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The emergence of forest age structures as determined by uneven-aged stands and age class forests

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ABSTRACT

This article explores the question under which conditions trees are managed in even- or uneven-aged stands or age class forests, respectively. The problem of uneven-aged management within stands and forests can be reduced to the analysis of simultaneous optimal times of harvest and regeneration of interdependently growing trees. Restricting attention to a market environment, a forest investment model is developed which accounts for the opportunity to manage trees or stands individually. As a consequence, age class forests evolve as the optimal compromise between two opposing effects. They allow for a combination of the advantages of uneven-aged management by utilizing differences in tree growth on a larger scale and of even-aged management by exploiting locally effective positive inter-tree dependencies on a smaller scale. Accordingly, the emergence of the forest structure is determined by the dynamics in the balance of value growth and impact rate differences.

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Introduction

Neighboring trees in stands as well as adjacent stands in forests can be observed to be of similar or of different ages. The existence or absence of regularities in the ages of interdependent trees in forests raises the question under which conditions trees in forests are managed in even- and uneven-aged stands or age class forests, respectively. Since these concepts share the differences or similarities in the ages of the constituting trees on different spatial levels, they must be fundamentally related to each other. In order to study the emergence of age structures in forests, it is necessary to focus on the factors inducing tree age differentials.

While ecological theories of these phenomena are available, for instance in terms of large-area disturbances (e.g. Oliver and Larson, 1996), social scientific theories for explanations in managed forests are scarce despite their relevance for understanding the emergence of forests in social systems. Although various analyses concerning the isolated management of forest stands have been proposed (cf. Amacher et al., 2009 for a recent review), theories connecting the harvest and regeneration of trees to accumulated stands and forests are rare or somehow unsatisfactory. Considering the management of forests and the worldwide conflicts arising thereof, the lack of theories in this field is surprising. Nevertheless, for the explanation of these conflicts, and for the design of solutions to them, it is necessary to understand and predict the patterns of forests evolving out of the interaction processes between people in a given environment.

Essentially, the Faustmann model (cf. e.g. Samuelson, 1976; Johansson and Löfgren, 1985; Amacher et al., 2009), based on the formula according to Faustmann (1849), marks the heart of the market theory of forest economic science (cf. Deegen et al., 2011; Deegen, 2013). Under the conditions of a partial equilibrium, forest owners maximizing the net present value of a periodically perpetual tree production are selected by the competitive process in markets. In the Faustmann model, however, all simultaneously growing trees are of the same age by definition. No endogenous action could induce trees of different ages to be growing at the same time. Through the synchronization of time and age, the Faustmann model depicts a forest stand without irregularities in tree ages on any micro- or macro-level.

The even-aged limitations of the Faustmann model have motivated several strands of research. Uneven-aged management and age class forests, though, are typically analyzed independently. Due to the inherent complexity, uneven-aged management of forest stands is often studied numerically (e.g. Adams and Ek, 1974; Haight and Monserud, 1990; Tahvonen, 2009). Analytical solutions have been proposed by Chang (1981), Haight (1985, 1987), Getz and Haight (1989) or, partially, by Halbritter (2014). While numerical approaches often involve quite specific model formulations which, despite of being capable of revealing internal relationships, are of limited scope, analytical procedures face structural problems resulting from density-dependent tree growth.

The harvest of age classes as interrelated parts of forests, on the other hand, has been investigated, among others, by Mitra and Wan (1985, 1986) and Salo and Tahvonen (2002, 2003, 2004). These studies, which are concentrated on the properties of long-run stationary states evolving in forest systems in a given environment, offer valuable insights into the dynamics of forest management, but are restricted to structural uniformity and narrow assumptions.

This paper offers a general perspective of uneven-aged tree management on both stand and forest level. It is shown how both concepts are fundamentally related through interdependent tree values and under which conditions regularities in tree ages can be expected. The model approach allows to derive empirically testable hypotheses on the emergence of forest structures. In order to relax the assumption of equal tree ages underlying the Faustmann model, the relationship between the optimal times of harvest and regeneration of individual trees are analyzed. Regularities in the tree ages arise due to the coincidence of harvests and regenerations. On the basis of the analysis of the implications of the model derivations in the light of prior contributions, the discussion section proposes a synthesis of the several strands of even-and uneven-aged forest and stand management from a more inclusive perspective.

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