Sustainability and Long-term Dynamics of Forests: Methods and Metrics for Detection of Convergence and Stationarity

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Presentation Structure

I. Some Related Ideas in 3 Presentations
II. Presentation Introduction
III. Convergence and Stationarity
IV. Metrics / Parameters
V. Summary
Motivation

Repercussions of the Gilleleje meeting

- Dynamics of full-scale forests
- The Volvo Theorem
- Discussion of inheritance taxes

I. Related Ideas in 3 Presentations

- Goal: To examine the impacts of alternative harvesting strategies on temporal and spatial dynamics of forests
  - Faustmann Harvest Rule
  - New Rules: Dynamic, Stochastic and Spatial
  - Impacts of constraints and disturbances
Why do we care?

- Gaps in the forest economics literature
  - Age class dynamics are under examined—(Optimal rotation is relatively over examined)
  - Landowner Models
- Age class dynamics determine future forest states—which determine future supply
- Historical fears of timber famine

Basic Questions

- What are the impacts of various decision rules?
- What are the long run impacts on age class distribution?
- What are the impacts of the initial age class distribution?
- What is sustainability in this context?
- What are the impacts of requiring sustainability?
- What is the role of flexibility?
- How do we measure convergence? cycles? orbits?
- What is the impact of natural regeneration?
II. Presentation Introduction

Does the age class distribution converge to a normal forest?

Does the optimal rotation age converge to the Faustmann harvest age?

Relevant Literature

- Kemp and Moore 1979
- Mitra, Roy and Roy 1991
- Mitra and Wan 1985, 1986
- Salo and Tahvonen 2001, 2002a, 2002b
- Wan 1982, 1985
- Wan 1994
Relevant Literature

- Highly mathematical approaches
- Simple situations
- Theoretical results with limited scope
- Convergence to a Faustmann Normal Forest or to cycles

Comparison with Previous Literature

- Less mathematical
- More numerical
- More complex situations (but still simple)
- More general characterization of convergence
  - time to convergence
  - level
  - amplitude
  - periodicity
  - type of patterns (cyclical or non-cyclical)
General Approach

- Forward DP procedure
- Numerical simulation
- Convergence detection
- Convergence metrics

Numerical Simulation Approach

- Forward DP Procedure
- Convergence Detection
- Convergence Metrics
III. Convergence and Stability

- Why convergence?
  - Characterize a path
  - Compare paths

- Why are convergent metrics important?
  - Need to characterize convergence
  - Impact answers

Characterization of Convergence

- Convergent
- Cyclic
- Unresolved
  - Chaos
  - Insufficient Monitoring
Characterization of Convergence

- As we only monitor the development of the system for $T$ years a cycle with period $p$ is in practice observed if
  \[ \forall k \in [1 \ldots \text{int}(T/t_c)/p], \]
  \[ \forall \tau \in [0 \ldots p-1]: |X_i(t_c + \tau + k p) - X_i(t_c + \tau)| < \varepsilon \]

- If the observed period is $p=1$, we will describe the trajectory of the system as convergent.

Cyclic Series

![Graphs showing cyclic series](image)
IV. Metrics / Parameters

- Parameter of Convergence
- Computational Algorithms
- Pattern Recognition Programs
- Structural Decisions
  - Tolerance
  - Area (unit)
  - Size of Forest

Possible Convergence Parameters

- Present value of the forest
- Rotations/Period
- Distribution of forest age classes
- Amplitude within a cycle
- Standard Deviation within a cycle
- Mean deviation from a normal forest
- Sustainability
Normal Forest and Stochastic Metrics

- Mean deviation from a normal forest
  \[ M = \int_{0}^{T} \left| a(t) - \frac{L}{T^*} \right| \, da + \int_{T^*}^{N} a(t) \, da \]

- Metrics for application with stochastic models
  - Within some tolerance almost everywhere.
  - F Tests
V. Summary

- Decision rules and long-term dynamics
- Simulation / DP approach
- Convergence / Stationarity
- Metrics
- Detection algorithms

- We will be back