MAGIS EXPRESS: SPATIAL MODELING FOR TIMBER AND ACCESS PLANNING

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ABSTRACT

MAGIS eXpress is a modeling system for spatially-explicit analysis of timber harvest scheduling and access management. GIS (Geographic Information System) layers are imported and used as the basis for formulating harvest and access models. Access issues that can be addressed include new road construction, existing road reconstruction, and road decommissioning. Vegetation growth is based on 'vegetative pathway' principles. Data are viewed, scenarios developed, and results analyzed using state-of-the-art ArcGIS map input screens. A MAGIS eXpress solution includes the schedule of harvest activities and associated volumes, present net value, values predicted for individual treatment units, and the predicted vegetation distribution, including standing volume. A sample problem is presented to illustrate MAGIS eXpress uses and features.

INTRODUCTION

Forest managers are increasingly in need of GIS-based planning tools for developing projects that are both economically efficient and environmentally beneficial. Integrated management, from the strategic level down to operational planning, across multiple objectives and over the long-term, is more cost effective than independent planning at various stages (Aspinall and Pearson 2000, Bellamy and others 1999, Hahn and others 2001, Jakeman and Letcher 2003). Projects including timber harvest in particular need to be planned with strategic or tactical consideration of the transportation problem. Software is available to determine optimal rotation times and maximize economic benefit both at the strategic level (Gustafson 1999) and at the tactical level with commercial software packages available (Mowrer 1997), but which does not consider access costs.

Conversely, operational-level planning software is available for supply-chain or traffic flow problems, but which assumes the user already knows which units are to be harvested (Chung and Sessions 2002). If the problems are considered together, a more complete picture of the problem emerges: an in-depth analysis of scheduling alternatives that will improve efficiency and minimized adverse environmental effects, leaving managers less vulnerable to criticism about data and information used to develop projects. With increased pressure on public land managers to provide economic and ecological justification for harvest projects, the use of analytical tools has become critical for efficient planning. Planning tools need to be flexible, fast, easy-to-use, and address the relevant economic issues for efficient planning.

We present here a software application: MAGIS eXpress, which was developed to address this need. MAGIS eXpress is an application for timber harvest scheduling which selects harvest activities on user-defined treatment units, with access and road 'management' considerations. MAGIS eXpress is an explicit model of timber harvest and road access issues. It addresses the need for incorporating access issues, including modeling of activities such as road maintenance or road improvement to reduce pollution sources, and temporary closure or permanent decommissioning of roads.

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MAGIS eXpress is an offshoot of the more robust ecological modeling tool, MAGIS, which, in addition to timber products, can incorporate non-timber outputs, including wildlife habitat, sediment and water yield, fire risk indexes, and other forest health issues. Economic benefit is the major criteria for selecting harvest schedules and access, but other resource values and environmental effects can be used as constraints.

Optimization is complimentary to other approaches that include simulation modeling, and 'blackboard' applications that make it easier to modify and collaborate on project design, with or without simulation (Argent and Grayson 2003). A common theme is the need for spatially explicit information, either within the model or in the solution; MAGIS eXpress incorporates many GIS-related input screens and solution displays.

Software Description and Features

MAGIS express is a PC-based, spatially explicit, timber harvest and network access modeling system that allows the user some flexibility in the ways that costs are accounted, and significant flexibility in defining treatment regimes and rules for treatment options. The user creates all the basic definitions, imports GIS data for a specific project area, and runs scenarios that are customized for the specific problem. Because it is spatially explicit, MAGIS eXpress features many map-based interfaces for data entry, scenario definition, and solution display that assist the user in setting up the planning problem in a meaningful manner.

The following seven custom GIS interfaces facilitate validation and import of geospatial databases, user-assignment of planning area feature attribute values and model specifications, assignment of user-selected scenario presets, and viewing of scenario solution values:

- Multiple, task-specific interactive maps.
- Custom task management controls side-by-side with the interactive maps.
- Custom, single- or multiple-feature, filtered selection tools.
- Custom interactive tables and table editing tools for single or multiple records.
- On-the-fly feedback of user decisions, both in map and table displays and status bar displays of attribute values.
- Customizable legends for user-defined categories for nominal or numeric attribute values.

