Subdivision of large uniform stands lacking natural bounding features

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Abstract

Champion International Corporation has adopted new operating practices as part of its Sustainability and Stewardship (S&S) initiative. Under these new guidelines, restrictions on clearcut size and green-up delays for adjacent forest types present new hurdles to the development of sustainable and spatially feasible harvest plans. To address these difficulties, the Forest Products Technical Center is developing a spatial planning system based on Intergraph GIS, MapInfo desktop mapping and the forest modeling software produced by Remsoft Inc.

The difficulty faced in Champion's southeastern regions is that the majority of the forest land has been converted to large, uniform plantations that exceed the maximum opening size restrictions under S&S. In order to use the Remsoft blocking tools effectively, these large tracts need to be subdivided into smaller units. However, since the topography in the area is virtually flat with minimal variation in site quality, natural boundaries could not be used to subdivide plantations. Instead, a systematic method of subdivision had to be developed.

In devising the subdivision method, we considered a number of possibilities: conversion of vector maps to raster format, subdivision using Thiessen polygons, overlaying a regular grid of squares, rectangles and hexagons over the area. Each of these methods posed unique difficulties in terms of implementation or suitability to task but the hexagonal grid seems to offer the fewest compromises. Development of the spatial planning system is ongoing.

Keywords: spatially constrained harvest scheduling, forest planning.

Introduction

Champion International Corporation has adopted new operating practices as part of its Sustainability and Stewardship (S&S) initiative. Under these new guidelines there are restrictions on clearcut size and requirements for green-up delays for adjacent forest types that pose significant technical hurdles to the development of sustainable and spatially feasible harvest plans. To address these new planning requirements, the Forest Products Technical Center is developing a spatial planning system that will be deployed throughout Champion's nine regions across the United States. The spatial modeling system will be composed of a strategic forest planning model, a block harvest scheduling model and desktop mapping software, all linked to the company's geographic information system and forest land database systems. In addition to MapInfo desktop mapping software, Champion is currently evaluating Remsoft's Woodstock forest modeling system and Stanley block harvest scheduling system for use in the spatial planning system.

The Remsoft tools are based on a hierarchical planning technique described by Jamnick & Walters (1993). The first step is to develop a strategic harvest schedule that determines the timing and kinds of silvicultural prescriptions that produce a profitable and sustainable yield of forest products over time. The next step is to allocate the silviculture prescriptions chosen in the initial planning periods of the strategic schedule to whole stands, to form feasible harvest units that closely approximate the strategic schedule. Finally, these harvest units are scheduled for harvest under flow and adjacency constraints. Smaller harvest units may be combined into a single harvest block if they do not violate maximum opening size requirements, and green-up delays are imposed for the combined harvest block. Linkage between these steps is provided by the underlying GIS data – only stands scheduled for harvest in the Woodstock model are eligible for blocking and scheduling by Stanley. This approach has been shown to produce sustainable and spatially feasible harvests through time (Cogswell 1995).

The Remsoft blocking and scheduling model, Stanley, works by combining smaller stands into contiguous harvest units. This method of blocking is appropriate to Champion's lands in the Northeast, where past forest practices, ownership boundaries and terrain differences have resulted in a mosaic of smaller stands. However, in the Southeast much of the company's forest land has been converted to large, intensively managed plantations. For example, the forest used in this case study (from southern Georgia) has an average stand size of several hundred acres but the desired clearcut block size under the S&S guidelines is significantly less. In order to harvest an entire plantation under the S&S guidelines will require multiple harvests spread over a number of years, but subdividing these plantations is not easy. The characteristics that made this forest such a good candidate for plantation establishment (flat terrain, uniform productive soils) now make it difficult to decide how and where to locate harvest blocks. The objective now is to minimize the negative economic impacts of being unable to liquidate the entire plantation at once.

Given that the Stanley model is capable of blocking and scheduling harvest blocks under spatial constraints, we decided that we should subdivide the large plantations into allocation units that are smaller than the maximum opening sizes allowed under S&S. Then, Stanley could be used to group these allocation units into harvest blocks and schedule them for harvest in such a way that maximizes present net worth while meeting all the opening size and adjacency constraints. The major difficulty was, *how large should these allocation units be, and how can the subdivision of stands be efficiently done within the GIS?*

Alternative strategies

The solution that first came to mind was to rasterize the vector-based maps in the Intergraph system. First of all, rasterization could be easily implemented with available software – no additional GIS software would be required. Besides providing a uniform cell size to work with in Stanley, raster maps could be manipulated using efficient map algebra routines for calculating adjacency and proximity relationships. Furthermore, raster-based maps would integrate better with the large quantity of point sampled data in the Champion NOMAD databases. However, several problems with the rasterization approach quickly surfaced.

