Journal of Forest Economics 21 (2015) 14–31

Contents lists available at ScienceDirect

Journal of Forest Economics

journal homepage: www.elsevier.com/locate/jfe

An economic analysis of double-cohort forest resources

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A R T I C L E I N F O

Article history:
Received 19 May 2014
Accepted 7 November 2014

JEL classification:
Q230
Q560

Keywords:
Uneven-aged forest management
Double-cohort resource
Generalized Faustmann model
Shelterwood
Seed-tree method
Growth competition
Natural regeneration

A B S T R A C T

Under increasing economic pressure the use of natural regeneration is steadily gaining importance in the forest sector. Double-cohort stand systems, such as seed-trees, shelterwood and many two-aged variations supporting natural seeding, are common silvicultural practices. This paper presents a unified economic approach integrating the most common management alternatives of a double-cohort forest resource in one generalized deterministic model. A three-dimensional problem is solved for regeneration age, overstory density and removal cut maximizing the land expectation value and analyzed in a comparative static analysis. The findings of the model analysis are discussed in a comparison with even- and uneven-aged management. In addition, the dynamic even-aged thinning problem is extended to two age-classes and solved.

Introduction

Increased economic and social pressures in forestry have induced a strong development towards a greater use of natural regeneration (e.g. Holgen and Hanell, 2000). A trend towards *continuous cover* and *near-natural* forestry (Gadow et al., 2008) has also been motivated by environmental considerations.

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http://dx.doi.org/10.1016/j.jfe.2014.11.001
1104-6899/

While uneven-aged stands comprising trees of several age classes (cohorts) are one possibility to use natural regeneration, the management of only two cohorts, termed *double-cohort* systems (Smith, 1997), offers another widely accepted alternative, which has grown in importance in recent decades.

The common double-cohort approach is to harvest an even-aged stand only partially, to support natural regeneration and thereby create a two-aged stand. Later the shelter is removed and the stand becomes even-aged again. Therefore, double-cohort management can be regarded as a hybrid approach combining many favorable elements of even-aged and uneven-aged silviculture (Nyland, 2002, pp. 29 et seq.). Compared with even-aged forestry, where planting is a main driver of silvicultural costs, the use of natural regeneration in two-aged systems and its protection against harmful climate conditions offers important economic advantages. Furthermore, the value increment of the shelter can generate additional returns. From an ecological perspective, the possible negative effects of clearcutting, e.g. water retention and soil erosion, are tempered. Aesthetic aspects as well as regulatory restrictions on clearcutting can also be important. Compared with uneven-aged forestry, double-aged management might offer a wider range of suitable tree species, and a higher level of control and economic efficiency, e.g. with respect to regeneration or harvest.

The silviculture literature distinguishes two general types of double-cohort management, the *seed-tree* and the *shelterwood* method, which differ in terms of density and growth period of the shelter (Matthews, 1991; Smith, 1997; Nyland, 2002). Commonly, the seed-tree method maintains only a few widely spaced trees for seeding purposes and removes them immediately after a mast has taken place. The focus, therefore, lies primarily on the regeneration of wind disseminated and rather shade-intolerant species (Nyland, 2002, p. 318). The shelterwood method preserves an overstory with a higher stocking density and a longer period of shelter. This exploits both the natural regeneration and the value increment potential of more shade-tolerant trees. However, the border between the two methods is often blurred and many variations exist (Hannah, 1988).

In Europe shelterwood has a long tradition and has been used to regenerate beech stands since the 18th century (Hartig, 1791). During the last decades it has also become important in the management of other species, especially Norway spruce (Hanell et al., 2000). In North American silviculture, many pines, e.g. loblolly, shortleaf, pitch and longleaf pine (Smith, 1997, p. 359) and other conifers, e.g. Douglas fir (Williamson, 1973), are managed as shelterwood systems. The seed-tree method is particularly common for Scots pine in Europe (Valkonen, 2000) but is also used for several pines in North America (Nyland, 2002, pp. 318 et seq.).

A wide range of economic literature exists on uneven-aged management with several age classes (e.g. Duerr and Bond, 1952; Adams and Ek, 1974; Buongiorno and Michie, 1980) and natural regeneration. Chang (1981) presented an optimal simultaneous solution for cutting cycle and residual stock using a stand unit model. Later Chang and Gadow (2010) extended this approach towards a generalized Faustmann model (cp. Chang, 1998) for uneven-aged management. Others, like Tahvonen (2011), followed a dynamic individual-tree approach on the basis of numerical analysis.

Although simple formulas for the calculation of the *land expectation value* (LEV) of the German 'Dunkelwald' (shelterwood) and 'Überhalt-Betrieb' (seed-trees) are known since the 1920s (e.g. Endres, 1923, pp. 74 et seq.) economic analysis in the field of double-cohort management is surprisingly rare. Zhou (1998) published a numerical solution to a seed-tree problem for a Scandinavian Scots pine stand, optimizing rotation length, number of seed-trees, seed-tree period and thinnings for maximal LEV. Khazri and Lasserre (2011) introduced a double-aged mixed rotation model, where the older cohort and parts of the younger age class is removed in the same harvest. They provided an analytical solution to the LEV-optimal number of residual trees and rotation length. Both of these papers focused on a very specific example or variation of two-aged silviculture.

The aim of this study is to provide a unified economic analysis of double-cohort forest resources, which not only covers questions of optimal management, but can also offer insights aiding in the decision whether to employ even- or uneven-aged forestry and natural or artificial regeneration. A deterministic model, following the generalized approach by Chang and Gadow (2010), is introduced and solved analytically. A comparative static analysis based on the distinction of the two relevant cases, shelterwood and seed-trees, is presented. Finally, the results are discussed in the context of existing literature and conclusions for silviculture are drawn.