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Estimating the effects of adjacency and green-up constraints on landowners of different sizes and spatial arrangements located in the southeastern U.S.

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Abstract

The maximum clearcut size and green-up period is important for land managers adhering to voluntary and regulatory guidelines. Therefore the impact of actual and hypothetical clearcut size restrictions is a concern for forest landowners who manage land and intend to practice forestry for profit. In this research, the effect of a 97.1 ha (240 ac) clearcut size constraint with a green-up period of 2-yrs is assessed for forest landowners with different forest land sizes, ownership patterns, and age class distributions. A meta heuristic which consists of threshold accepting, 1-opt tabu search, and 2-opt tabu search is used to develop spatially-constrained forest plans for 27 hypothetical forest landowners. These results are compared to a relaxed solution produced with linear programming, and statistical analyses are used to determine significant differences. The analysis provided enough evidence to suggest that two factors (size of ownership pattern and initial age class distribution), and one interaction factor (ownership size × initial age class distribution) are significant in explaining the differences in the percent reduction in forest plan value among the forests managed by the hypothetical forest landowners. From an absolute value reduction perspective, small-sized older forests were most affected. From a percent value point of view, one can conclude from this analysis that landowners with small-sized forests and young initial age class distributions will be significantly more affected by potential adjacency and green-up restrictions in the southeastern U.S. than other types of landowners.

Keywords: Forest planning; Harvest scheduling; Heuristics; Tabu search; Threshold accepting; Meta heuristic

1. Introduction

In the southern U.S., over 5 million landowners control 89% of the forest land, and a dynamic patchwork of land uses and land conditions has resulted (Wear and Greis, 2002). While the objectives of private landowners are diverse, ranging from timber production to recreational opportunities, the objectives of industrial landowners, who own about 20% of the forestland remain centered on economics. Increases in the human population in the southern U.S. have resulted in an interspersion of land uses and road systems within what was once a vast rural, forested landscape. This has resulted in the fragmentation of the forested landscape, where the size of contiguous forest patches has decreased (Wear and Greis, 2002). More recently, large vertically integrated paper companies have been divesting themselves of their forestland, selling land either to timberland investment management organizations (with objectives similar to industrial management) or to private individuals.

Many industrial forestry organizations in the southeastern U.S. have adopted the Sustainable Forestry Initiative (Sustainable Forestry Initiative, Inc., 2005) to show a commitment to social responsibility, and to demonstrate that their forests are managed in a sustainable manner. Like the Forest Stewardship Council (Forest Stewardship Council–U.S., 1996), participation in the program is voluntary, and the program contains a number of principles and objectives that need to be implemented and achieved. One of those performance measures relates to the size, shape, and placement of clearcut harvests, which restricts the average size of clearcuts 48 ha or less. In addition, many companies have developed internal policies to voluntarily limit

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the maximum clearcut sizes to 96 ha or less (Boston and Bettinger, 2001). Some private landowners have also expressed an interest in adhering to these principles and objectives without the formality of becoming a member of a certification program (Batten et al., 2005). Barrett et al. (1998) suggest that ownerships with the least amount of fragmentation of cover types will experience greater costs related to these types of management restrictions.

Traditionally, larger forestry organizations have developed strategic forest plans using linear programming to assess both sustainability and achievement of objectives. More recently, tactical forest planning has been used to assist with the development of plans that address spatial concerns such as the juxtaposition of harvests across the landscape. Tactical forest planning problems are different than strategic forest planning problems in that they can include spatial constraints, to recognize voluntary and regulatory forest-based programs (Bettinger and Sessions, 2003), and they generally cover shorter time horizons. Nowadays, forest planning problems are becoming complex because of the need to integrate ecological, economical and management objectives into the planning process. As a consequence, heuristic techniques are increasingly being used in forest planning as an alternative to exact methods (i.e. linear programming). A number of studies (e.g. Boston and Bettinger, 2001) have illustrated the cost of adjacency on forest landowners in the U.S. These studies typically utilize a single hypothetical landowner as an illustrative case to determine the percent reduction in land value between a relaxed case (i.e. no adjacency constraints) and a constrained case. The purpose of this work is to move beyond the determination of the cost of adjacency for southeastern U.S. landowners and to determine which landowner groups (defined by size, spatial configuration of parcels, and age class distribution) are most affected by a typical green-up and adjacency policy.