Interface designs are implemented via ESRI ArcGIS ArcObjects as Microsoft Visual Basic standalone ActiveX user controls or ArcMap VBA projects. The standalone ActiveX controls are embedded in and managed by Microsoft Visual FoxPro forms launched by the MAGIS VFP framework.

Users can make decisions about treatment unit and road options using GIS-based queries and selection tools. Solutions are fully displayed using both maps and tables.

Basic Operating needs

In its final configuration, MAGIS eXpress will have a dedicated solver incorporating both simulated annealing and heuristic algorithms. Currently, it is functioning with a commercial linear programming and mixed integer programming solver package which is launched from the MAGIS eXpress application.

MAGIS eXpress runs in any PC-based Microsoft operating system. The GIS-based graphical interfaces rely on ArcGIS capabilities and objects; ArcGIS must be installed on the same computer. Any PC computer with the capability to run ArcGIS can run MAGIS.

Model Parameters

A MAGIS eXpress model consists of four main components: the planning framework, project area, effects functions, and scenarios. The planning framework is the definitions of the parameters for the model, including activity-costs, timber products, management regime definitions and rules for assignation to individual treatment units as options, and the vegetation pathways. These pathways consist of individual states linked either by succession or by management activities; a stand exists in a given state until it is changed by succession or management action into a new state. Trajectories from state to state are determined by habitat-type group, and length of time in a given state. Selection of management actions can change the projected state in particular ways. For example, a selective harvest treatment could reduce both the density and dominant species components of the state, setting the stand down a different pathway.

The Project Area data model consists of the specific geographic area, represented as two GIS coverages: a polygon coverage and a road network coverage. Each coverage needs to be attributed with specific information determined by the definitions in the planning framework (for example, the vegetation growth model has a set of pathways using definitions of dominant species, size class and density: the polygon coverage vegetation attributes have to match these definitions.). Each treatment unit polygon has one or more management options, in one or more time periods. Each treatment unit with management options has 'connections' to the network (loading nodes). As units are selected for harvest, traffic from the harvest is loaded onto the network. If the loading point is on a 'proposed' road, or a road that requires reconstruction before it can carry traffic, the road options for those construction or reconstruction options are selected as well. The model selects the least cost route to the 'exit' or final demand node, and keeps track of the total amount of traffic (of each type) by road segment and for each period. Each coverage has specific criteria and attributes it needs to have before being used in a MAGIS model.

The effects functions are the items of interest, defined by the user, that are to be calculated as part of the solution. The types include: 1) harvest quantities, either as a total, or by product, 2) net costs, either total or split out by type, 3) net revenues, also split or lumped as the user sees fit, and 4) area control, which is the acreage of land in user-defined conditions. These include acres of activity (groups), acres by vegetative state characteristic (acres of large or v-large size class, for example), and acres by management schedule. Length control functions report miles of road by activity type (again, user-selected criteria) for example, miles of new construction, or miles of road decommissioning.

To define a scenario, the user selects one of two possible objective functions (maximize PNV or minimize total cost), and sets constraints using any of the defined effects functions. There is no explicit limit on the number of constraints that can be used; any of the cost, revenue, and area control functions can be used. For example, a constraint could be set for a specific number of acres in the entire area to be in the saw size class. This could be used to control the amount of old growth or new growth, as the user requires.

The scenario setup allows the user to create, solve, and save any number of individual scenarios. Each scenario consists of the objective function, constraints, and preselected decision variables. Constraints are limits (upper or lower) placed on other defined effects functions (most effects functions are available for this use). Preselected decision variables are road network or treatment unit options that the user either sets into or excludes from the solution. The user may choose to set any number of constraints and decision variables.

Example Problem: Upper Belt Planning Area

This example problem will be used to schedule two alternatives in addition to the No Action alternative using MAGIS eXpress, based on the idea that a combination of harvest and non-harvest treatments can be used to improve forest health and reduce risk of catastrophic fire.