In order to accurately reflect location of stand boundaries and roads, the required cell size in the raster would have to be rather small. This has no impact on the strategic planning model since it is a stratum-based approach, but small cell sizes dramatically increase the solution time for blocking and scheduling. Stanley creates blocks by grouping together allocation units (cells) and thus, decreasing the cell size by half increases the number of cells to be allocated by a factor of 4. Furthermore, because

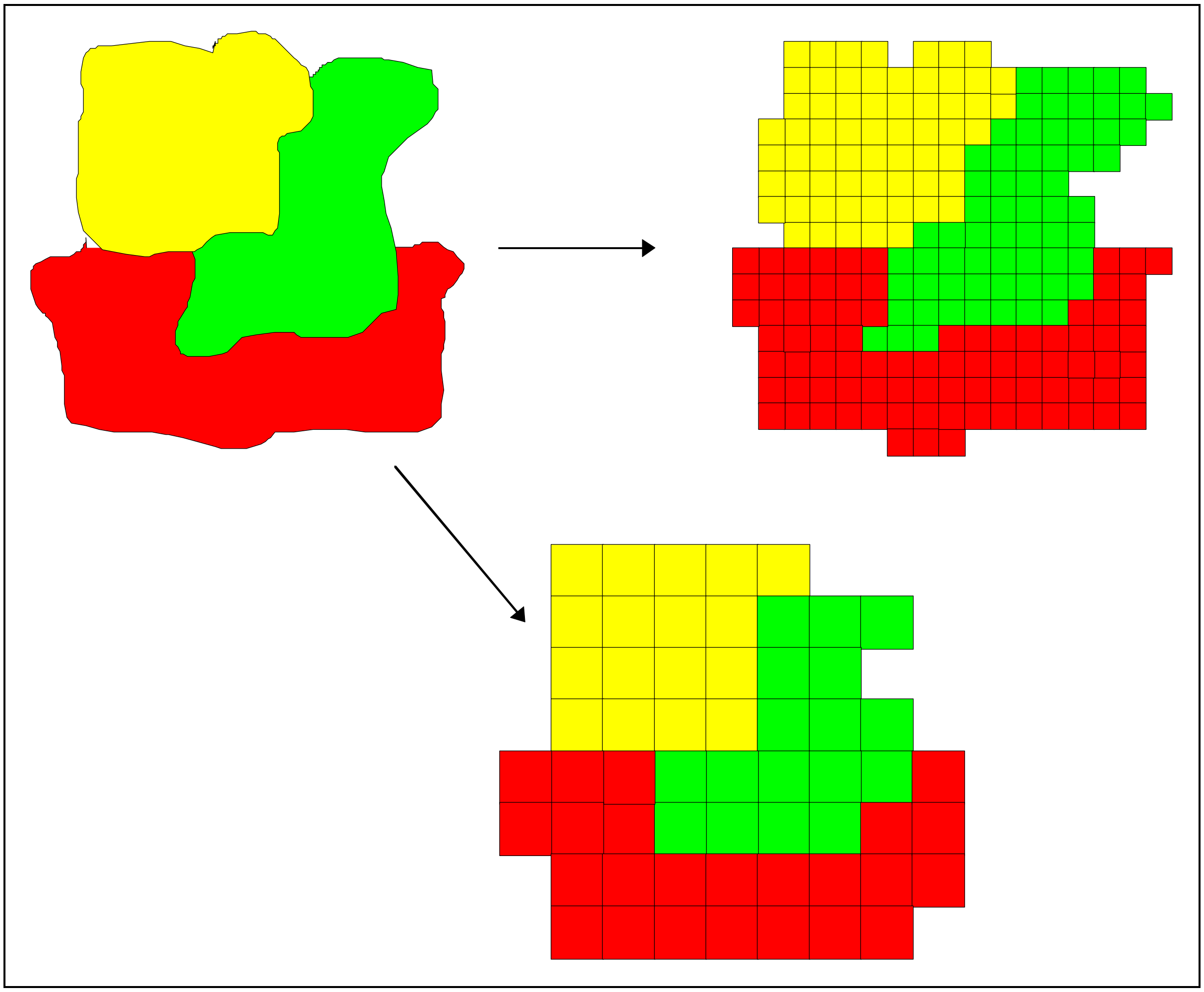

Figure 1. Rasterization of vector-based GIS maps for stand subdivision at different cell resolutions.

the scheduling algorithm exploits growth and yield differences among stands to perturb the solution, large numbers of identical allocation units increase the number of iterations required to generate an alternative solution. Figure 1 illustrates both how cell size affects spatial resolution and the number of allocation units to keep track of.

