COMPARISON OF LANDSCAPE PLANNING MODELS

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Contents

Summary

Landscape planning models range from those that focus on land management to those that focus on ecological functions, and they can be relatively simplistic or relatively complex to construct and operate. We have chosen here to focus on forest landscape planning models and the components that are typical of today's contemporary models. We assume that landscape planning models have a time horizon and recognize a number of individual planning periods. We also assume that models involve the scheduling of activities across the landscape and perhaps assessments of the value of other resources such as wildlife habitat, aesthetics, and water quality. Natural disturbances could have been incorporated into the models we considered, as long as the focus of the model was

on the planning and assessment of land management activities. Finally, although forest harvest scheduling models are indeed landscape models, they generally focus on one landowner. Landscape planning models are conventionally assumed to encompass an entire landscape (all ownership groups), and to emulate the behavior of each group.

There are a number of common elements or components among forest landscape planning models, and these inform the development of new models. A direct comparison of landscape planning models is difficult due to continuous changes in politics, research agendas, and funding situations. We describe here the essential components of forest landscape planning models, and illustrate a number of ways in which they may differ. The conceptual comparisons of landscape planning model components should be of value to those considering landscape management efforts.

1. Introduction

Landscape planning involves modeling individual components of a larger system in a manner that recognizes that the components interact and function as a whole. Forest landscape planning simulates spatial-temporal characteristics of one or more processes at a large scale and over a long period of time (He 2008), and may emphasize land management or natural processes. Since the 1990s years a number of landscape planning models designed for natural resource management purposes have been developed, aided by advances in computer technology and scientific theory (He 2008). For example, Turner et al. (2002) describe a case in Australia where the goal of the landscape planning effort was to assess economic and ecological goals as reflected by potential timber production, biodiversity, aquatic habitat impacts, and revenues and costs of management. These assessments are made of the entire land base within a defined area, and include all of the different landowner groups. Areas of concern illustrated in Turner et al. (2002) could be evaluated at a smaller scale, and thus smaller components of a landscape may be well-suited to address several of these. However, other goals ultimately require taking a broader view of the landscape, thus hierarchical scales and modeling efforts are often used in forest landscape planning efforts.

Although not the focus of this work, one could extend the methods and models described here to the management of other ecosystems such as grasslands or shrublands. Grasslands, for example, would be composed of herbaceous plant species that may be either natural or managed, and would have a rate of growth determined by management practices, soil conditions, and other variables. If managed, grasslands may be applied in a range of management practices suitable for the objectives of the farmer. In either case, managed or natural, the contribution of grasslands to economic, ecological (species richness perhaps), and social goals would likely need to be evaluated in conjunction with agricultural land use options (Gibon 2005). Since land conservation efforts can be strongly constrained by economic realities, the trade-offs between the goals need to be adequately assessed, perhaps with an integrated landscape model (Schröder et al. 2008).

This work represents a summary of the typical components of forest landscape planning models, and describes how some of the more frequently referenced models address the model components. A point-by-point analysis of the differences between models is difficult to make given that the developmental stages of each are constantly changing, and a summary today may not be valid one year or more from now. For example, the works of Mowrer (1997), Barrett (2001), and He (2008) are extensive and provide significant depth in comparing models. Yet while the general concepts presented are of value, at some point the comparisons become a historical record, and very few of the direct comparisons of models will continue to be of significance. Further, some landscape planning models operate differently at various levels of planning, making direct comparisons difficult. Therefore, we take a different approach and describe the components that ideally would be contained within a forest landscape planning model, and how these components would ideally work. We then relate these ideal components and their function to contemporary models. As a result, we concentrate on landscape planning models that have the following characteristics:

- They recognize land units and the characteristics of vegetation found inside
- They recognize land ownership boundaries
- They facilitate modeling the management behavior of landowners
- They model common practices at a reasonably small scale as to provide sufficient detail for assessments of the quality and value forests and other resources
- They account for economic, ecological, and social outcomes of management activities

Along these lines, some of the more recent landscape planning models developed, such as PANDORA (Gobattoni et al. 2011), are not explored in much detail here since they lack one or more these characteristics. Other more seasoned models (those that have been used widely for a decade or more), such as the economic model IMPLAN are also not explored, because a spatial representation of the landscape is either too aggregated (perhaps at the county level) or lacking completely.

