PROJECT SUMMARY:
RESULTS FROM THE MINNESOTA FOREST SPATIAL ANALYSIS AND MODELING PROJECT

A Report to the Minnesota Forest Resources Council

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in consultation with the Project Strategy and Technical Teams

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INTRODUCTION

Importance of Forest Spatial Patterns

Forest spatial patterns are important for numerous forest values, including wildlife, forest productivity, and recreation. For example:

- Some wildlife species require large patches of forest, while others require smaller patches of several forest types in close proximity.
- Forest productivity depends on spatial patterns of soils and landforms, and costs associated with logging vary according to harvest size and arrangement on the landscape.
- Spatial patterns affect a whole range of recreational opportunities such as hunting, birdwatching, hiking, and off-trail vehicle use.

Forest spatial patterns refer to the size, shape, and arrangement of "patches" in forested landscapes. Patches are defined by any feature that can be mapped, such as forest types (e.g., aspen or pine) and disturbances (natural or human-caused).

Despite the importance of spatial patterns, they have not been assessed comprehensively in Minnesota, and a lack of information on spatial patterns has contributed to controversy. The 1994 Generic Environmental Impact Statement on Timber Harvesting recommended that the State conduct a spatial assessment. Increasingly, forest managers recognize spatial analysis as a key element of sustainable forestry (Davis et al. 2001).

The Minnesota Forest Spatial Analysis and Modeling Project

Conducted from 2000-2003, the Minnesota Forest Spatial Analysis and Modeling Project aimed to improve understanding of past, present, and possible future spatial patterns in Minnesota, along with implications for forest management.

Financial sponsors of the project included the MFRC, the DNR, Minnesota Forest Industries and its members, The Nature Conservancy, and Audubon Minnesota. In addition to sponsors, several institutions contributed staff time. These cooperators included the U.S. Forest Service, Natural Resources Research Institute, the University of Minnesota College of Natural Resources (CNR), the Minnesota Association of County Land Commissioners, and others.

The MFRC formed two interdisciplinary, multi-stakeholder teams to design and carry out the project. The project strategy team (PST) and the project technical team (PTT) provide strategic and technical leadership, respectively. The PST developed the initial vision and questions for the project, and is composed of 11 members from a variety of organizations, including public land management agencies, environmental groups, forest industry, conservation groups, and research organizations. The PTT developed the methods to answer questions posed by the PST.

Members were scientists from a wide range of organizations, each with expertise in fields relevant to spatial analysis (see inside cover for list of members of both teams).

The Project Strategy Team developed the following project purpose statement:

- Improve the understanding of conditions and changes in landscapes through the depiction of past, current, and possible future spatial patterns
- Develop effective tools that assess those conditions and changes through an iterative process of implementing, testing, and interpreting
- Identify strengths and limitations in data, in the uses of spatial data, and in the interpretation of analyses

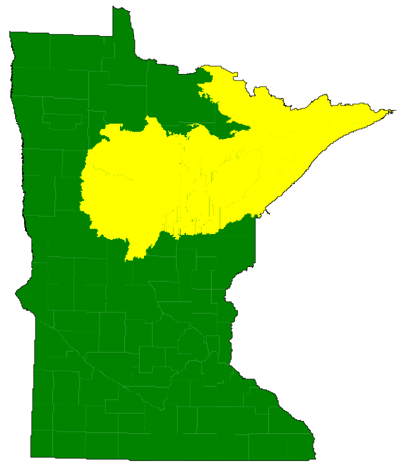


Figure 1. Study area in Minnesota

To narrow the project scope, the team agreed to focus the study on the Drift and Lake Plains and Northern Superior Uplands ecological sections in Minnesota (Fig 1.).

In brief, project components included:

1. Developing GIS databases of past (1800s to present) and current spatial patterns using several different data sources, including original land survey records, aerial photographs, and satellite data;
2. measuring spatial patterns using these GIS maps and assessing changes;
3. modeling potential future scenarios, using an ecological landscape model called LANDIS and a new spatial harvest scheduling tool called DPspace; and
4. producing a background paper describing effects of spatial patterns on plant and animal species.

Six separate technical reports were developed to address these components (see list of reports at end of this document). The project budget ($365,000) was not distributed equally among project components. Seventy percent of the budget went to historical and current analyses (items 1-2 above), 22% of budget went to future scenario modeling, and 8% went to the species background paper. The reports are available at http://www.frc.state.mn.us/Spatial/SpatialIntro.html . The purpose of this document is to summarize results from all of the studies, along with describing key concepts and terms.

KEY CONCEPTS AND TERMS

What are spatial patterns?

Spatial patterns refer to the size, shape, and arrangement of landscape patches. Patches can be any feature that can be mapped such as:

- Forest types, habitats, vegetation communities
- Landforms, soils, aquatic systems, etc.
- Disturbances (natural or human caused)

This project focuses on spatial patterns of vegetation types and age-classes, land uses, along with natural and human-caused disturbances.

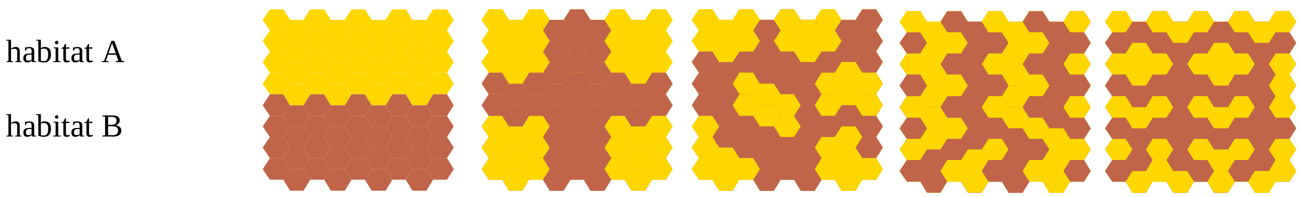
What is spatial analysis?