As Walters (1996) notes in his paper, using a raster representation brings up the corner-point problem and its impacts on blocking. If you consider as *adjacent* cells that are touching at the corner points only, it is possible to come up with harvest block configurations like that illustrated in Figure 2. Although the cell arrangements are not violating any

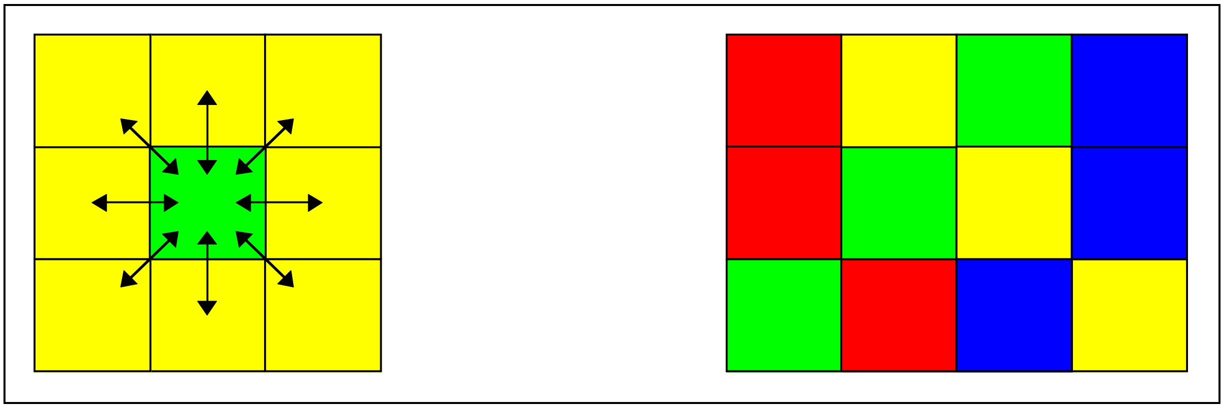

Figure 2. Corner point adjacencies and resulting non-viable harvest blocks.

spatial constraints, the blocks are not easily implemented as contiguous harvest blocks. In addition, the large number of adjacencies to be checked for possible violations adds additional processing overhead.

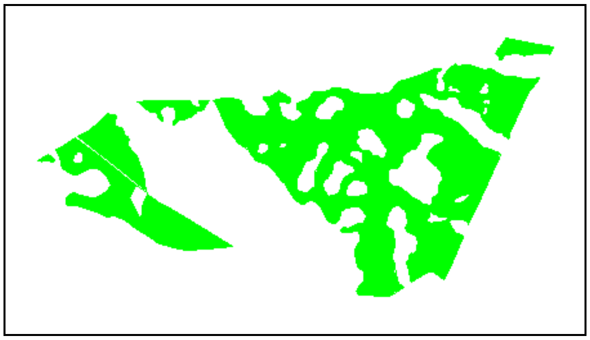

Figure 3. A typical stand (plantation) from the Georgia study area (489 acres).

Although the plantations in the study area tend to be large, they are not uniform, rectangular blocks. Instead, they tend to be irregularly shaped with numerous cypress ponds and bays interspersed throughout (Figure 3). In order to subdivide these stands without incurring the penalties associated with a raster format, we considered using the ponds and bays as the focal points for subdivision. By connecting the centroids from ponds and bays within a stand, as illustrated in Figure 4, we hoped to create a mosaic of irregularly shaped allocation units that would be simple to automate within the GIS as well as easily implemented on the ground.

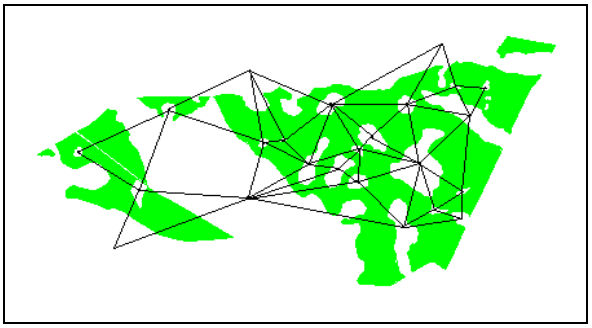

Figure 4. Thiessen polygons generated from centroids of ponds and bays.

As it turns out, neither the GIS automation nor the field implementation was feasible. The distribution of ponds and bays resulted in many small stand fragments in some areas area and few very large patches in others. Furthermore, the programming effort required to pick out centroids, connect them with line segments and then dissolve those portions outside the plantation boundaries exceeded the resources for this study. Therefore we were left to consider grid overlays of the forest area.