Conventionally, there are three levels of forest planning: strategic, tactical, and operational. Strategic planning examines long periods of time and uses broad descriptions of the landscape and management actions. Assessments of resource sustainability are generally best performed at this level. Tactical planning examines the spatial relationships between proposed activities and resource outcomes, and assesses management efficiency and impacts over shorter periods of time (5 to 20 years, for example). Operational planning involves the very specific measures necessary to meet weekly, monthly, and annual goals. The level of detail required to perform each type of planning process increases as one moves from the strategic to tactical levels, and then to operational planning. However, in many cases these three are not necessarily distinct phases of planning any longer. In the past, limitations related to computer technology caused distinctly different models to be developed to address the different types of questions posed. However, with contemporary computer technology, the distinction, for example, between strategic and tactical planning has become vague. In essence, modern methods can be developed to examine sustainability of a large area over a long period of time while also recognizing the level of spatial detail (and associated processes used to schedule specific activities) that was once typical of a tactical planning model. A number of contemporary forest landscape planning models therefore include aspects of strategic and tactical planning processes.

Planning for the management of landscapes also usually involves acknowledging and recognizing conflicting objectives of a variety of land management entities, and this often presents challenges to planning teams as they seek solutions meant to guarantee the long-term vitality of ecosystems (Turner et al. 2002). Landscape planning efforts that recognize and evaluate realistic economic, ecological, and social objectives can have a significant role in decision-making processes (Jørgensen 2000). Advances in landscape planning models naturally follow advances in computer hardware systems, software, geographic information systems, and optimization and simulation methodology. In fact, the incorporation of spatially-related goals into planning efforts has only been actively pursued since the 1990s (Bettinger and Chung 2004, Shan et al. 2009). While vegetative natural resources (i.e., forests) can address the provisional, regulatory, and cultural ecosystem values desired by humans today, other societal concerns of land management are also commonly addressed. These concerns center on issues such as the cumulative effects of human activities, the maximum size management actions, and habitat fragmentation (Bettinger and Sessions 2003). Since the 1990s, this has resulted in a new planning environment that is focusing on broad landscapes, rather than individual properties or individual land management area. Increasingly, we are finding that landscape management planning focuses on the development and maintenance of resource goals other than those specifically related to commodity production. For example, regional and national entities in Europe have begun to examine public policies in the urban-rural interface, and these involve examinations of patterns and trends in the spatial development of the landscape (Dühr et al. 2010). One of the most problematic aspects of landscape planning, however, is that there may be more than one landowner within the landscape; another involves emulating or predicting their land management behavior. In areas where most of the land is controlled by a single entity (e.g., the state or federal government), the development and implementation of plans across a broad landscape may be easier to both develop and accept. However, in areas where there is a heterogeneous mixture of land ownership (Figure 1), landscape plans may be both difficult to develop and to accept, and only serve to describe the effects of potential policy scenarios.

Embarking on landscape planning can represent a significant technological challenge for an organization or agency. In order to be successful, four areas of concern need to be addressed sufficiently. These include (1) employing a sufficient staff with the appropriate skills, (2) having access to databases that can accommodate the types of analyses that are desired, and (3) having access to the appropriate technology for managing data, developing scenarios, and creating output products of value to the decision-makers and stakeholders. Perhaps the most important area of concern is the fourth, which involves obtaining the commitment of one or more organizations to support the project (with funds and other positive endeavors) for the period of time necessary to completely meet the expectations of the planning process. If any of these four areas of concern are absent or provided at a level less than desirable, the effort will likely fail (Bettinger 1999). It is not uncommon for developers to experience challenges unlike other previous efforts, and it is not uncommon for planning team members to continuously offer new ideas. Further, landscape planning not only involves developing scenarios for landscapes, but also involves a complex system of data development, management, and analysis. When deadlines are identified for the production or reports or other outputs, a system such as this is usually stressed, the competence and professionalism of groups of people are tested, and compromises are made. Understanding how planning systems may operate when deadlines loom will lead to a more effective work environment (Bettinger and Boston 2001) and increase the probability of attaining the goals of the landscape planning effort.