There are many types of spatial analyses, but for this project, spatial analysis simply means mapping and measuring spatial patterns. Modern spatial analysis software programs (e.g., FRAGSTATS) can calculate dozens of spatial metrics from GIS maps. Different metrics quantify a range of attributes that characterize size, shape, and arrangement of patches identified on the maps. While some of the metrics are quite complex and difficult to understand, a few of the basic ones can reveal important characteristics of landscapes. For example, Figure 2 depicts two habitats (320 acres each) arranged five different ways. The number of patches, average patch size, amount of edge, and amount of interior area varies dramatically from left to right, while habitat acreage of each type is constant. It is important to clarify terms here:

> **Patch:** An area that is relatively homogeneous in some attribute (e.g., forest type or age) and is distinct from its surroundings. It is important to note that there is no single way to delineate patches, and the delineation method depends on objectives and available data. In this project, patches are defined mainly by vegetation type or age.
>
> **Edge:** Junctions or transitions between different patch types.
>
> **Edge Effect:** Some change in physical attributes or habitat quality near edges. Edge effects can be positive or negative, and need to be defined for different edge types and species. For example, some game species such as whitetail deer or ruffed grouse tend to favor edges between young and mature forest, because they can get needed food or cover resources from both the young and mature forest. However, other species are negatively affected by edges. Some songbird nest predators are known to concentrate along farm-forest edges, resulting on high predation rates on the nests. Elevated predation rates have also been documented near young-mature forest edges.

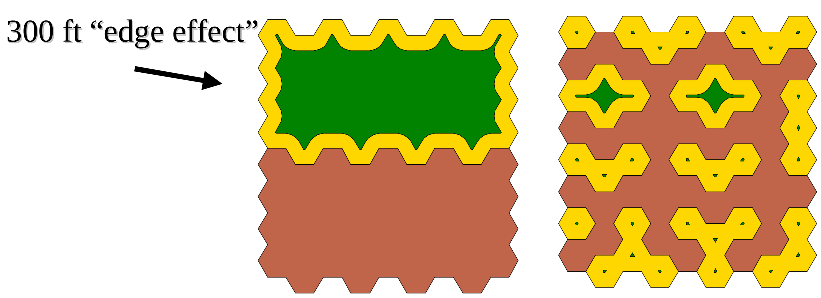
Interior Area: For some species, negative effects of edges extend a certain distance into the interior of patches, so that quality habitat (interior area) for those species is limited to the area within the patches beyond this distance. For example, if the "edge effect" distance (zone of influence) is 300 feet, then the area of quality habitat within a 320-acre block is reduced to the darkest area, at 210 acres (Fig. 3). If the 320 acres is divided into small blocks, such as those on the right, then interior area declines to 25 acres.

Figure 2. Example of potential variation in spatial patterns for two habitats, with values for several spatial metrics.



Number of Patches (habitat A)	1	4	6	6	12
Average Patch Size (habitat A, acres)	320	80	53	53	27
Total Edge (miles)	3.6	6.4	8	9.6	11.6
Interior Area (acres habitat A, 300 ft buffer)	210	137	100	50	25

Figure 3. Example of decrease in interior area as patch size decreases.



Interior + edge zone	320 acres	320 acres
Interior space	210 acres	25 acres

PROJECT METHODS AND RESULTS

Change in Spatial Patterns and Disturbance: 1800s –1990s

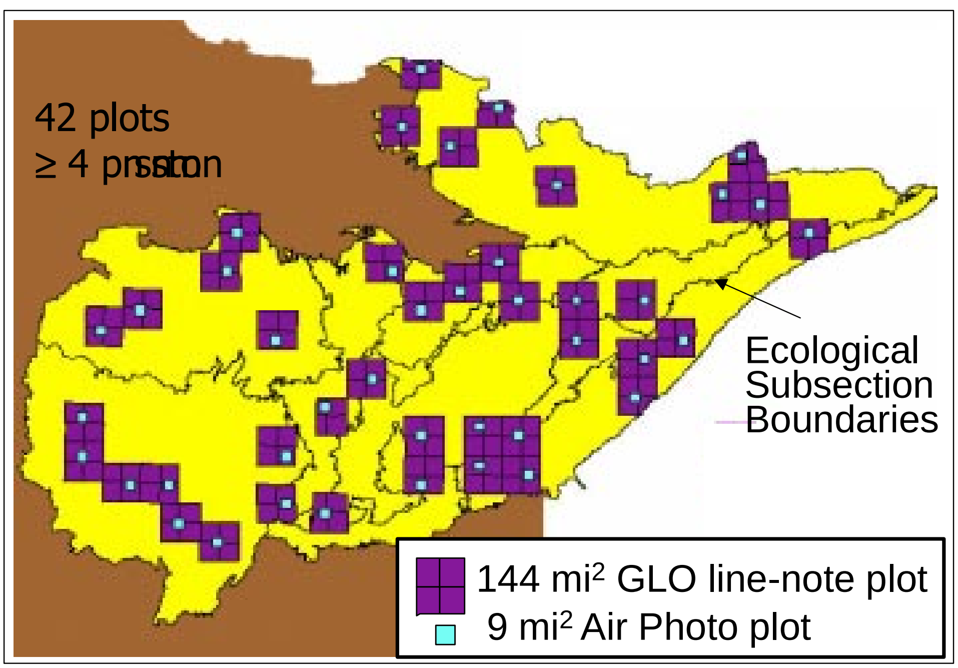
Methods

We assessed Pre-European disturbance characteristics on 42 sample plots (each 144 square miles) in the study area by digitizing surveyor's line-notes from the 1847-1910 General Land Office (GLO) survey. More recent change was assessed using aerial photos from plots within the line-note blocks (each 9 square miles), covering 1930s, 1970s, and 1990s time periods (Fig. 4). Study plots were allocated proportionally within ecological subsections by size, with a minimum of four plots per subsection (subsections defined as part of the National Hierarchical Framework of Ecological Units). Within subsections, plot locations were randomized.

Because surveyors noted vegetation and disturbance types as they parceled a grid of mile^2 sections, we were able to estimate natural disturbance patch sizes and frequencies by direct delineation and through transect sampling theory (DeVries 1974, Canham and Loucks 1984).

Natural disturbances, harvests, vegetation type, and four forest age classes were stereo-interpreted from the aerial photos, and were digitized in GIS format (See Appendix 1 for list of patch types used). In addition, vegetation and land-use classes were assessed over the entire study area, using two different LANDSAT Classifications from the 1990s. A full description of methods and results are available in White and Host (2003) and Host and White (2003).

