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MULTI-SCALAR SPATIAL MODELING OF NORTHERN FOREST DYNAMICS: FOUNDATIONS, THEORIES, AND APPLICATIONS

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MULTI-SCALAR SPATIAL MODELING OF NORTHERN FOREST DYNAMICS: FOUNDATIONS, THEORIES, AND APPLICATIONS

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Ecology

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ABSTRACT

Multi-Scalar Spatial Modeling of Northern Forest Dynamics:

Foundations, Theories, and Applications

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This dissertation describes the development and analysis of a new forest dynamics model. The *NORTH*ern *W*oodland *D*ynamics *S*imulator (*NORTHWDS*) was designed to spatially model forest pattern and process for the northern Lake States, and to incorporate multiple spatial scales. While ecologically detailed, this stand table-based model is sufficiently parsimonious to be able to simulate 100s to 1000s of hectares for centuries. Processes like tree regeneration, growth, and mortality, herbaceous and shrubby competition, biogeochemistry, carbon cycling, edge effects, and climatic influences are incorporated in *NORTHWDS*. Wind disturbance and white-tailed deer browsing were also included to help forecast stand and landscape dynamics under managed and unmanaged scenarios. Preliminary results suggest that *NORTHWDS* can reliably predict long-term forest ecosystem responses to succession and disturbance. *NORTHWDS* was also applied to test the effectiveness of a managing-for-old-growth strategy, with results indicating that this type of

management can provide improvements over traditional even- and uneven-aged harvest systems in desirable old-growth attributes like aboveground live biomass and coarse woody debris patterns. The results of the *NORTHWDS* developmental and application chapters were then synthesized to produce a new conceptual approach to landscape simulation that incorporated space, multiple scales, and a hierarchical design. A user's guide, the source code, and model defaults complete this dissertation.

(532 pages)

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Abstract

Advances in computer technology and more sophisticated ecological theory should permit the creation of better forest dynamics models. This chapter describes the motivations behind the development of the *NORTH*ern *W*oodland *D*ynamics *S*imulator (*NORTHWDS*), a new, multi-scalar model of forest dynamics. The features, advantages, and disadvantages of some existing forest models are described, including their relevance to the northern Lake States. Three new features for ecological simulation are proposed: homogeneity in detail, logical consistency in and across scales, and the interaction between relevant factors. Examples of how some popular models fail to address these features are provided, and the chapter finishes with a brief summary of the contents of the remaining sections.

Introduction

What is seen is transitory; what is unseen lasts forever.
2 Corinthians 5:18

Anything that explains everything explains nothing.
Allen and Hoekstra (1992, p. 285)

The need for good information has increased dramatically with the advance of technology, but there are limits to what can be achieved through observation alone. This is especially true in natural resources where the understanding of pattern and process at large spatiotemporal scales leads to questions not easily addressed. For example, how does one duplicate the dynamics occurring over a landscape covering thousands or millions of hectares

for scores of species decades to centuries into the future? The lack of resources and shortness of human lifespan prevent answering these questions through traditional field work, but these are exactly the issues presented by burgeoning resource demands. While far from perfect, computer modeling offers considerable promise in building and testing hypotheses on large-scale resource management as long as issues of efficiency, realism, and prediction accuracy are addressed. In other words, utility must be balanced with reality lest science fails to convince a skeptical public of the value of simulation.

Forest modeling began in the 1960s with the advent of "practical" computer processing. Early models (e.g., Botkin et al. 1972) were able to reproduce some pattern and process, but sacrificed considerable ecological realism as a consequence of compromises made for computational efficiency. In the intervening decades, both computers and scientists have become increasingly sophisticated, enough so that the pendulum may have swung to the other side and confidence in current technology may produce models too concerned with environmental minutia.

This dissertation represents an attempt to develop a forest dynamics model that balances technology with reasonable ecological detail. Initially developed for the Ottawa National Forest in the Upper Peninsula of Michigan, the *NORTH*ern *W*oodland *D*ynamics *S*imulator (*NORTHWDS*) incorporates the most significant forest dynamics found in this part of the world, including the impact of many factors (e.g., biogeochemistry, disturbance, herbivory, etc.) on pattern and process across several scales. After reviewing relevant literature and describing *NORTHWDS* assumptions, chapters on various applications of

```
SUBROUTINE WRITE_TREELST1
!
!*********************************************************************
! THIS SUBROUTINE WRITES A STAND TABLE TO THE TREE LIST OUTPUT FILE
!*********************************************************************
!
USE PARAMETERS
USE SPECIES
USE STDELEM
!
IF (ASCII_ON == 0) THEN
   TREELST1_ON = 0
ENDIF
!
IF (TREELST1_ON == 1) THEN
   IF ((Q == 1) .AND. (II == 0)) THEN
      OPEN (22, FILE = TL_FILE, STATUS = 'UNKNOWN', ERR = 1)
         GOTO 2
         1 PRINT *, '  ERROR OPENING TREE LIST OUTPUT FILE-  PROGRAM &
         &ABORTS!!'
         STOP
      2 CONTINUE
      WRITE (22, 3) 'OGI', 'REP', 'CYC', 'X', 'Y', 'SPP', 'SC', 'COUNT'
      3 FORMAT (A3, 1X, A3, 1X, A3, 3(1X, A3), 1X, A2, 1X, A5)
   ENDIF
   DO 11 I = 1, XMAX
      DO 12 J = 1, YMAX
         DO 13 K = 1, MAX_SPP
            DO 14 L = 1, MAX_CLS
               IF (CAT(I, J, L, K) > 0) THEN
                  WRITE (22, 15) HARV_CODE(I, J), Q, II, I, J, SPPCODE(K), &
                  & L, CAT(I, J, L, K)
                  15 FORMAT (I3, 1X, I3, 1X, I3, 3(1X, I3), 1X, I2, 1X, I5)
               ENDIF
            14 CONTINUE
         13 CONTINUE
      12 CONTINUE
   11 CONTINUE
ENDIF
!
END SUBROUTINE WRITE_TREELST1
```

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Senator, Graduate Student Senate, USU Forest Resources Department 1995 - 1997

Voting member, Dean Search Committee, USU College of Natural Resources 1996 - 1998

Member, Xi Sigma Pi forestry honors fraternity:
- Forester, USU chapter 1996 - 1998
- Fiscal Agent, MTU chapter 1991 - 1992
- Coordinator of forestry tutoring, MTU chapter 1991 - 1992
- Co-chairperson, spring symposium on wetlands, MTU chapter (April 2, 1992)

Member, Phi Sigma biology honors fraternity

Member, Society of American Foresters, national and local chapters
Member, Ecological Society of America
Member, Natural Areas Association

Judge, Utah Envirothon for high school students (April 30, 1999)

Vice President for Research Fellowship, (USU, 1994 - 1995)
Dean's Award for Outstanding Senior in Forestry (MTU, 1992)