This information can be extracted from several sources, such as existing forest cover type maps, color-infrared aerial photography and LANDSAT satellite imagery. Inventory information alone, however, may not yield accurate estimates of actual roundwood supply as affected by physical considerations. Many forested areas, for example, may be too remote from existing access routes for effective harvesting. Other areas may have highly erodable soils or steep slopes that would likewise make certain harvesting techniques inappropriate. Such areas must be eliminated from consideration or the estimated supply of available roundwood will be too high.

Social factors must also be considered before an adequate estimate of roundwood availability can be made. Some extensively forested areas, such as federal and state parks, may be legally excluded from harvesting. Prudent management practices may also exclude certain areas such as buffer strips around highways and water courses. Of the remaining potentially harvestable areas, ownership characteristics, such as parcel size, can be used to determine propensity of owners to sell stumpage.

The analytic method used to assess timber supply in this manner must be spatially consistent. In addition to producing tables summarizing supply, maps depicting the distribution of the supply can be invaluable. The method used should be flexible and provide for simulation of various harvesting alternatives and economic environments. It should be easily transported, both in terms of its variables and its processing requirements.

PRELIMINARY MODEL

This paper summarizes the results of an exploratory study of computer-assisted map analysis techniques to characterize timber supply. Figure 1 is a generalized flow chart of the analytical process. The model consists of four major submodels: inventory, access, availability, and supply. In this preliminary form, only a few considerations for each submodel are included. The "inventory submodel" for this study identifies areas of appropriate forest cover types. The "access submodel" consists of two parts: transport distance, and harvesting characterizations. Transport distance uses a map showing a

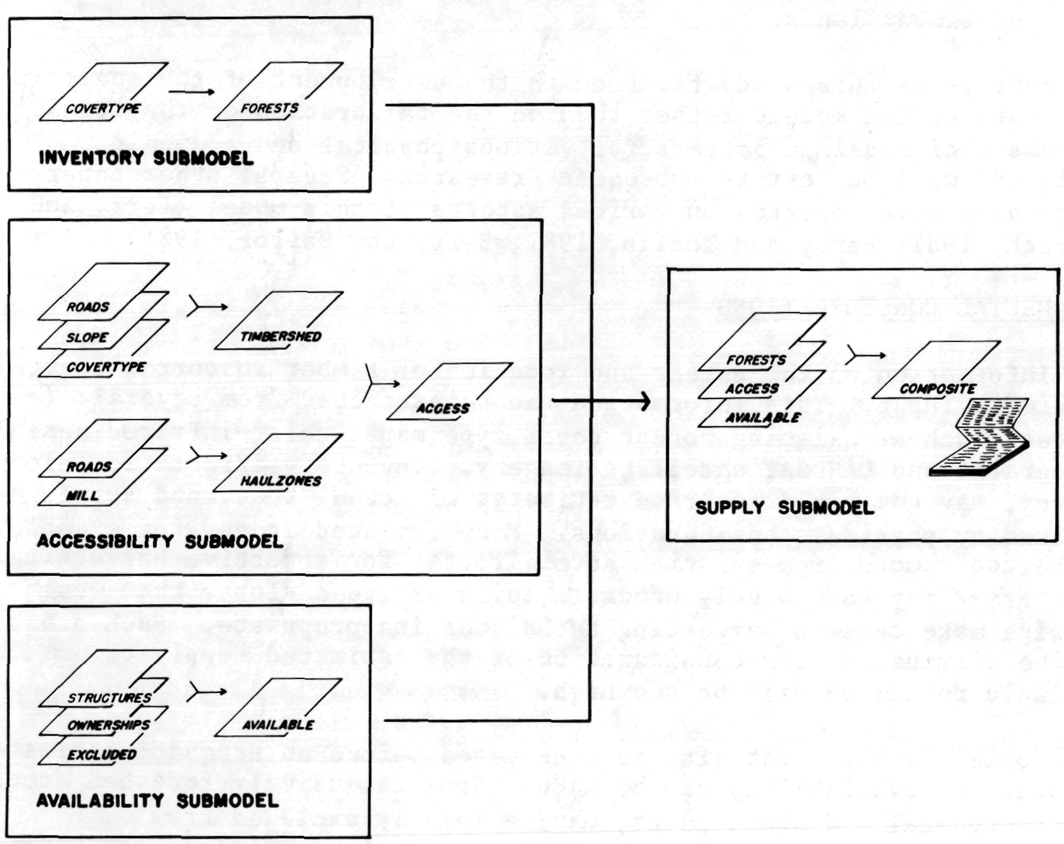


FIGURE 1. Generalized Flowchart of Model. The cartographic model considers harvesting/hauling access and stumpage availability as well as forest inventory information to spatially characterize the effective timber supply.

