Setting Analyst: A Practical Harvest Planning Technique

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ABSTRACT – Setting Analyst is an ArcView extension that facilitates practical harvest planning for ground-based systems. By modeling the travel patterns of ground-based machines, it compares different harvesting settings based on projected average skidding distance, logging costs, and site disturbance levels. Setting Analyst uses information commonly available to consulting foresters, timber buyers, or loggers for harvests on non-industrial private forest timber sales (NIPF). We discuss the techniques, illustrate its practical applications, and compare logging plans generated with Setting Analyst on a recently harvested site.

INTRODUCTION

Operational harvest planning involves the design and organization of a timber harvesting operation and focuses on locating improvements such as roads, logging decks, skid trails, and stream crossings. The planner's objective is to find a procedure that balances economic efficiency with environmental considerations while ensuring legal compliance and minimizing potential safety hazards for all associated parties.
The harvest planner may be a consulting forester who works for the landowner, a procurement forester who purchases the timber, or the logging contractor who actually performs the harvesting or combination of the above. The planning horizon influences the amount of information acquired and how the information is stored. Information technologies such as global positioning systems (GPS), geographic information systems (GIS), and the Internet are advancing rapidly and present new opportunities for collecting information pertinent to timber harvesting.

Harvest/sales planning is common practice in many parts of North America and in other parts of the world. However, for various reasons formal harvest planning has not been as widely used in the southern USA. The principle reason is the lack of regulations that require it. State forest practice acts are rare in the South and most southern states employ non-regulatory Best Management Practices (BMPs) to protect water quality. The terrain in the South is relatively gentle, hence the planning required for cable or ground-based harvesting on steep terrain is not needed. Non-industrial private timberlands provide a significant portion of the southern timber harvest, often in small tracts or small timber sales. Finally, harvesting is performed exclusively by contractors, not company-owned crews. Harvest planning may be increasingly important in the future as more environmental regulations are adopted. Regulation of harvesting at the local or county level has increased rapidly in many states. In Georgia, for example, 101 Of 158 counties have county timber harvesting regulations and ordinances (WSFR Service and Outreach, 2001). Some local and county governments now require the submission of formal harvest plans to obtain a permit or approval to harvest timber in their jurisdictions. In addition, forest managers and contractors
are increasingly expected to justify their decisions in the event of a disagreement or for a third party audit. Private and corporate landowners are concerned about site disturbance and damage during logging. As clearcuts get more complex in shape to meet aesthetics objectives, skid trail design will be increasingly important. Machine travel paths may be predetermined rather than simply evolving during skidding. As always, there will be an increasing push for economic efficiency and greater emphasis on reducing environmental impacts by either market or regulatory forces.

OBJECTIVE

The objective of this project was to develop a computer based harvest-planning tool that would allow the comparison of alternative harvest settings based on estimates of harvesting costs and site disturbance. Our focus was to keep the model simple and use the resources commonly available to forest managers, wood buyers, and logging contractors. This tool should be an aid to, not a replacement for, field-based harvest planning and should help document the planning procedures used. Finally, it should work with commonly available software.

BACKGROUND

Estimating harvesting costs is a crucial component of harvest planning. The aim is to design an operation that will minimize road construction, logging deck construction, equipment setup, and skidding costs. Matthews (1942) provided the early groundwork for harvesting cost analysis and inspired the further development of the average skidding distance principle. Average skidding distance (ASD) is a variable that can be used in the cost analysis of a harvest plan. ASD is the average distance a machine must travel from felled wood to the logging deck for a particular setting. ASD can be used to give an estimated total direct skidding cost.

Suddarth and Herrick (1964) described a method to ASD estimation for irregular tract boundaries. It is called the approximation method. This method forms the foundation of this research project, as it is consistent with raster or pixel-based GIS data structure. The horizontal area of the setting is divided into a finite number of mutually exclusive rectangles. The sum of the area-weighted distances from the logging deck to the geometric center of each rectangle divided by the total area of the setting gives an estimate of the ASD. As the number of subdividing rectangles approaches infinity, the calculation produces the exact average skidding distance.