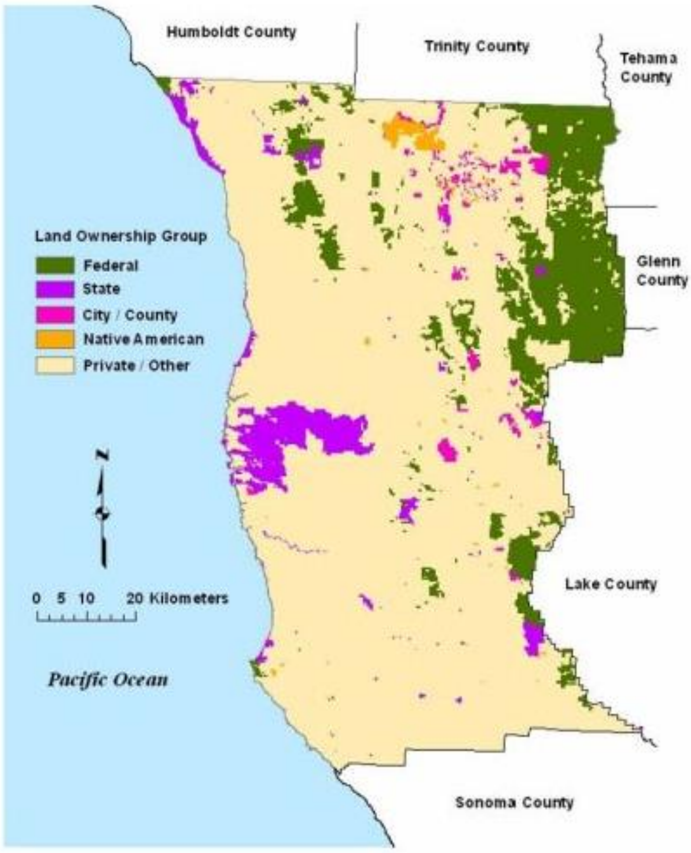

Figure 1. Mixed-ownership character of a landscape (Mendocino County) in California.

2. Common Components of Forest Landscape Planning Models

Landscape planning, for the purpose of this work, involves developing alternative scenarios for an entire, complete landscape. This includes all of the forest holdings or ownership groups contained therein. It involves the assessment and valuation of management activities over time for every action conceivable (within reason, to make the modeling effort tractable) in this defined area. Although the modeling approaches are similar, landscape planning differs from forest harvest scheduling in that the latter usually only involves a single land owning entity, and usually focuses mainly on commodity production goals. Of course, it is possible that large expanses of land, such as Forest Enterprise Offices in Turkey, are all owned and managed by a single entity (the state, in this case). However, in areas of the world where land tenure programs allow private ownership of land, multi-owner analyses of alternative futures within a defined landscape are fairly rare. In regions like the southern United States, it is not uncommon to find that there are hundred or thousands of individual landowners within a *landscape*, or that a single large landowner owns parcels that are scattered and interspersed with many other landowners. In these cases, planning usually is performed separately for each landowner, and a coordinated effort for a landscape is generally lacking. In fact, activities may be planned without regard to the status or condition of resources outside of an ownership boundary. Therefore, there are distinct challenges to landscape planning in some areas of the world that are much more complex than simply developing a harvest schedule for a specific landowner.

Landscape planning models vary from one form to another based on a wide variety of driving influences (funding, expertise, management problems). However, the ideal model should include a number of basic components (Figure 2). For example, inputs into a landscape planning model should include a description of the landscape, as expressed through forest (or other resource) inventories and geographic information system (GIS) databases. The latter of these is often called the *spatial data*, while the former is often *non-spatial* in nature. The planning group would also need to decide upon the set of management intentions that it proposes to model. These will not only affect how the inventories are projected into the future, but also how the landscape planning model itself will operate in emulating landowner behavior. Prices and costs of forest management actions, products, and resources are necessary requirements if economic analyses are to be performed on the alternative plans that are developed. Guidance from policies is critical if one were to simulate the current management environment of a landscape. This guidance can arise from federal, state, local, or organizational policies. The extent that these are recognized will likely represent the result of trade-offs considered in the ability of the planning model to recognize and accommodate each policy. Land use patterns and projections of land use changes can be difficult to develop. However, if one were projecting landscape changes many decades into the future, and these projections involved land areas containing significant urban and sub-urban growth, land use change projections may also be necessary.