Figure 4. Sampling design for GLO line-note and aerial photo interpretation.

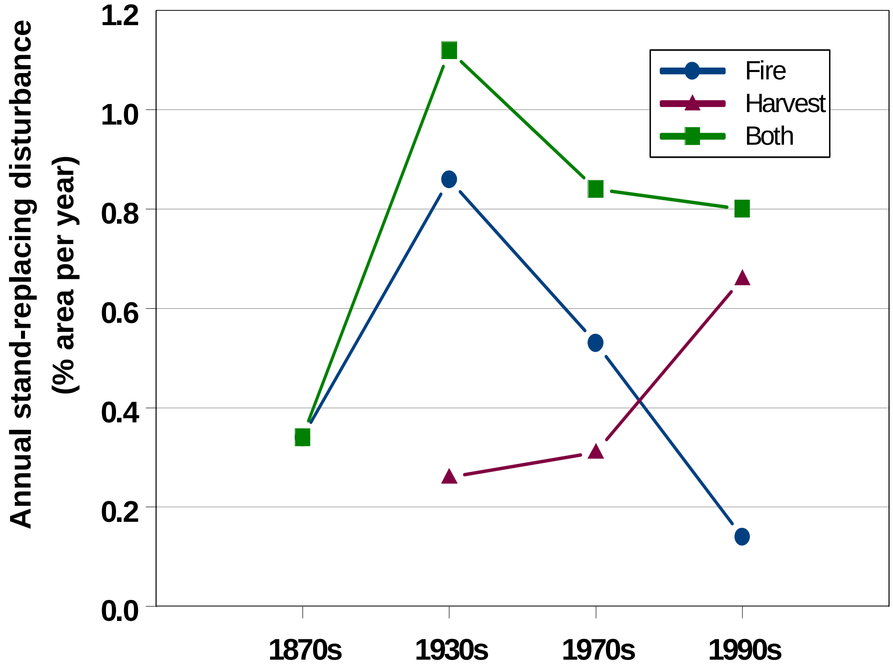


Results

Disturbance Rates

- The settlement period (1900-1930) produced a short-term increase in fire frequency in the study area, followed by a dramatic decrease by the 1990s. Timber harvest increased over the same time period, and is now the dominant disturbance type (Fig. 5) (White and Host 2003).
- GLO line note data produced similar high severity fire frequency values to estimates derived from tree-ring analysis in the Mixed Forest Province of the lake states region. Estimates for catastrophic windthrow derived from GLO data in this study are similar to or within the range of those derived in other studies in northern lake states forests. Harvest rate estimates from this were in the same range as reported by other studies using different methods (White and Host 2003).

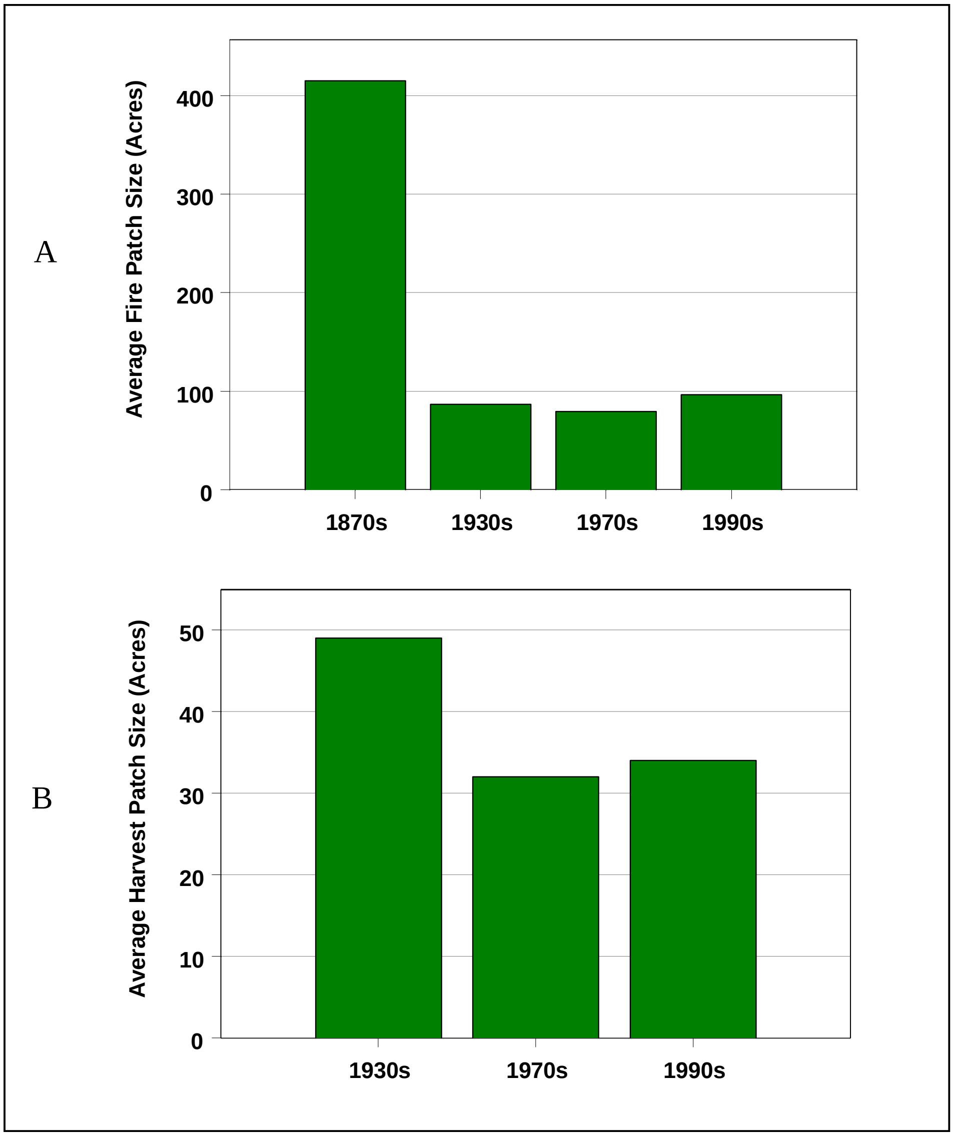
Figure 5. Estimated annual stand-replacing disturbance frequency (% forest area) over the four time periods (1% per year is equivalent to a 100-year rotation). Not enough wind data were recorded in the 1930s-1990s time period to make a comparison.