One of the advantages of using a grid overlay on a vector map is that there is no loss in spatial detail unless sliver reductions are performed. Unlike the raster format, a grid overlay subdivides polygons into smaller pieces of varying size, the largest of which is a complete grid cell. Therefore, a grid cell size of 40 acres could be employed without problems, whereas the resolution of a raster map with such a large cell size would be too coarse. Another advantage of the grid overlay is that you are not limited to square cells – a uniform grid of equilateral triangles, squares or rectangles can be used.

Given that the number of corner point adjacencies is related to the number of line intersections within the map, overlaying a uniform triangular grid would increase the number of corner point adjacencies by at least nine-fold and a uniform square grid by a factor of 4 (Walters 1996). Therefore, we considered using a 2:1 rectangular grid for two potential advantages (Figure 5).

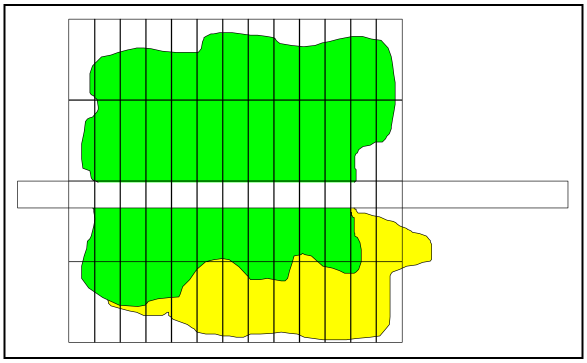

Figure 5. Rectangular grid oriented perpendicular to road.

First, the rectangular grid could be oriented perpendicular to the road network which would facilitate access to harvest blocks from the road. Second, by increasing the size of the cell, the number of cells is reduced and thus fewer corner point adjacencies are created. Unfortunately, the road network in the study area is not oriented in any particular direction, and the number of corner-point adjacencies generated is still large.

Finally, we decided upon a hexagonal grid that has the advantage of no corner point adjacencies – polygons that are touching share a common arc (Figure 6). Although overlaying the grid onto stand boundaries results in line intersections, at least the hexagonal grid does not add to the problem with corner point adjacencies inherent to the grid it self. We also decided to limit the grid to plantations and natural pine stands larger than 60 acres. Since the other forest types would not be clearcut, they are not subject to the opening size and green-up restrictions and thus subdividing these stands serves no purpose. Reducing the extent of the overlay also reduced processing time and data storage requirements.

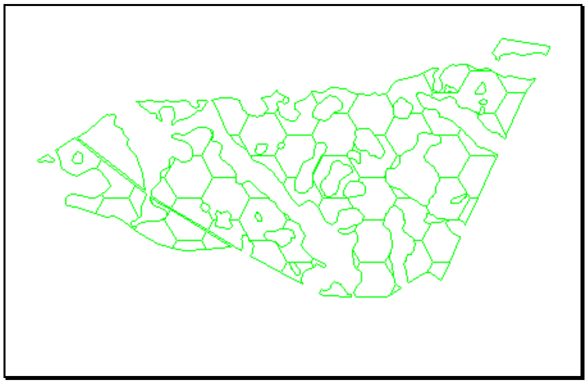

Figure 6. Plantation subdivided using 20 acre hexagonal grid.

Since Champion's target clearcut size is 120 acres, we needed to set the grid size smaller than that. For this study, we used a grid size of 20 acres which provides Stanley with sufficient flexibility in configuring allocation units as harvest blocks. Figure 6 illustrates a plantation subdivided using the hexagonal grid. Notice that there are no complete hexagons visible because the cypress ponds and bays were not subject to the overlay, and therefore, all of the allocation units are less than 20 acres.

Summary

The spatial planning system is still in the early stages of development. Although Woodstock has been commercially released, Stanley is still undergoing development by Remsoft staff. Champion's FPTC staff are working at developing consistent GIS structures for the various regions within the company and they are trying to simplify links among the various mainframe, workstation and PC databases and software tools to facilitate spatial forest management planning.

Although the results from the Georgia case study are very promising, there remains a great deal of work to be done in terms of data flow and user interfaces to make the process much more streamlined.

Of all the methods to subdivide plantations, the hexagonal grid seems to offer the fewest compromises. Although it does not completely do away with the problem of corner-point adjacencies and the difficulties they raise in blocking and scheduling, the hexagonal grid produces far fewer of them than the alternatives we looked at. Additionally, the hexagonal grid was easily implemented and does not require a large amount of manual intervention. We still need to determine an appropriate cell size for the hexagonal grid, one that minimizes the total number of cells yet still provides a great deal of flexibility when blocking and scheduling. This is just one of several areas of ongoing study by Remsoft and Champion staff.

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