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Ecological Modeling for Informing Forest Restoration and Management

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Forest restoration planning, evaluation, management and implementation are major and urgent challenges for forest health and sustainable development in the United States and many other regions of the world [1]. Forest managers, stakeholders and private landowners need to use all possible means to assist in this important undertaking. The use of ecological models to assess restoration strategies and their possible outcomes provides forest professionals, with a temporal and spatial forecasting tool to assess change in forests affected by a variety of environmental threats, including insects, pathogens, wildfire, hurricanes and invasive species.

Ecological Modeling for Restoration and Management -How?

A major challenge for forest restoration is that its effects are difficult to measure at the time of implementation. Thus, restoration represents a long-term investment with potentially high risk and uncertainty. Ecological modeling helps to reduce these variables by providing projections of long-term and broad-scale forest change, and by allowing experimentation and comparisons between restoration scenarios. This approach can lead directly to a determination of the best strategies for restoring forests that may be significantly impacted by multiple threat interactions [2].

Ecological modeling has been used successfully to explore the reciprocal interactions between forest structure and various natural disturbance agents, including wildfires and forest pests, as well as the effects of a variety of anthropogenic disturbances, such as harvesting, thinning and planting to a geographical area. Ecological models simulate change through time using spatially referenced data across a broad spatial scale (10^2 to 10^3 km^2). These models integrate natural disturbance agents and restoration strategies into an ecological model capable of simulating vegetation dynamics through space and time [2]. Using auxiliary models, forest patterns and restoration strategies-described as scenarios-can be evaluated according to various criteria (e.g. economic, ecological, and social).

An Example from Southern Appalachian Pine Forests

The southern pine beetle (SPB), *Dendroctonus frontalis,* Zimmermann is the most destructive native insect affecting southern US forests. In the years of 2000-2003, SPB caused catastrophic damage in the southern Appalachian Mountains. Restoring these affected yellow pine forests is an important and challenging task for forest owners and managers. The ecological modeling can be used to evaluate and plan management strategies for forests damaged by SPB in the southern Appalachians. The specific goal of this work was to develop a procedure to facilitate restoration planning and evaluation for SPB-damaged pine forests in the southern Appalachians [3].

The LANDIS (Landscape Disturbance and Succession) model was used because it provides a framework for determining the effects of disturbances, such as fire, insect outbreaks, harvesting and planting on changes in forest structure [4]. Existing forest stand conditions and land types are the starting point for the ecological simulations. Site specific Forest Management Plans based on Forest Service Practices are then used to determine the desired future forest conditions and the specific restoration goals.

The model outputs suggest that a combination of fire and SPB disturbance creates sustainable yellow pine forests. This regime of multiple interacting disturbances has important implications for succession in yellow pine forests of the southern Appalachians. Moreover, it identifies Table Mountain pine (*Pinuspungens* Lamb.), as a potential species of importance for restoration efforts on low- to mid-elevation ridges and southeast-west facing open slopes in the southern Appalachians. In addition, the model projections imply that reintroducing fire would help maintain open woodland conditions on xeric sites similar to those historically found in this area.

Broader Applications and Research Needs

Many forest restoration and management problems are within the spatial and temporal scales of the ecological modeling approach. As a result, ecological modeling is best described as a multi-tiered approach where models integrate detailed knowledge of vegetation dynamics and provide a quantitative output amenable to the evaluation of restoration goals. In the context of forest restoration, such an approach is important because while vegetation dynamics may operate over relatively long time scales, the costs of restoration practices are high and the demand for effective research is often immediate.

Through the use of ecological models, these functions can be performed efficiently and procedurally. Ecological models can be effectively parameterized to address many forest restoration problems. In doing so, researchers and forest managers gain the benefit of using a model that has been well studied, has a significant user base and produces comparable quantitative outputs. This is, especially true in the United States, where publicly available data allows models to simulate real landscape, and where there is considerable data detailing the life-history of relevant species.

More research on investigating the utility of ecological models as decision-making tools for pre-damage impact analysis and post-damage restoration of forest landscapes is needed. Forest management decisions could be especially aided by a focus on testing the capability of ecological models to evaluate changes in composition and structure of forests undergoing multiple interacting environmental threats, including global climate change. Finally, developing methods that make the parameterization of models and their interpretation more efficient, accurate and available is of paramount importance.

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