Disturbance Patch Size

- In the 1850-1900 landscape, average fire disturbance patch sizes were considerably larger than those created by timber harvests in the 1930-1990s landscape (Fig. 6A). Average timber harvest patch size decreased from the 1930s to the 1990s (Fig. 6B) (White and Host 2003).

Figure 6. Change in Average fire and harvest patch sizes over the four time periods. Harvest data were not available for the 1870s time period.



Vegetation/Land Use Patch Size

- Mean overall patch size, defined by 12 vegetation/landuse types and 3 age classes, declined by nearly 50% from the 1930s to the 1990s (Figs. 7-9). Total amount of edge (all edge types) increased and core area (defined by 100 m edge buffer) decreased (Host and White 2003b).

Figure 7. Example of change in patch structure in one of the sample plots, 1930s-1990s.

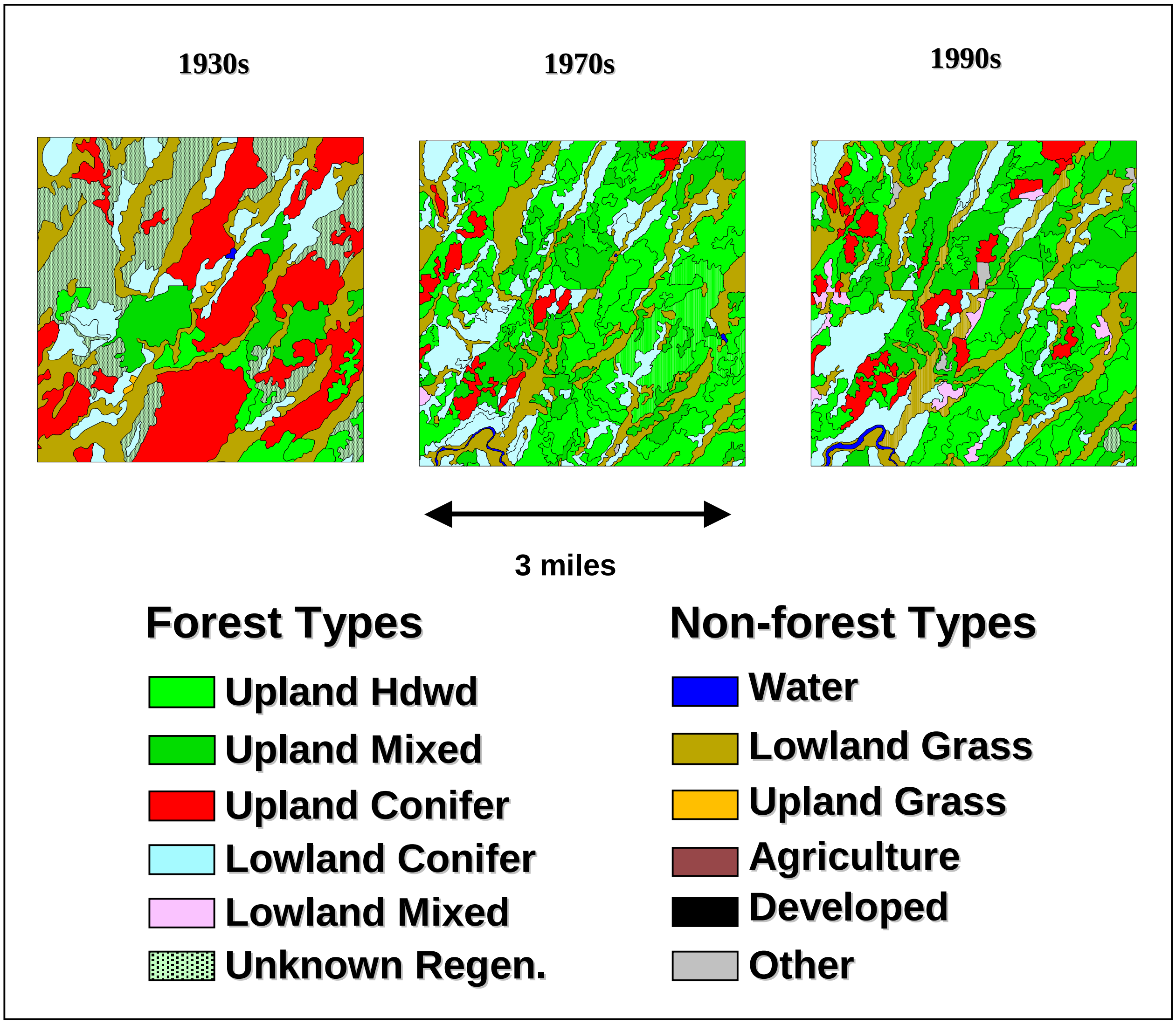


Figure 8. Change in mean patch size from the 1930s to the 1990s in the study area.

