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Application of the generalized Faustmann model to uneven-aged forest management

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ABSTRACT

In this paper, a generalized Faustmann model is developed for uneven-aged management to allow the number of years and the level of residual growing stock to vary from one cutting cycle to the next. Comparative static analyses are conducted to determine the effect of changes in interest rate, stumpage price of the trees selected for harvest, the stumpage value of the residual growing stock, and the future land value on the decision variables. The model is then applied to study the uneven-aged management of a loblolly-shortleaf pine stand in south central U.S. to determine the length of the cutting cycle and the level of residual growing stock for the first cutting cycle as well as for a case involving four cutting cycles. Sensitivity analyses reveal that for the uneven-aged loblolly-shortleaf pine stand both the length of the cutting cycle and the level of the residual growing stock are very sensitive to changes in land value in the future, in the stumpage prices of trees selected for harvest, in the stumpage prices of the residual growing stock, and in the interest rate.

Introduction

Ever since Chang (1998) published the generalized Faustmann model for even-aged management, it would be natural to extend the theory to the case of uneven-aged management. The extension represents more than just an intellectual curiosity. For various reasons, uneven-aged forest management has become the preferred method in many regions. For example, "near-natural" forest management,

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favoring mixed stands of site-adapted tree species and selective harvesting, has become a dominant type of forest management in Europe (Butter, 1998; Detten et al., 2009; Pommerening, 2001; Röhe, 2003). Selective harvesting, also known as "*Continuous cover*" or "*near-natural*" forest management (Gadow et al., 2008) is being practiced in many parts of the world, albeit on a smaller scale than even-aged forest management (see, for example, Guldin, 2002; Muchiri et al., 2002; Seydack et al., 1995; Trasobares and Pukkala, 2005).

Under uneven-aged continuous cover forest management, standard even-aged silvicultural regimes are not applicable. The most profitable silvicultural prescription is primarily dictated by the current state of a particular forest stand, by the availability of certain product types, and by the particular development potential. The possible development scenarios of a continuous cover forest are thus unique and often non-repeatable. No longer will the same residual growing stock level and cutting cycle length be applicable for all cutting cycles, which demand the development of something similar to the generalized Faustmann model for even-aged management (Chang, 1998).

Although uneven-aged management is probably the oldest form of forest management, formal inquiry in this area has been a relatively recent phenomenon. Early work in this area, typically assumed a fixed cutting cycle, then proceeded to determine the optimal residual growing stock. For example, in their classical work on financial maturity Duerr and Bond (1952) assumed that the cutting cycle will be 1 year and determined the optimal level of growing stock accordingly. Similarly, Adams and Ek (1974) attempted to determine the optimal level of growing stock by assuming that the cutting cycle will be 5 years. It was not until Chang (1981) addressed the simultaneous determination of the optimal cutting cycle and residual growing stock. In this paper Chang established the maximization of the land expectation value as the objective of uneven-aged management and thus provided a unified theory for even- and uneven-aged management. Later on, a similar article was published by Hall (1983). Getz and Haight (1989) studied the theory and application of matrix models to uneven-aged management. Subsequent empirical studies of uneven-aged management included, among others, the works of Bare and Opalach (1988), Boscolo and Buongiorno (1997), Buongiorno and Michie (1980), Chang (1990), Favrichon (1998), Haight (1985, 1987), Haight et al. (1985), Haight and Monserud (1990a,b), Kant (1999), Lu and Buongiorno (1993), and Schulte and Buongiorno (1998). In Europe, studies on uneven-aged management with an economic perspective include the papers by Bochert (2002), Deegen (2000), Knoke (1999), Knoke and Bochert (2001), and Sánchez Orois et al. (2004). One of the common shortcomings of all these papers is the fact that a fixed length is used while, in reality, the length of the cutting cycle may vary as suggested above. The paper by Hille et al. (1999) involving several successive harvests of varying intensity and intervals of varying length between harvests over a fixed time window represents one of the few exceptions. To overcome this limitation requires the development of the generalized Faustmann model for uneven-aged management, which allows the number of years between harvests and the residual growing stock level to vary from cutting cycle to cutting cycle.

The generalized Faustmann approach

Let:

FV_0 be the value of the uneven-aged forest before any management activities,
S be the existing stand volume,
$Q_i(t_i,g_i)$, $i = 1$ to ∞, be the volume of the ith uneven-aged stand with an initial residual growing stock of g_i and a cutting cycle of t_i years,
$V_0(S)$ be the stumpage value of the existing uneven-aged stand,
$v_i(g_i)$, $i = 1$ to ∞, be the value of the residual growing stock at the beginning of the ith cutting cycle.

As a cost function, it is convex with respect to g_i as additional and potentially larger and therefore more expensive trees are added to the residual growing stock. As such, $(\partial v_i(g_i)/\partial g_i) > 0$ and $(\partial^2 v_i(g_i)/\partial g_i^2) \geq 0$. Note that even if the unit cost of the residual growing stock is a constant the resulting straight line cost function is still convex. These conditions imply that the value of the residual growing stock is always increasing as the level of residual growing stock increases. Further the value is increasing either at an increasing rate or a constant rate as the residual growing stock increases.