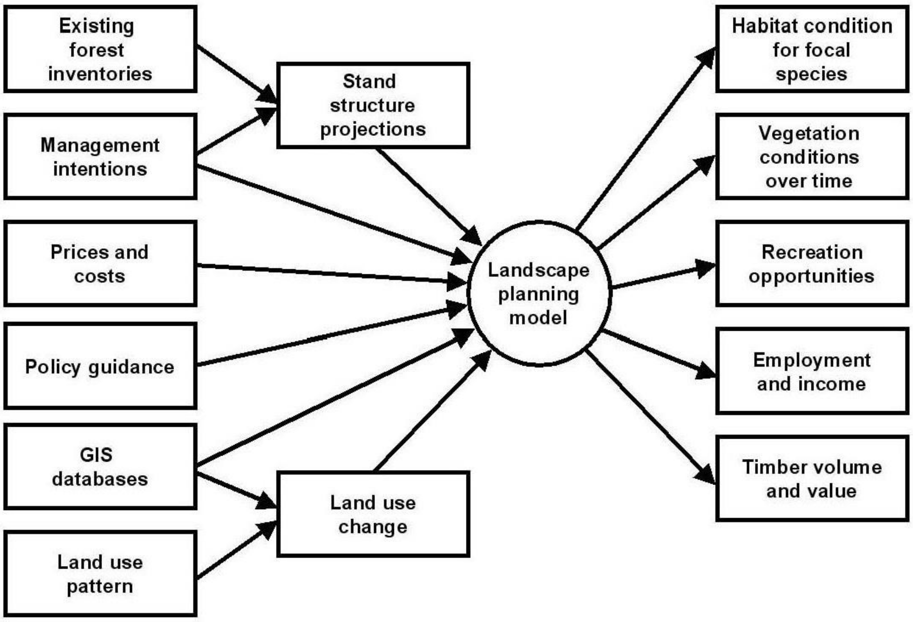

Figure 2. One representation of data and knowledge flow through a landscape planning process.

Outputs from landscape planning models also vary from one form to another based on the variety of driving influences in model development. In some cases, these are directly developed by the landscape planning model itself, through graphs, tables, or geographic representations of activities and resource quality through time. In other cases these are accommodated by the landscape planning model through data developed from model projections, and passed electronically to another model for *a posteriori* analysis. Timber volume and value projected from harvest schedules are basic outcomes of forestry-related landscape planning models. Changes in vegetation, habitat condition, recreational opportunities, and employment and income are others that are representative of environmental and social concerns.

The typical components of contemporary landscape planning models are described in more detail in Section 3 of this report. The remainder of Section 2 addresses the common inputs into a landscape planning model. Section 4 addresses in more detail some of the outcomes from a landscape planning model.

2.1. Forest Inventory

Current and future descriptions of vegetative resources across a landscape are usually described as (or by) inventories of the resources. In a more complete sense, an inventory would list on a per-unit area basis the number of trees (or more widely, plants) of a given size (diameter, height) and species, and perhaps would note whether they are alive or dead. This type of information is expensive to measure across large landscapes, and may be estimated or imputed using techniques such as nearest-neighbor classification processes. The attributes chosen to represent the current and future vegetation need to be obtained from both the current inventory data and from the growth and yield process used to project vegetative condition into the future. The attributes chosen must also be able to accommodate other resource assessment models that either are embedded within the landscape planning model, or are used on an *a posteriori* basis to assess, like habitat conditions (Chew et al. 2004). For example, in order to estimate the value of different forest products produced, an inventory must contain sufficient information (tree heights, diameters, species, etc.) to arrive at estimates of volume. Further, if habitat suitability for a woodpecker (for example) is to be assessed, it is likely that the number of snags (dead trees) present during each period of the time horizon is needed. This requires knowing how many snags were present initially (in the current landscape), how these will decay and eventually fall, and how many will be produced over time through natural tree mortality processes.