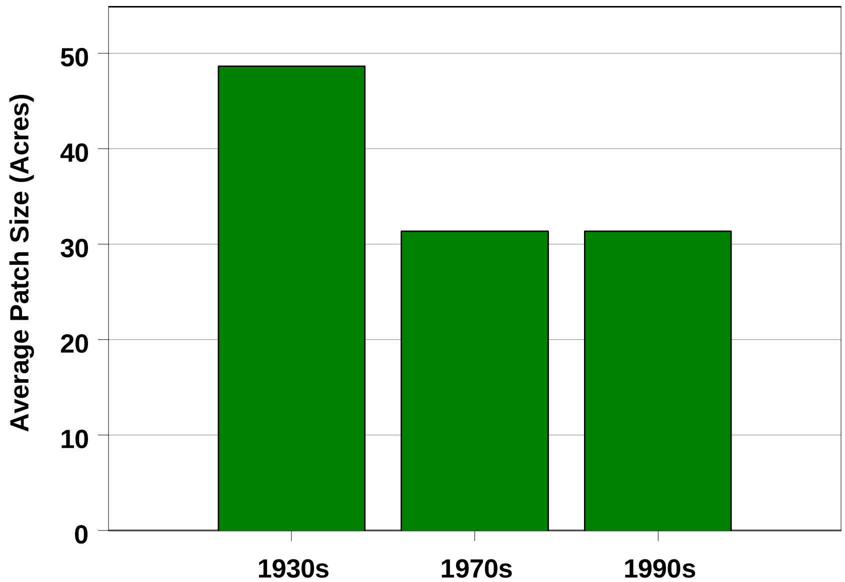
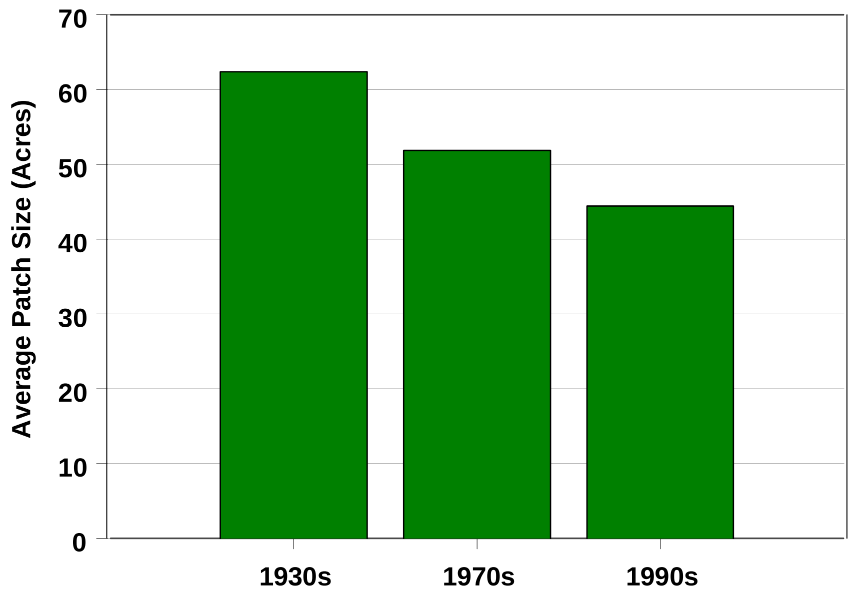


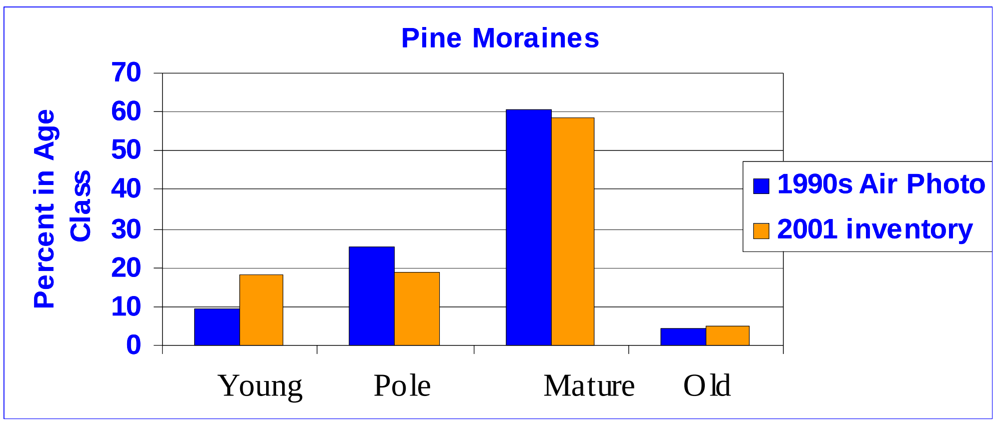
Figure 9. Change in mean patch size of upland hardwood forest types from the 1930s to the 1990s in the study area.

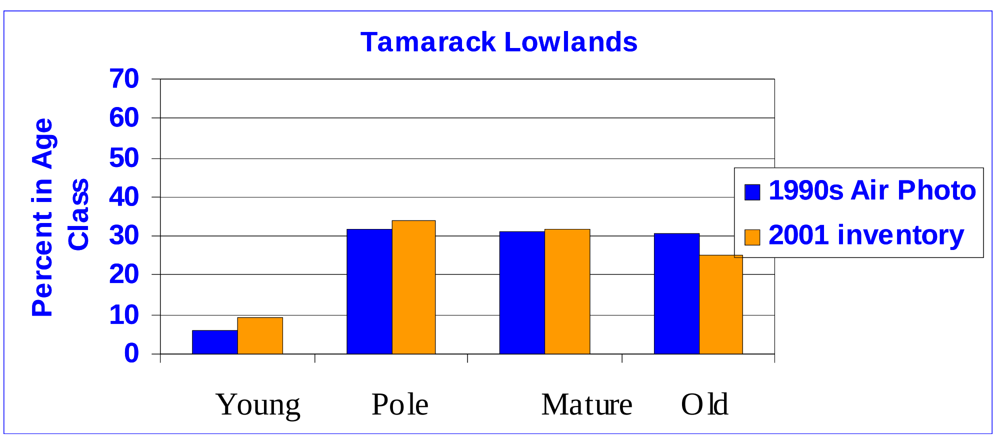


Age Structure

- Age-structure in the region shifted from dominance by mature (50-100 yrs) and old (>100 yrs) forests in pre-settlement times to pole (21-50 yrs) and mature forest in the post-settlement era. The 1990s showed movement from pole and mature to old-forest stages, with higher values occurring in subsections with lower management intensity (e.g., Border Lakes and Tamarack Lowlands) (White and Host 2003).
- Interpreted aerial photography age class data showed strong similarity to age data derived from forest inventory (FIA and agency stand inventories), and thus is a useful tool for monitoring forest conditions including age-structure when using broad age-classes or growth stages (Fig. 10) (White and Host 2003).

Fig. 10. Example of similarity between aerial-photo derived and inventory derived age-structure data.