proposed mill site and measures haul distance and harvesting accessibility of timber. Haul distance is measured along the existing road network. Constraint maps are used so that distance is measured only along roads and is weighted by road type. For the purpose of this demonstration, timber hauling along secondary roads was assumed to take 50% longer as that along primary roads; hauling on tertiary roads was assumed to take 100% longer than on primary roads; and hauling on unimproved roads was assumed to take 200% longer than on primary roads. From the resulting map of weighted haul distance, a map of haul distance zones was created. A map of accessibility of timber, or effective yarding (skidding) distance to roads in these haul zones, can be generated by taking into consideration steep slopes and water areas that must be circumvented. For the demonstration, slopes were used to weight the distance such that moderately limiting slopes of 11-15% required 100% more time to traverse (and thus for cost purposes are twice as "far" away), severely limiting slopes of 16-20% required 200% more time to traverse, and slopes greater than 20% were avoided. The map resulting from this measurement was converted to show zones of weighted harvesting distance (or cost). The resulting zones are then combined with the vegetation map to produce tables of transport cost versus timber supply.

The second part of the access submodel is concerned with finding minimum yarding distances to haul roads. A map of weighted distance from haul roads is made using the same characteristics as in the transport distance characterization. Using a road intersection map, a map of boundaries of equal haul distance to two or more roads is produced. This map is created by generating lines from road intersections that are constrained to being on the weighted distance margin between two roads. These boundaries are areas that are equally accessible to two or more roads, using the weighted accessibility measure. On either side of these boundaries, timber is more accessable to a particular haul road, and therefore will cost less to harvest if it is yarded to that road.

The "availability submodel" considers housing density in characterizing the propensity of owners to sell stumpage. Areas with a relatively high density are ranked as having a lower likelihood of being available for harvesting. Those areas of relatively low housing density, conversely, are considered more likely to be sold for stumpage. Maps of housing density are derived from maps identifying residential and commercial structures within a study area. For purposes of this study, the total number of structures with a radius of 1/8 mile was used to indicate the relative housing density for an area. A second consideration of availability involves ownership parcel size. If an area falls within a large parcel, that is, grater than 10 hectares, it is considered more likely to be available. The submodel also eliminates from consideration any areas which prohibit harvesting.

The maps of harvesting potential and owners' propensity to sell are combined in the "supply submodel" to characterize the forest resource in terms of effective supply. The primary output of this submodel are tables summarizing the areal extent of each forest type in each accessibility/availability class. In addition, maps locating the various combinations can be generated. Contiguous units of user-defined classes are identified and their areal extent computed. Parcels that are too small for efficient harvesting can be easily identified and elminated.

SPATIAL DATA BASE

Information used in this study is part of a general purpose data base being developed for the Harvard Forest vicinity (Petersham, Massachusetts). Each map represents 1770 hectares or 17.7 square kilometers. (1/4 hectare per cell, 7080 cells in all). The maps used for this study include vegetation cover types, elevation, roads, and water features.

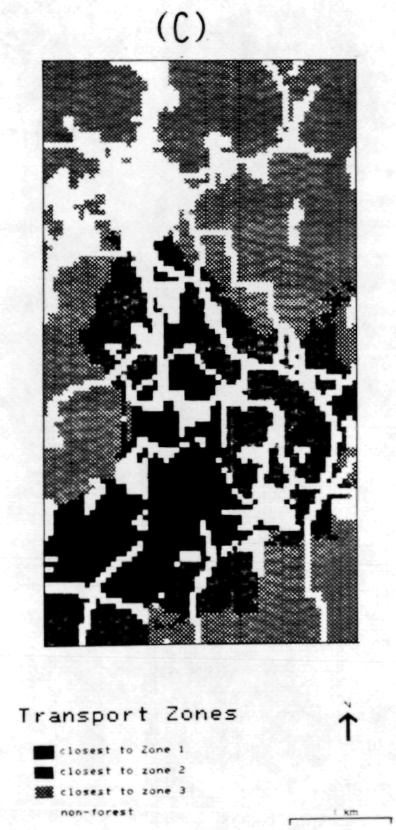
Data encoding, analysis, and display capabilities for this study were provided through the use of software developed at Yale University as part of the Map Analysis Package (Tomlin, in preparation). Information on the biological, physical, and cultural features of a given geographic area is encoded to correspond with a grid cell data structure. Each grid cell is assigned a value which represents one member of a set of mutually exclusive categories (e.g. dry land, stream, pond, lake). These data are analyzed using a flexible package of fundamental processing operations that are logically sequenced to form a cartographic model (Tomlin and Berry, 1979; Berry and Tomlin, 1982).