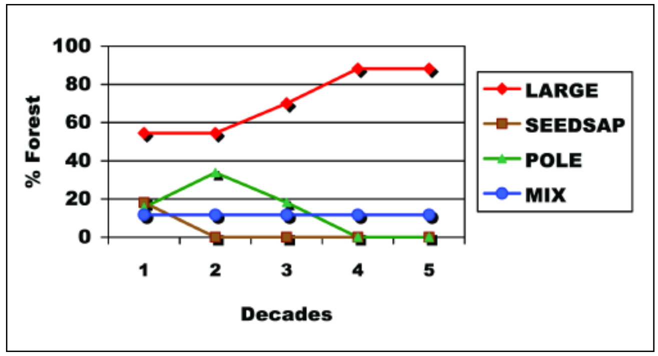

Figure 1—Relative distribution of vegetation size classes for the No Action scenario.

Goals will be set based on forest vegetation stand-structure classes and economics. Analysis of the No Action simulation indicates the direction of the vegetation pattern without management intervention. If desired, instead of using the MAGIS eXpress vegetation simulation, one could run a No Action simulation using SIMPPLLE (same GIS, same pathways, but with disturbance processes factored in) to determine a more realistic projection of vegetation patterns over time, and use the outcomes of the SIMPPLLE projection to set the vegetation pattern constraints for the MAGIS eXpress scenario.

The Upper Belt Planning area is an actual planning area on the Helena National Forest, in Montana. Timber is mostly lodgepole pine or mixed lodgepole pine and Douglas-fir. The vegetation description in the model includes a simple set of 'pathways' (total 109 records), with three species groups; four size classes (Saw, Mix, Pole, and SeedSap); and seven density classes (including the non-stocked category). The planning area is approximately 47000 acres of mostly forested land, within Forest Service administrative boundaries. There is an established road system with two main exit points (north to one mill, south to a different mill). For access, a harvest systems engineer designed an extensive system of proposed roads, to illustrate what could be done if all areas were accessible by road. Activity-costs and harvest specifications for three levels of harvest (a commercial thin, a more aggressive commercial 'restoration' thin, and a regeneration harvest) and a flat rate for log prices were entered in the model. Some areas are not considered for harvest because they are too rocky, too steep, or both.

No Action: This scenario is created by maximizing the acres of No Action in period 5 and setting the road cost constraint to zero. The results of the No Action scenario suggest explicit parameters for developing alternatives.

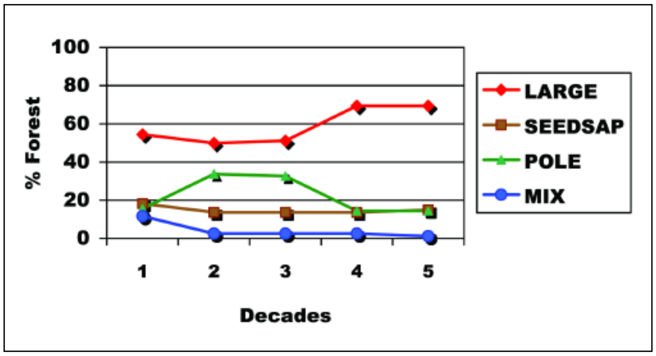

Figure 2—Relative distribution of vegetation size classes for Scenario 1.