Vehicle traffic during logging can cause soil compaction, rutting, loss of soil structure or other types of soil damage. Numerous studies over many years have shown that the number of machine passes over a piece of ground is highly correlated with site damage and that most damage occurs during the first five passes (Reisinger *et al.* 1988). Tree growth and survival are influenced by soil properties, hence travel intensity or the number of passes through a particular area, is often a concern to foresters and harvest planners (Carruth and Brown 1996, Aust *et al.* 1998). Wang (1997) found that no programs simulated harvesting systems from the standpoint of travel intensity and included it as a component of an interactive computer simulation program. A travel intensity grid was produced in which the pixel value was equal to the number of machine passes through the cell. Areas of high travel intensity could be used in conjunction with soil maps to compare skid trail configurations and identify a configuration with an acceptable level of compaction matched to soil types.

SETTING ANALYST

We created a tool dubbed Setting Analyst in the ArcView GIS 3.2 environment. ArcView was selected for its popularity, cost, and capabilities. Setting Analyst estimates economic measures such as skidding and improvements costs. Improvements costs are the cost of opening and closing features such as roads, logging decks, and skid trails. In addition, Setting Analyst highlights areas of greatest machine travel thus identifying areas of potential soil compaction. The tool works as a simulation allowing the comparison of alternative user-defined scenarios. Setting Analyst is not an optimizer but rather simulates using information provided by the user and lets the user decide the preferred setting.

Setting Analyst was written in Avenue, ArcView's built-in object-oriented scripting language. The functionality contained in the scripts is packaged in the form of an ArcView extension. Extensions expand ArcView by enhancing the working environment with additional objects, scripts and customization independent of the current working session (ESRI, 1999). A certain level of ArcView and GIS knowledge is required. Setting Analyst relies on the Spatial Analyst extension, which is used for grid or raster data. Setting Analyst uses existing functions to model machine travel in what is effectively a grid-based network analysis. The model consists of a series of Spatial Analyst grid functions, reclassifications, binary masks, and grid manipulations. The user creates a cost or friction surface that controls the machine travel through the tract. The tool then uses the CostDistance function to generate a Machine Path grid based on this cost surface. This is then used by the FlowAccumulation and FlowLength functions to calculate travel distances and travel intensity.

The Cost Surface grid is the essence of Setting Analyst. A cost surface is a grid surface where the cell value is the cost-per-unit distance of passing through that cell. The CostDistance function selects the lowest cost path through the cost surface. Low cost cells are preferred; thus by assigning low cell values to skid trails and high values to areas to avoid, we can control the machine travel. While harvesting, the felling machine will make piles or bunches of logs in preparation for the skidding phase of the operation. Setting Analyst assumes that each bunch is removed with a single visit from the skidding machine. The tool randomly generates a representative distribution of bunch locations based on the harvested timber tonnage per acre and the extraction machine's payload. Each cell with a value represents a bunch. The machine travels to that cell to collect the logs and haul them to the logging deck. The FlowAccumulation function generates the travel intensity grid that relates to the number of machine passes through a cell. The FlowLength function calculates distance along the machine path for each cell. In the resulting grid each cell value represents the distance from that cell (a log bunch) to the nearest deck along the machine path. The average cell value of this grid is the average distance from all log bunches to the nearest logging deck or the ASD.

OPERATING PROCEDURE

The initial stages of planning a harvesting operation are to conduct a field reconnaissance to get an understanding of site features and consider possible locations for logging decks, skid trails, stream crossings, and roads. Back in the office using ArcView, the planner begins by creating shape files representing these features in potential locations. At least four methods are available to create shape files: digitized onscreen with a digital orthophoto background, digitized onscreen with a digital raster graphic (DRG) background, upload GPS data, or existing data sets (Figure 1). All the shape files are converted from a vector to raster (grid) data structure with a 5m (~ 0.25 chain) cell size.