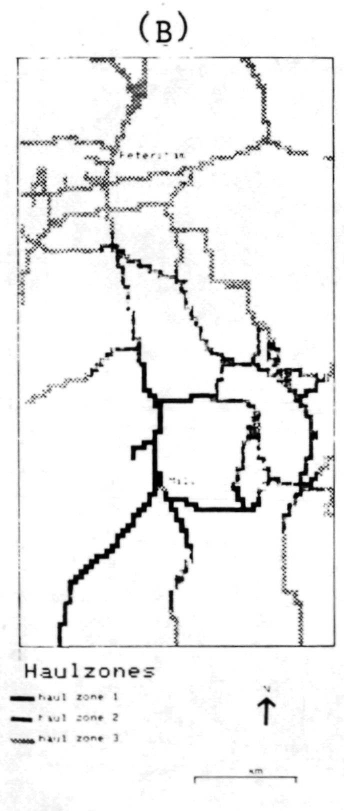
DEMONSTRATION RESULTS

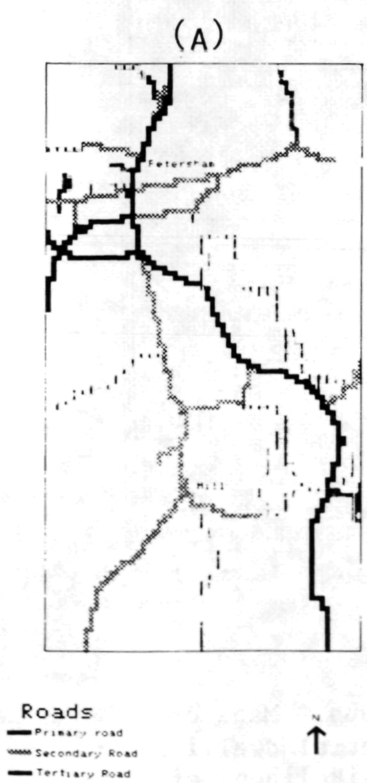
The thirty-four vegetation types occuring in the Petersham area were collapsed into nine classes of merchantable forests. For display purposes, these are grouped into five categories (Figure 2). Forested areas comprise 83.6% of the study area. However, these areas have different accessability and transport costs which must be considered in determining potential supply.

Figure 3 shows important intermediate maps associated with the transport submodel. For display and tabulation the road network was divided into three zones of haul distance, and the timber areas were divided into two zones of accessibility. Because the distances measured are a function of the roads or terrain traversed, the maps can be considered travel time maps or transport cost surfaces. The units can be expressed in time, cost, or in distance equivalents. In this case, "distances" are expressed relative to kilometers travelled on primary roads for haul distance and kilometers skidded on level ground for accessibility. Figure 4 shows intermediate maps from the "timbersheds" submodel. The results of the access submodel allow the strategic planner to characterize the timber supply surrounding a mill site in terms of harvesting costs. This information can then be used to determine if the supply, within economic transport and access "reach", is sufficient to sustain the proposed facility. Table 1 shows the forest types as a function of harvesting and hauling considerations.

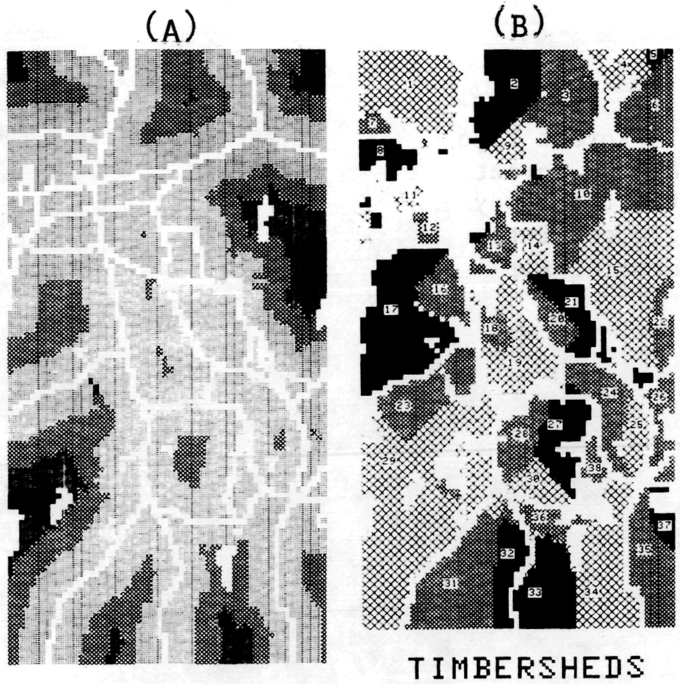
<u>Figure 2</u>. Forest Type Map. The nine forest classes for the study are are grouped into five categories for display.