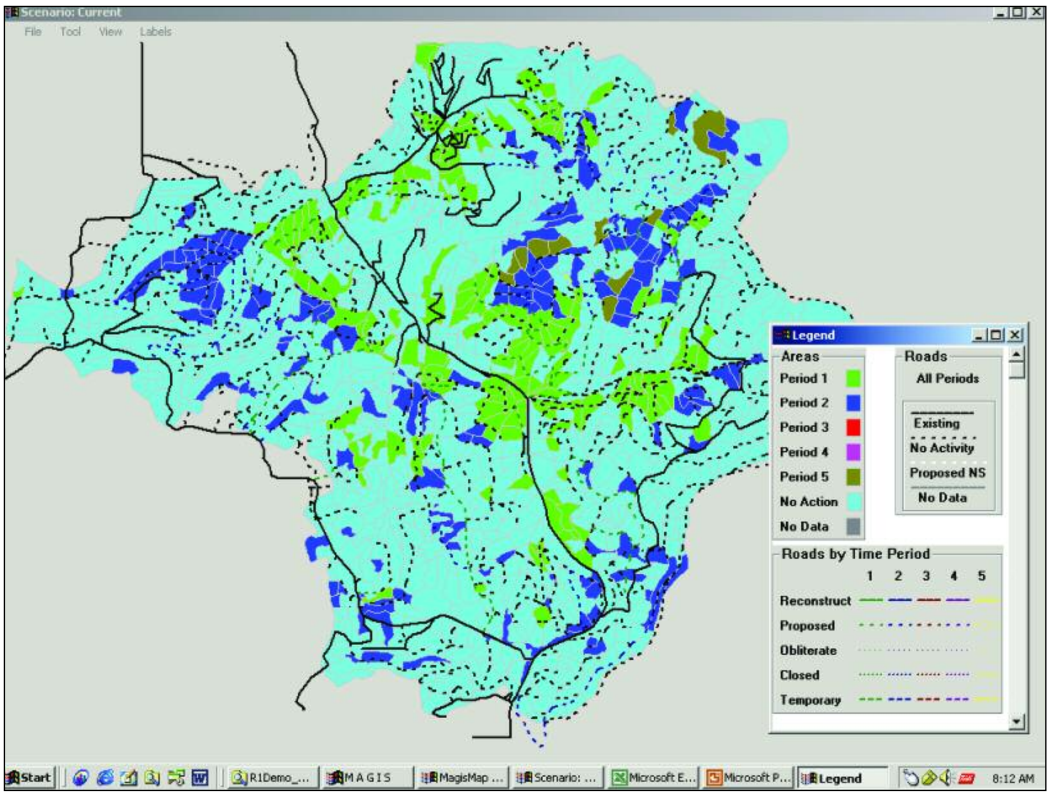

Figure 3—Scenario 1 Schedule of Treatments.

Results: In the No Action scenario, we see that, given successional changes (but no disturbance processes are modeled here) there is a predicted increase overall in large size class, and a decrease in the early successional size classes. If we assume that a mixture of large (saw), pole and seedsap size classes is more desirable, and the 'mix' size class is less desirable from a fire risk standpoint, the user would adopt this strategy.

Scenario 1: The objective function is set to minimize costs, and constraints are set on the relative mix of size classes as follows: Large is to comprise 70% of the acres, Seedsap and Pole comprise 15% of the acres each, and Mix is set to 0% of the acres. These specific goals are to be reached by the third decade of the planning horizon.

Results of Scenario 1: Vegetation constraints were met within the time alloted, but with a total projected cost of

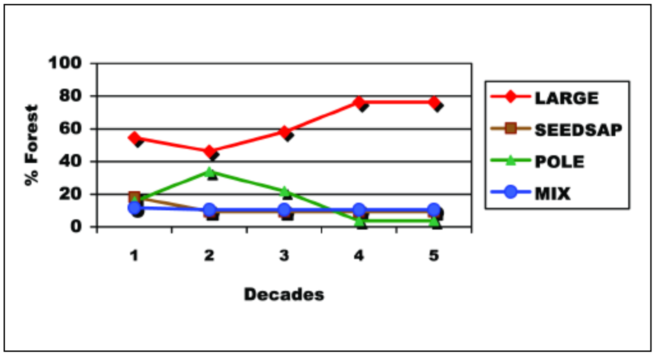

Figure 4—Scenario 2 Relative Distribution of Size Classes.