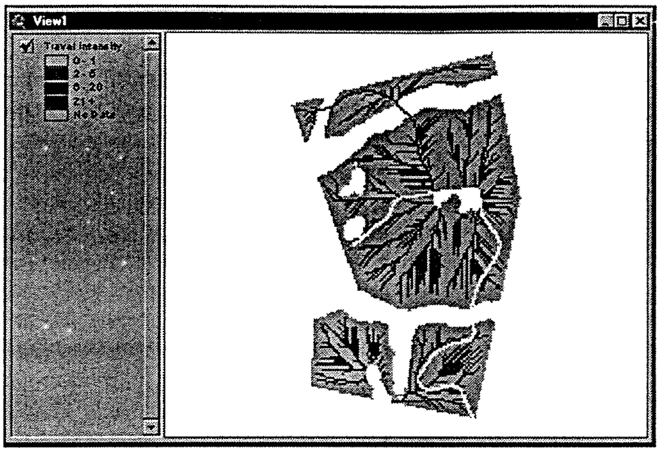


Figure 1. Setting features compiled from GPS data and by onscreen digitizing.

The next stage involves generating a random bunch distribution grid. The user enters machine payload (tons/turn) and the number of tons of timber harvested per acre via the dialog box. Next, the user creates a cost surface to control machine travel through the tract. Selected feature grids are assigned weightings and then combined to form a composite or cost surface grid. The user can select from two cost surface generation approaches: merge and addition. The addition approach takes into account original cell values whereas the simpler merge approach does not. The cost surface is modified to incorporate stream crossings. The resulting cost surface restricts machine movement through the SMZs forcing the machine to cross at designated locations. A further modification accounts for prohibited areas such as ponds. This forces the CostDistance algorithm to guide the machine around rather than through. The user selects the appropriate boundary, deck, cost surface, bunch distribution, and road grids that make up the setting to be analyzed. The simulation is run and the resulting grids added to the Setting Analyst Output view. The Summary Statistics function produces a summary report for the setting configuration. Overall tract ASD and the maximum skid distance are calculated. The Travel Intensity grid is reclassified in 0-1, 2-5, 6-20 and 21+ passes and the area in each travel intensity class is reported (Figure 2). Cost Calculator, the final stage of the analysis, uses previously generated statistics and user entries to calculate skidding cost, improvement cost, and total cost on a per ton basis.

FIELD TRIALS

Ten recently harvested tracts were modeled in an effort to further refine Setting Analyst and test its capabilities. Notable features were recorded by GPS (Figure 3). Additional unimproved skid trails were subjectively added to direct the flow of machine traffic. In addition to the actual harvest settings two alternative settings were designed for each tract, modeled with Setting Analyst, and then contrasted with actual settings. The first setting type, "with existing roads", assumed that all the actual roads were present before harvest planning commenced (Figure 4). In this situation, the planner has the option to use the existing roads or not and simply locates decks and other additional features. This scenario often occurs where the tract is on industrial land with an existing road network. This setting type was designed with each deck servicing at least 20 acres. The second setting type, "without existing roads", assumed there were no or minimal existing roads (Figure 5). This setting type had fewer restrictions. The number of decks was of less concern, but truck stream crossings were avoided wherever possible in favor of temporary skidder crossings. A situation like this often occurs on non-industrial private lands.

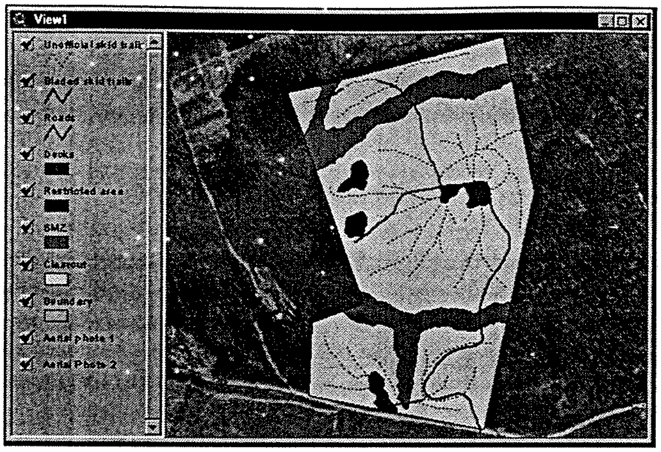


Figure 2. Travel Intensity grid indicating the simulated number of machine passes through each cell.

