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Sustainable Resource Development and the Unification of the Studies of Forest Fire, Climate Change, and Forest Landscape Dynamics

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The ultimate goal of contemporary forest land management is to achieve sustainable resource development and to maintain biodiversity for the benefit of present and future generations. In Canada, forest land management has received substantial attention with emphasis on land use and harvest planning, as well as fire and insect pest management.

Fire management is among most important components in forest land management because of the significant role of fire in shaping Canada's forest landscapes, especially for the boreal region. Numerous studies have revealed that many tree species in the boreal forest have adapted to environments with frequent fires, and that fire reacted differently in different types of forests. Therefore, a reasonable inference is that fire regimes are the results of interactions among vegetation, fire events, and environmental conditions such as weather. If this inference were true, then fire management would play a role in altering the course of a fire regime under natural conditions. Consequently, the understanding of how ecosystem components interact with each other to produce observed fire regimes and forest dynamics is crucial in the design of future fire management practices. This understanding, unfortunately, has not been fully developed and hence provides a puzzling task for both forest researchers and managers.

Forest landscapes are complex ecosystems. The challenge is to understand their spatial and temporal dynamics under the conditions of natural, human intervention, and climate change scenarios. The landscape dynamics are determined by the complex interactions among ecosystem components, and the prediction of the ecosystem behavior as a whole in response to the changes in one ecosystem component might not be as simple and straightforward as we thought previously. The spatial issue of how results from studies that are carried out at a smaller scale (such as a forest stand) can be used to interpret data and provide predictions at a larger scale (such as a forest landscape) continues to be of concern. Consequently, many theoretical and methodological issues need to be addressed in the study of forest landscape dynamics.

Emulation of natural disturbance (primarily fire) patterns in harvest planning has become an important issue and attracted enormous attention in many North American and European countries. Its premise is that "Mother Nature knows best". For millions of years, natural forest landscapes have maintained their functions and structures regardless of the disturbance types and their frequencies. It is hoped that emulating natural disturbance patterns could serve as an alternative or better way of overseeing timber harvest planning. The forest industry's commitment to incorporating ecological theories and principles into forestry practices has lead to a greater interest in natural fire patterns. It is necessary to understand how natural fire patterns are formed in order to predict the dynamics of forest landscapes under different fire management options.

The issues related to possible climate change effects on the dynamics of both forests and fire have also attracted many researchers worldwide. In Canada, the strategic policies developed from the results of research programs are aimed to help limit, adapt, and mitigate the effects of climate change. The scale issue has received much more attention in these studies than in other research fields because the climate change effects are usually considered at larger spatial scales and longer temporal scales. In addition to the scale issue, there are other factors that need to be taken into account such as vegetation species adaptation and compensation to climate change, and these are recognized knowledge gaps.

In the past, forest and fire dynamics have been extensively studied through the empirical approach. The understanding of forest growth and fire processes has been well documented; however, in many cases they were presented separately. The ecological modeling approach may serve as a useful means to neutralize this gap, in considering the difficulties in balancing the time and expense associated with data collection against the time-sensitive demands of forest and fire management decision making. The ecological modeling approach may help forest and fire managers to address "what-if" types of questions under different management and disturbance scenarios, through the assessment and organization of existing knowledge and information based on ecological concepts and framework.

Scientists in the Canadian Forest Service have been working on comprehensive research to unify the studies of forest fire, climate change, and forest landscape dynamics in order to achieve the goal of sustainable resource development. This investigation is carried out through the development of a computer simulation framework with the integration and synthesis of research results from Canadian forest fire studies, forest growth and forest regrowth at the stand scale. The premises of this study are that ecosystem components are interrelated with each other, and that over-simplified assumptions should be avoided to prevent possible biased estimations and predictions of the landscape-scale dynamics of forest and fire. The focus of this simulation framework is the interactions among the ecosystem components for the purpose of providing landscape-scale predictions from a mechanistic perspective.

The landscape disturbance modeling approach employed in this investigation implements the synthesis and integration of existing knowledge and information from different research fields, as well as available data sets pertaining to landscape structure and environmental conditions. The predictions from landscape disturbance models represent the logical consequences of available knowledge obtained from the stand-scale studies. The landscape disturbance models can also serve as analytical tools to evaluate the impacts of different forest and fire management options under current and future environmental conditions. The spatially explicit model for landscape dynamics (SEM-LAND) is one such landscape disturbance model designed to capture the major characteristics in forest landscape dynamics.

The SEM-LAND model was developed, calibrated, and validated by using the data from a study area in west-central Alberta. The SEM-LAND model was designed to simulate the future forest conditions starting from current forest conditions. The current forest conditions here indicate the geographic information system (GIS) data of land cover type, digital elevation model (DEM), forest age, and the quality of physical conditions. The future forest conditions include the dynamics of both forest and fire under various conditions. This model input and output structure appeared suitable to estimate natural and current fire regimes and the associated dynamics of the forest, hence wood supply.

In a case study, the SEM-LAND model has been used, in combination with a Canadian global change model, to investigate the dynamics of both forest and fire on a study area in west-central Alberta in which the carbon-dioxide level were doubled in the climate change scenario. The simulation results suggested that under such a climate change scenario, while the fire frequency and landscape fragmentation could increase, the wood supply, landscape diversity, and wildlife core habitat could decrease. This information is useful to forest land managers in the planning of land use, harvest scheduling, and fire management. Thus, the SEM-LAND approach is useful in predicting forest landscape dynamics under various management conditions and disturbance scenarios.