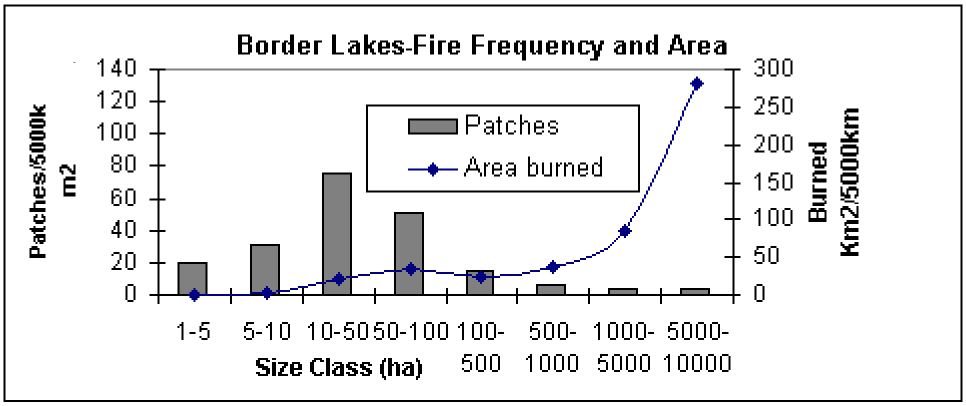


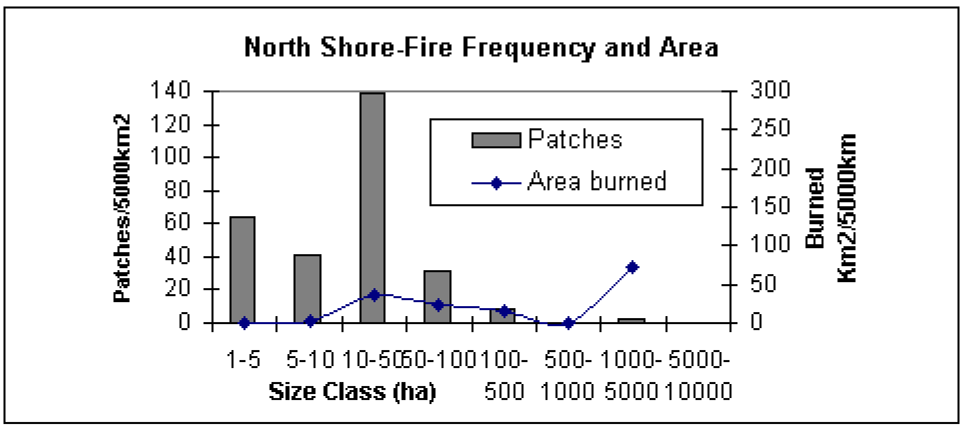


Variability among subsections

- Natural disturbance frequency, severity and accompanying patch size distributions varied considerably across the eight subsections studied (Host and White 2003a, 2003 b; White and Host 2003). Natural disturbance, interacting with soils, landforms and climate, produced characteristic landscape pattern and structure in the eight subsections (Fig. 11).

Fig. 11. Example of variability in fire patch size distributions and among ecological subsections, derived from GLO line-note data. The Border Lakes subsection had fewer burned patches in the smaller size classes, and more large patches when compared to the North Shore Highlands subsection.





Potential Future Spatial Patterns

Given the change in spatial patterns documented in White and Host (2003) and Host and White (2003b), questions arise about how managers can change spatial pattern structures in the future. In particular, the following key questions arise:

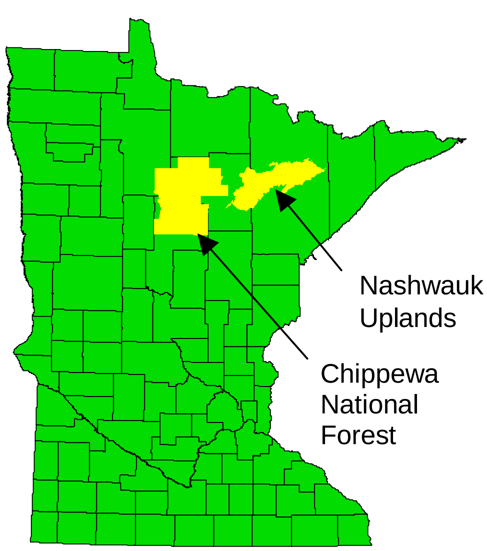
- What are the effects of changing the size and type of harvest?
- What are the best strategies for maintaining large patches of forest?
- What are the economic costs of different spatial management strategies?

These kinds of questions are very difficult to answer without computer models that project future conditions, given different management scenarios. Models are powerful tools for simulating forest growth and disturbance, and for evaluating many different management options. (Davis et al. 2001).

Methods

To examine the questions described above, we used an ecological simulation model called LANDIS (Mladenoff and He 1999) and a new spatial management scheduler called DPspace. LANDIS scenarios tested several ways to increase forest patch size over a 120-year period: increasing clearcut size, increasing public landowner coordination, and eliminating harvest, among others. DPspace developed 100-year harvest schedules that optimized timber volume while simultaneously valuing forest interior space (50 m edge buffer) at different levels ($ per acre). Modeling was conducted on smaller study landscapes, including Chippewa National Forest (DPspace) and the Nashwauk Uplands ecological subsection (LANDIS) (Fig. 12). These landscapes were chosen to build on previous work where the models have been applied.

Fig. 12. Landscapes used for LANDIS and DPspace scenario modeling.



Results--Modeling Exercises

LANDIS model

The following results are from Mehta et al. (2003):

- With the LANDIS scenarios, it was more difficult than expected to increase patch size over the 120-year simulation period. Mean patch size was very similar for all scenarios. In part, this was because of the natural physiography of the Nashwauk Uplands landscape, where many small wetlands are interspersed within upland forests.
- Increasing landowner coordination and clearcut size did increase the proportion of old multi-age spruce-fir patches larger size classes. The no harvesting scenario did not increase proportion of larger spruce-fir patches, but did increase mean patch size of mature aspen forest from 5 ha to 18 ha. This was because large fires created large aspen patches in the simulation, and these patches were not fragmented by harvesting.
- In all scenarios balsam fir and white spruce trees became more abundant in the Nashwauk Uplands Landscape. This result makes sense given that harvesting is a low-to-moderately severe disturbance (including clearcutting) that favors regeneration of shade-tolerant conifers, as compared to the unique sequence of disturbances—harvesting followed by slash burning—that created the current widespread distribution of the aspen-birch forest type. Gradual return of conifers is expected as time goes forward, especially as far north and east as the Nashwauk, where the climate puts conifers in a much stronger competitive position than in most of Minnesota. FIA plot data from St. Louis County corroborate this finding, where the number of live spruce and fir stems increased by 29% from 1977-2002 (County data from FIA Mapmaker program, Miles 2001).