<u>Figure 3</u>. Transport Analysis Maps. The existing roads (a), weighted haul distance along these roads (b), and the final transport zones, (c) are shown.



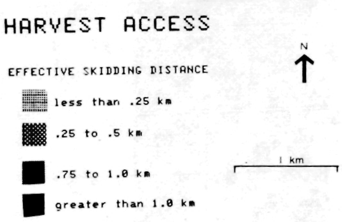
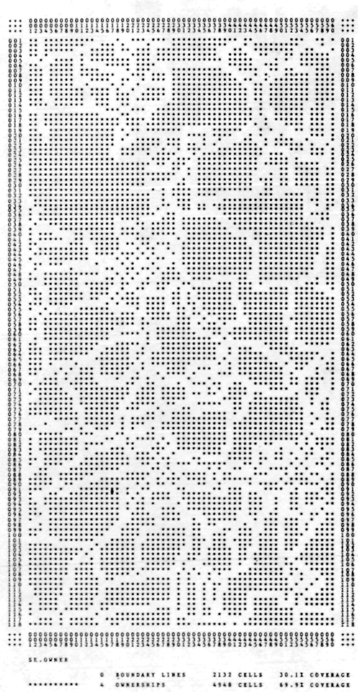


Figure 4. Harvesting Analysis Maps. Accessibility of timber characterized as weighted skidding proxmity (a) and areas of common access to haul road segments (b) are shown.



(A)

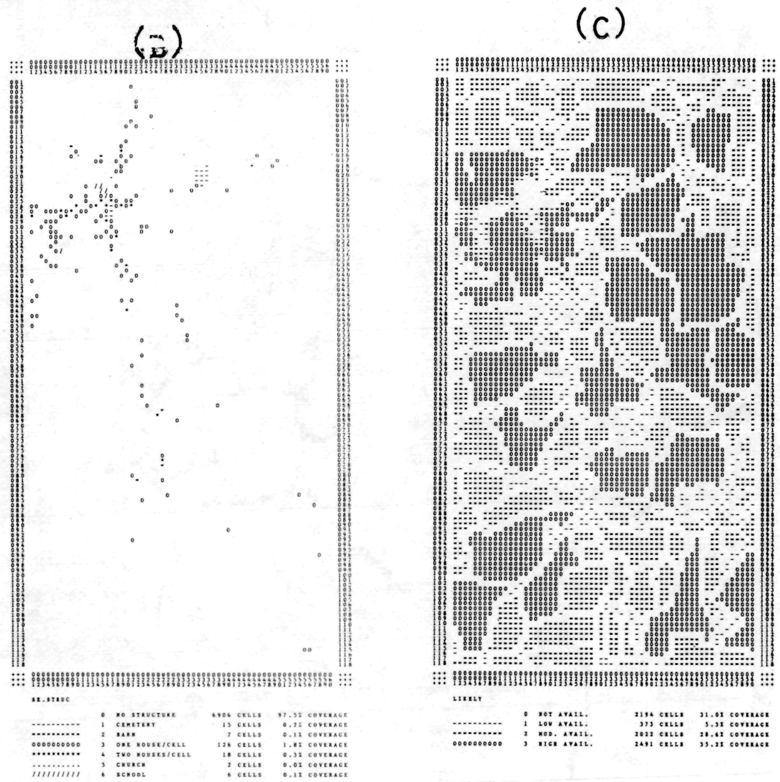


Figure 5. Availablity Analysis Maps. Maps of ownership patterns (a) and residential dwellings (b) are used to characterize the likelihood of areas to be sold for stumpage. Combining these three maps yields a map (c) of the relative availability for harvesting.