Some states have Laws that stipulate that the clearcut areas should below some maximum size. Currently, none of the states in the southeastern U.S. have these types of Laws, however, many landowners are consciously planning to maintain clearcut sizes below some maximum threshold (Batten et al., 2005). In this research, we will assume that landowners of various sizes, spatial configurations, and initial age class distributions agree to be guided by these considerations in their forest planning processes. We develop a set of 27 hypothetical forest landowners, and subsequently intend to estimate the effect of a 97.1 ha (240 ac) clearcut area constraint with a 2-yr green-up period on the value of associated forest plans to determine which group (or groups) are most affected by these planning guidelines.

2. Methods

In this section, we describe the solution processes used to generate the forest plans for the hypothetical landowners and the statistical analyses that will be performed to determine whether one or more of these hypothetical landowners are more affected by the adjacency and green-up constraints than the others. Linear programming (LP) has traditionally been used to develop strategic forest plans, and continues to be used in conjunction with planning efforts in natural resources management. LP-based models were used from the 1960s to 1990s to develop the long-range plans for the U.S. National Forests and are classic in the sense that they allocate resources and activities to timber stands based on linear equations, and to a limited extent they recognize spatial relationships. Since LP-based models are not able to express spatial relationships in a practical manner, researchers began to study and apply mixed integer programming (MIP) models (Jones et al., 1991) in the late 1980’s and early 1990’s. An integer decision variable is often used to express a particular harvesting or road management decision. This type of variable allows users to develop a planning model to accommodate spatial relationships and allows user to control adjacency restrictions. However, when integer decision variables are used, the problem size of forest planning increases, the potential solution space also increases, but at a disproportionately greater rate (Lockwood and Moore, 1993). Consequently, MIP-based solutions may not be suitable for solving spatial harvest problems with large numbers of integer decision variables, because they are difficult to interpret and may be impossible to implement. As a result, both heuristics and simulation models are now being considered as possible alternatives for the development of natural resource management plans with spatial relationships because the large numbers of integer variables and adjacency constraints are not restrictive in these techniques.

There have been numerous studies exploring the usefulness of heuristic optimization techniques in forest planning efforts. Bettinger and Chung (2004) illustrate the increase in use of heuristics in North American forestry over the last 20 yrs. Many types of complex, non-linear goals (e.g. spatial and temporal distribution of elk habitat, as described in Bettinger et al. (1997)), which have traditionally been considered impossible to solve with exact algorithms, are now being incorporated into heuristics. Heuristics have been used to solve forest transportation problems (Murray and Church, 1995), wildlife conservation and management problems (Arthaud and Rose, 1996; Bettinger et al., 1997; Haight and Travis, 1997), aquatic system management problems (Bettinger et al., 1998), and the problems that deal with the achievement of biodiversity goals (Kangas and Pukkala, 1996). The most popular heuristics used in natural resource management include Monte Carlo simulation, tabu search, simulated annealing, threshold accepting, and genetic algorithms. Some efforts are also being made to integrate aspects of each into hybrid heuristic techniques. Two disadvantages are the amount of time and expertise required to develop a heuristic, and the fact that a heuristic does not guarantee one will locate a global optimum solution to a scheduling problem. One can be confident, however, that a *good* heuristic will generate high quality, feasible solutions to complex problems in a reasonable amount of time.

The heuristic used in this research combines aspects of threshold accepting and tabu search, and thus is known as a meta heuristic. Threshold accepting was introduced by Dueck and Scheuer (1990). The technique uses a localized search process which is similar to simulated annealing, but uses a slightly different, and somewhat simpler set of acceptance rules for each