The current and future vegetation could be described as simply as the major species group and the density (basal area or trees per unit area). This level of representation of forest inventory is perhaps too coarse to accommodate a reasonable projection of potential timber harvests volumes, and perhaps too course to accommodate further analyses of habitat condition (for example). On the other end of the spectrum, the LAMPS model (Bettinger and Lennette 2004) requires detailed tree record information to emulate the growth and development of forests when forest policies required leaving a certain number of trees within final harvest areas. Further, subsequent wildlife and aquatic habitat models required detailed information on the type and quantity of dead and down wood, which was partially obtained from the mortality predictions of growth and yield models (see Section 3.1). This amount of data for landscapes over 400,000 ha in size created a significant computational load on the modeling system. LANDIS, on the other hand, uses 10-year age classes (cohorts) of tree species to represent forest structure. This is an aggregate of sorts of tree-level or tree record inventory data, which does reduce the computational load on the modeling system (He et al. 2005).

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Biographical Sketches

Pete Bettinger received his PhD in forestry in 1996 from Oregon State University in Corvallis, Oregon (U.S.A.). In 1996 he moved to the State of Washington to work for two years as research forester and geographic information systems manager for Champion Pacific Timberlands. In 1998 he was appointed Assistant Professor - Senior Research at Oregon State University in Corvallis, Oregon. In 2002 he was appointed Associate Professor of forest landscape planning and harvest scheduling at the University of Georgia. He was promoted to professor in 2009. He is a member of several professional societies that include the Society of American Foresters and the Japan Society of Forest Planning. His main research interests are focused on the study of new methods for harvest scheduling and landscape planning, advances in forest management and economics, geographic information systems, and global navigation satellite systems. He has published a number of scientific articles in these research areas, along with five books. His teaching duties include Field Orientation and Measurements, Forest Planning, and Aerial Photogrammetry. He recently served as Chair of the 8th Southern Forestry and Natural Resource Management GIS Conference.

Krista L. Merry received her MS in Geography in 2003 from the University of Georgia, Athens Georgia (U.S.A.). Between 2003 and 2005 she worked for the University of Georgia as a Project Coordinator in the Department of Environmental Health Sciences on wood smoke monitoring projects. In 2005, she began working for the Warnell School of Forestry and Natural Resources at the University of Georgia as a Research Coordinator providing spatial analytical support for projects as diverse as forest fragmentation visualization, hurricane risk assessments, and urban carbon estimation. Her main research interests are in GIS, spatial analysis, cartography, and remote sensing. She has published a number of scientific articles in these areas, along with one book. She has served as editor of the proceedings of the 7th and 8th Southern Forestry and Natural Resource Management GIS Conferences.

Kevin Boston received his PhD in forestry engineering in 1996 from Oregon State University in Corvallis, Oregon (U.S.A.). Upon completion, he moved to New Zealand and accepted a position with the New Zealand School of Forestry at the University of Canterbury. In 1998, He accepted a position with the Center Forest Business as the University of Georgia where he developed spatial harvesting scheduling system to meet the Sustainable Forestry Initiative green-up constraints. In 2000, he returned to New Zealand and held several positions with Carter Holt Harvey, Inc., He returned to Oregon State University in 2002 and was appointed as Assistant Professor in Forest Engineering. He was promoted to Associate Professor in 2010. He is a member of several professional societies that include the Society of American Foresters and the California License Foresters Association. He holds licenses as a Registered Professional Forester and as a Professional Forest Engineer. He has been an associate editor of the Western Journal of Applied Forestry since 2008. In 2009, he began studying environmental law at the Northwest School of Law at Lewis and Clark College. He has published numerous scientific articles and has coauthored three books. His research area is spatial harvest scheduling, forest policy and law, and forest transportation.