Table 1 -- Tabultion of forest classes by transport distance zones

Forest[2] Class	Total Area (ha)	Transport Zone[1] (Haul/Access) (ha) 1/1	1/2	2/1	2/2	3/1	3/2
1	26.25	0	0	3.5	0	21.75	1.25
2	22.75	1.75	0	10.5	0	9.25	1.25
3	47.0	2.0	0	10.75	0.75	11.5	22.0
4	76.0	7.75	0	12.25	0	44.25	11.75
5	73.0	11.0	0.75	23.75	0	21.25	16.25
6	235.75	21.25	1.5	48.5	0	132.0	32.5
7	477.25	45.5	5.25	142.0	1.5	194.75	78.5
8	53.75	104.0	4.25	83.0	3.75	177.75	52.0
9	53.75	9.0	0.5	14.0	2.0	12.75	17.0

[1] Transport Zones (for example, 1/2 is Haul Zone 1, Access Zone 2)

<u>Haul Zones</u>
Haul Zone 1 - less than 2 km. haul
Haul Zone 2 - 2 km. to 4 km. haul
Haul Zone 3 - greater than 4 km. haul

Haul distances weighted by road type and expressed relative to hauling on primary road.

<u>Access Zones</u>
Access Zone 1 - less than .5 km skid
Access Zone 2 - .5 km skid or greater
Skid distance weighted by slope and expressed reltive to skidding on flat surface

[2] <u>Forest Classes</u>
Class 1 - hardwoods; 41-60 ft.; 81-100% closure
Class 2 - hardwoods; 61-80 ft.; 81-100% closure
Class 3 - softwoods; 21-60 ft.; 30-80% closure
Class 4 - softwoods; 61-80 ft.; 81-100% closure
Class 5 - mixedwoods; (S/H); 21-60 ft.; 30-80% closure
Class 6 - mixedwoods; (S/H); 61-80 ft.; 30-80% closure
Class 7 - mixedwoods; (H/S); 21-80 ft.; 30-80% closure
Class 8 - mixedwoods; (H/S); 61-80 ft.; 30-80% closure
Class 9 - mixedwoods; (uneven aged)

Figure 5 shows the maps of the availability submodel. Ownership parcels of more than 20 hectares comprise 37.4% of the study area. These larger parcels can be considered as having a high probability of being sold for stumpage. Similarly areas of less than five structures per 0.5 square kilometer (approximately one house per 10 hectares) are considered as being likely for sale. These relatively unpopulated areas comprise 97.0% of the study area. Combining these two maps creates a map of overall availability. This map identifies 35.2% of the study area as being likely to be available for stumpage. However, some of these areas may actually be unavailable due to legal statue or management policy. For this demonstration, areas to be excluded from harvesting include institutional areas and park lands. These comprise only 9% and are spatially coincident with populated areas in most instances. As a result the consideration of excluded areas only slightly decreases the "likely to be available" areas to 35.1%.

The final phase of the model combines the information on access and availability for the merchantable forested areas. Figure 6 locates the forested areas that have good access and are likely to be available. Of the 1480 hectares of merchantable forests only 200 hectares are in this desireable category. In addition, with the exception of a few tracts, most of these areas are well dispersed and relatively small. Maps similar to the one in Figure 6 can be displayed for any of the various combinations of accessibility and availability of the forested areas. The total amount of forested areas which meets the minimum requirements of this analysis is 960 hectares. The purely physical inventory of timberlands greatly overstated this acreage and offered no information as to the relative desireability or spatial distribution of the remaining land.

CONCLUSION

An advantage of computer-assisted map analysis is that once a model is developed and the appropriate data encoded, repeated simulation of the model using different calibration coefficients yields insight into the unique character of an area. For example, if effective skidding distance is extended from 0.3 kilometers to 0.5 kilometers and parcel size reduced from 20 hectares to 10 hectares, the highly desireable forested acreage increases from 200 hectares to 325 hectares. This method of sensitivity analysis can be used to identify the more important considerations as well as give a range of expected supply under various engineering and economic environments.

The model serves as an excellent strategic planning tool. It locates general areas of likely accessible and available forests and provides insight into the significant factors affecting potential supply. The analysis, however, is not intended to provide output useful to the harvesting crew. Rather it is intended to better indicate actual timber supply than conventional inventory-driven procedures.

Figure 6. Effective Timber Supply. This map depicts the forested areas that are likely to be available and easily accessible by forest cover classes 1-9 (see Table 1). Although 84% of the study area has forest cover, this analysis shows that only 11% is in the most desirable category.

ACKNOWLEDGEMENTS

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