DPspace model

The following results are from Hoganson et al. (2003):

- Providing adequate older forest interior space is likely more of a short-term problem than a long-term one. Interior space levels are likely low today simply because spatial arrangement of the forest received little consideration in past forest planning efforts. In the short-term, forest conditions cannot change rapidly so focus may need to be on the more limited interior space production options for the short-term. Short-term actions have potential long-term impacts so both short term and long term impacts need to be considered simultaneously. With good planning and the lead-time associated with long-term planning, spatial conditions can be improved over the long-term.

- The DPspace model results suggest that simple management guides such as "harvest in large patches" are oversimplified and can be detrimental for maintaining older-forest interior space in the short term. Such a strategy tends to eliminate existing large patches of older forest when they are in short supply. Effective and efficient strategies likely involve a variety of harvest sizes, with modeling a key to identifying good spatial and temporal management schedules that fit well with existing landscape patterns.

- The DPspace study area has perhaps as much of an intermixed public ownership pattern as anywhere in Minnesota. Yet for the two ownerships considered (state and federal), most of the area capable of providing interior space involves areas of single ownership. Assuming 150-foot buffers for interior space, over 95 percent of the study area capable of producing interior space is in blocks of single ownership. With 300 foot buffers, over 90 percent of the area capable of producing interior space is in blocks of single ownership. In effect, much can likely be gained from good planning for each ownership. While coordination doesn't seem critical for increasing interior space as defined in the study, there are caveats to this finding. The study did not consider directly the patch sizes associated with interior space areas. From a biodiversity perspective, some large patches of older forest interior area (500 acres +) are likely critical with ownership coordination important for their production.

Effects of Spatial Patterns on Plant and Animal Species

Approach Used

For this project component, a background paper was created to describe the effects of spatial patterns on plant and animal species. The paper summarizes literature on 49 species of birds, mammals, amphibians, insects, vascular plants and lichens. The goal was not to do a comprehensive literature review covering all available literature on the topic, but to develop a "primer" that illustrates concepts with examples, describes critical uncertainties, and develops a foundation and framework for further investigation. The following results are from Lane et al. (2003).

Results

- Spatial patterns are clearly important for numerous species.
- Some species prefer large patches, while others prefer smaller patches of different types in close proximity.
- Little is known about how most species respond to spatial patterns, though research is growing rapidly.
- The most important determinants of species' sensitivity to changes in spatial patterns are: abundance, reproductive rate, dispersal ability, interactions with other species, and habitat specificity, and whether species require interior forest or two or more sub-habitats in close proximity.
- In general, permanent habitat loss is a greater concern for species than spatial arrangement. It appears that spatial patterns are most important when habitat is reduced to < 20-30% of the original amount.

- Better tools and approaches are needed for categorizing species for analysis, and for modeling approaches that link species to forest models.
- Species may have positive, negative, or neutral responses to the types of changes in spatial patterns seen in the study area over the past century (reduced patch size, increased edge, reduced core area). Key species characteristics determining type of response are summarized in Table 1.

Table 1. Key species characteristics determining type of response to the types of changes in spatial patterns seen in the study area over the past century (e.g., reduced patch size, increased edge, reduced core area).

Positive or neutral response	***Negative response***
♦ Common, large population size ♦ High Reproductive rate ♦ Good Disperser ♦ Habitat generalist ♦ Good competitor	♦ Uncommon, small population size ♦ Low reproductive rate ♦ Poor disperser, resource dependent ♦ Habitat specialist – interior forest/area-sensitive, single habitat ♦ Poor competitor

SUMMARY: MANAGEMENT IMPLICATIONS OF PROJECT FINDINGS

The findings of the MFRC's Forest Spatial Analysis and Modeling Project show a substantial decline in forest patch size over the past 70 years. This finding is significant because, once a smaller patch structure is in place, it is difficult—and it takes time—to restore large patches.

Management implications include the following:

- Important wildlife, recreational, and timber values (cost savings from larger harvests, for example) depend on larger patches.
- Larger patches of both young and older forest are under-represented today compared to past conditions.
- If a larger patch structure is desired, using simple rules such as "harvest in large patches" or "reserve large patches" can result in unintended consequences, such as loss of older large patches when they are in shortest supply or, conversely, unnecessary reduction in timber harvest levels.
- Maintaining adequate representation of large patches over time requires careful, long-term planning and depends on models that help determine the most efficient ways to meet a variety of management objectives.
- Ecological subsections show differences in patch size and disturbance patterns. As a result:

    There are no "one-size-fits-all" solutions to spatial pattern management.

    It is important to tailor forest management plans to existing conditions. For example, utilize small patch management where the landscape is already finely divided, and utilize large patch management where large patches already exist or where there is the best potential for restoration.

FUTURE WORK AND COMPLEMENTARY PROJECTS

A number of spatial analysis research projects will continue in Minnesota. These projects will build on and complement the work completed for the MFRC project. These projects include:

- A two-year spatial modeling project that focuses on the Manitou Forest Landscape near Finland, Minnesota
- An exploration of opportunities for increasing forest productivity by utilizing spatial analysis
- Continued development and use of DPspace and LANDIS models to explore spatial management options in Minnesota landscapes
- More detailed analysis of historical line-note and aerial photo data

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REPORTS COMPLETED AS PART OF THIS PROJECT:

Historical and Current Spatial Patterns:

White, M.A., and G.E. Host. 2003. Changes in disturbance frequency, age and patch structure from pre-European settlement to the present in north central and northeastern Minnesota. St. Paul: Minnesota Forest Resources Council Report LT-1203a. 44 pp.