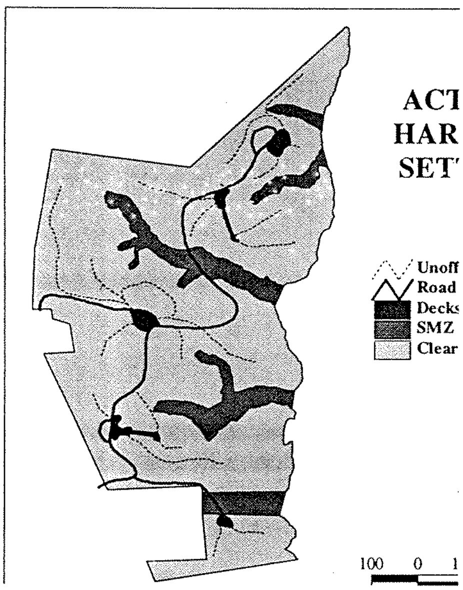
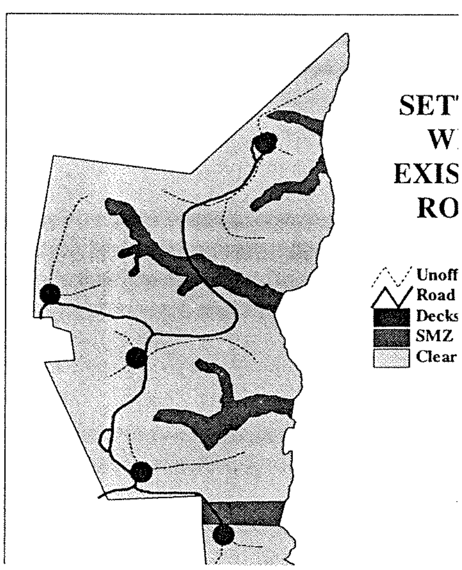


Figure 3. Example of an actual harvest setting.



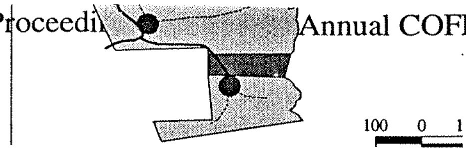


Figure 4. Example of a setting designed with an existing road network.

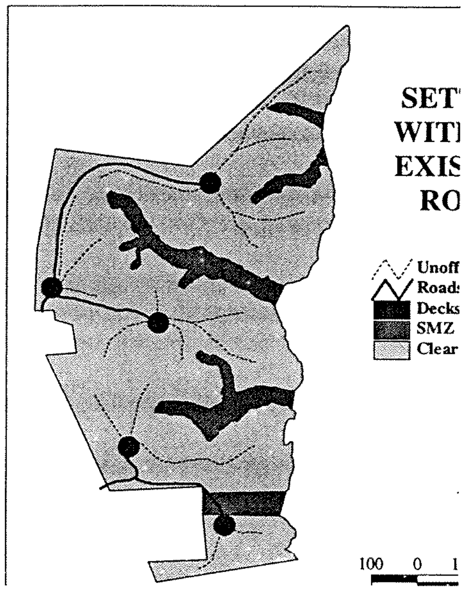


Figure 5. Example of a setting designed without an existing road network.

DISCUSSION

The obvious question after modeling will be which is the best setting. It depends on the objectives the planner is trying to meet and the priorities. Cost estimates provided by Setting Analyst can be interpreted in two ways. The costs can be regarded as either percentage differences or as approximate dollar figures. Again, the reason for planning will indicate the appropriate interpretation.

The nature of ASD makes model verification difficult. A hands-on approach to model verification could include using a GPS unit mounted on a skidder in an actual harvesting operation. The actual vehicle movement pattern and resulting travel intensity could be compared with that predicted by the model using a series of point samples. Setting Analyst does not currently take slope into account. The tool was developed with gentle or rolling terrain in mind. However, incorporating slope would further increase the tool's utility. Incorporating soil maps to indicate potential for compaction into the model would be advantageous. A soil grid with high values for soils prone to compaction could be incorporated when constructing a cost surface. However, soils data are often not available to planners when planning sales on NIPF lands.

CONCLUSION

Setting Analyst is a tool that can assist harvest planners in preparing sales using software and data that are readily available. The tool allows comparison of alternative settings based on economic and site disturbance evaluations. It provides a means of formally documenting proposed settings. Setting Analyst is a simple and straightforward tool that should find utility with a range of sale planners, including forestry consultants, wood buyers, and logging contractors.

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