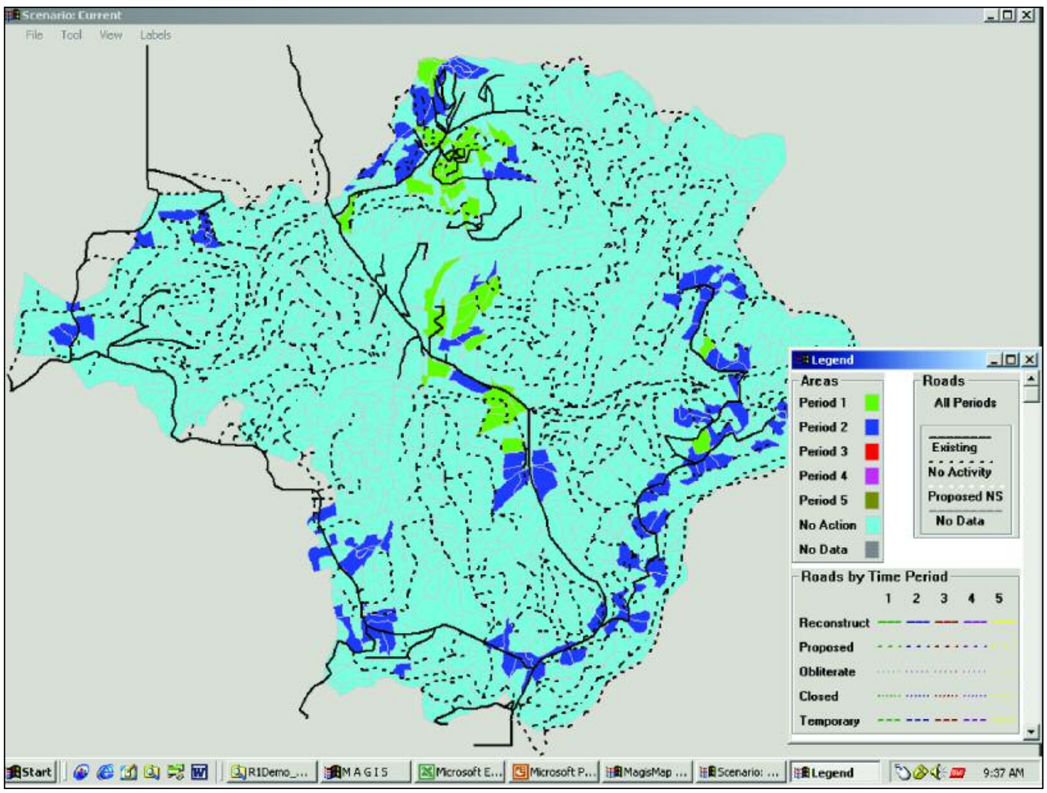

Figure 5—Scenario 2 Schedule of Treatments.

62.5 million dollars, with almost 30 miles of new road construction in each of the first two decades. This is not acceptable because the cost is too high and there are too many miles of road construction with negative environmental impacts, so there is a need to limit the miles of new road construction and still achieve (or come close to achieving) the vegetation management goals.

Scenario 2: Minimize costs with the same vegetation constraints, and allow no new road construction.

Results of Scenario 2: Vegetation constraints were not able to be met with the road construction constraint (apparently many stands with the mix size class are inaccessible.) However, some shift towards the 'ideal' goal is still possible. Total projected cost is now 3.44 million dollars, with some reconstruction costs. There has been a tradeoff for the ideal vegetation pattern goal, for one with fewer economic (and environmental) costs. One can analyze this new solution and then explore additional modifications by entering new constraints, or, using the vegetation management goals that are achievable, set up a new scenario that maximizes present net value (rather than minimizing costs) to achieve the same vegetation patterns. There are now many possibilities where predicted outcomes are calculated quickly and consistently, allowing the development of feasible alternatives that are determined by different combinations of objectives and constraints.

CONCLUSIONS

The example problem illustrates how a MAGIS eXpress model can be used to efficiently schedule harvesting and road access with vegetation management goals (not strictly 'timber production') and use constraints to modify scenarios to reach management objectives. MAGIS eXpress can assist forest planners and timber sale designers in building feasible, economically efficient alternatives that address forest health, vegetation management, fuels treatment considerations and access problems, including road maintenance, removal, and new road construction.

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