Host, G.E., and M.A. White. 2003a. Contemporary forest composition and spatial patterns of north central and northeastern Minnesota: An assessment using 1990s LANDSAT data. St. Paul: Minnesota Forest Resources Council Report LT-1203b. 56 pp.

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Future Scenario Modeling:

Mehta, S., L.E. Frelich, and M.T. Jones. 2003. Potential future landscape change on the Nashwauk Uplands in northeastern Minnesota: an examination of alternative management scenarios using LANDIS. St. Paul: Minnesota Forest Resources Council Report LT-1203d. 42 pp.

Hoganson, H.M., J. Bixby, and S. Bergman. 2003. Scheduling old forest interior space and timber production: Three large-scale test cases using the DPspace model to integrate economic and ecological objectives. St. Paul: Minnesota Forest Resources Council Report LT-1203e. 74 pp.

Species Background Paper:

Lane, C.P., C. Carr, and E. Perry. 2003. Background paper: relationships between forest spatial patterns and plant and animal species in northern Minnesota. St. Paul: Minnesota Forest Resources Council Report LT-1203f. 136 pp.

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APPENDIX 1. LIST OF PATCH TYPES USED IN AERIAL PHOTO ANALYSIS

Patch type description	Age/Structure groups[1]	Includes these types also delineated with aerial photography[2]
Upland conifer	Young, Pole, Mature	Jack Pine Red-White Pine Spruce-Fir
Upland hardwood	Young, Pole, Mature	Aspen Paper birch Northern Hardwood
Upland mixed	Young, Pole, Mature	Aspen-Birch-Spruce-Fir Upland mixed hardwood/conifer
Lowland conifer	Young, Pole, Mature	Lowland conifer
Lowland mixed	Young, Pole, Mature	Lowland hardwood Lowland mixed hardwood/conifer
Unknown Regen	Young	Unknown regeneration[3]
Upland grass/brush		Upland grass Upland brush
Lowland grass/brush		Lowland brush Lowland grass Sphagnum/emergent
Agriculture		Agriculture
Developed		High density developed Low density developed
Water		Water
Other		Bare ground (barren) Dead hardwood Dead conifer Not classified

[1]Approximate ages for young, pole, and mature classes are 1-20, 21-50, and >50 years respectively. Technical forest ecology terms for structure classes were used in the aerial photo interpretation protocol developed for this project. These were: Stand Initiation (young), Closed Canopy Stem Exclusion (Pole), Understory Re-initiation (early Mature), and Mature Multi-age (late mature). The two older classes were lumped into a single "mature" class for analysis, because the types were difficult to distinguish with aerial photographs and accuracy was greater when using the broader class in analysis.

[2] All of these types were delineated using aerial photography, but these classes were lumped into the more general types for comparisons across time periods. This lumping was done because it was much more difficult to distinguish the types listed in column 3 using the older photography, and the more general classes are more comparable across time periods.

[3] Areas that were recently disturbed, but the forest was too young to identify type with aerial photos.

APPENDIX 2. ANALYSIS AND DATA LIMITATIONS

Historical Analyses

- Disturbance frequency estimates derived from line note data and aerial photography are sensitive to the time window, or period over which disturbances were assumed to be detectable. However, upper and lower bounds of the time windows can be used to develop ranges for disturbance frequency estimates, and these ranges will be reported in a future publication based on White and Host (2003).
- The difference in plot size between aerial photo and line-note plots limits the size range over which disturbance patch size comparisons can be made, and is some cases the smaller size of the aerial photo plots may bias the patch size estimates downward. In particular, the fire patch size estimate for the 1930s time period should be viewed with caution. It is well known that during the 1900-1940 period there were large catastrophic fires that covered > 100,000 ha in the region (Haines and Sando 1969). However, DNR and Forest Service fire records from the 1990s suggest that the fire patch size estimates from the 1990s time periods were reasonable (MN DNR unpublished data).
- Disturbance frequency estimates from aerial photography are similar to, but generally lower than estimates derived from other sources. The land base used for calculations may be one source of variability. The aerial photo estimates include all forested land, including non-productive land and protected or un-managed lands.
- There are potential errors that result from comparing spatial characteristics interpreted from different scales and types of aerial photography (black and white vs. color infrared). We attempted to overcome this limitation by using relatively broad categories for classifying cover types and growth stage classes. The selection of the cover classes, in fact, was done specifically by the project technical team to balance the resolution needed for the study with what the team believed to be interpretable from older aerial photography. An independent inspection of the mapped types by team member Bill Befort of the MN Dept. of Natural Resources reported that the mapping was as good as could be expected from the data (B. Befort, personal communication).
- The size of the aerial photo plots is smaller than some landscape patches. While natural disturbances, particularly fire, occurred over extensive areas in the presettlement forest, the patterns produced by forest management are relatively fine-scale, typically not exceeding 60 acres. The 5760 ac size of individual analysis plots is therefore a reasonable size to quantify the fine-scale effects of forest management, development and other human activities on landscape pattern.

Modeling

- Both the Landis and DPspace models are data-intensive and difficult to learn how to use. However, both are in active stages of development, so user-friendliness will likely improve over time.

- In the LANDIS model, some important management considerations cannot be adequately simulated. Thinning simulations are risky because the removal of a cohort in an even-aged stand may result in the removal of every tree in the stand. There are no constraints on location of harvests that would be imposed by the road network in the real world.
- The current version of LANDIS does not allow planting, an important management strategy that could have spatial consequences. Also, LANDIS does not project timber volume to allow economic comparison among scenarios. Both of these issues are being addressed in a LANDIS revision.
- The DPspace model does not address explicitly objectives related to very large patches or specific distributions of patch sizes. Large patch objectives are addressed only by using larger buffer distances for interior space, larger interior space values, or pre-allocating some areas for large patch production by planning period.
- The the DPspace model is deterministic. It does not recognize natural disturbances. Clearly, losses from natural disturbances would have some impact on the forest-wide output levels if schedules were implemented exactly as modeled. It is erroneous to assume that the management schedules developed will be implemented precisely over the long term. It is assumed that the planning process is dynamic with schedules updated on a fairly regular basis to adjust to uncontrollable events, changing market conditions and changing values. It is assumed that schedules in the short term would need to be adjusted to integrate responses to natural disturbance events.