Journal of Forest Economics 24 (2016) 106–122

Contents lists available at ScienceDirect

Journal of Forest Economics

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

Optimal forest management with sequential disturbances

Ying Xu*, Gregory S. Amacher, Jay Sullivan

Department of Forest Resources and Environmental Conservation, Virginia Tech., Blacksburg, VA, United States

ARTICLE INFO

Article history:
Received 5 March 2015
Accepted 26 April 2016
Available online 28 June 2016

JEL classification:
Q23
C61
C63
L73

Keywords:
Forest management
Rotation age
Sequential disturbances

ABSTRACT

Previous work in forest management under uncertainty has been based on the assumption that landowners face a risk of only one damaging event during any forest rotation, with the main result being that landowners choose shorter rotation ages. These models are universal in an assumption that, should the disturbance arise in a given rotation, the landowner salvages what is possible through a harvest and replants to begin a new rotation. However, a real possibility exists that multiple disturbances may occur in one rotation, with the landowner retaining the damaged stand thereby waiting through the first or even a subsequent disturbance to harvest and begin a new rotation. We develop a new approach for rotations models and choices that allows more than one event and flexibility in the timing of harvest, where tree recovery and damage may make continuance of the rotation, rather than starting over, a rent maximizing strategy. We thereby generalize the highly-cited body of literature based on Paul Samuelson's and William Reed's seminal contributions. Results demonstrate that failure to consider these new features leads to suboptimal harvest decisions and highly suboptimal land rent values. Important parameters are found to be arrival rates of future disturbances and survival proportions and growth rates after each disturbance.

* Corresponding author at: Cheatham Hall Rm 313, Virginia Tech., Blacksburg, VA 24061, United States. Tel.: +1 540 553 4590; fax: +1 5402313698.
E-mail address: ying83@vt.edu (Y. Xu).

http://dx.doi.org/10.1016/j.jfe.2016.04.003

Introduction

Disturbances play a major role in determining forest composition and structure. Events such as fire, drought, ice storm, windstorm, insect and pathogen outbreaks often lead to considerable damage and loss, in many years exceeding two billion dollars and twenty million hectares in the United States alone (USDA, 1997). Wildfire has been a regular occurrence in the Western United States and Alaska (Westerling et al., 2006), while repeated droughts have affected nearly all regions of United States (Hanson and Weltzin, 2000). Moreover, insects and diseases remain an ongoing concern in forest management and have affected greater than 750 million acres of forest land and millions more acres of urban treed areas in the U.S. alone (USDA, 2013). The reality in fact is such that any given landowner could experience more than one event during the typical time span covered by a forest rotation, and if the stand is not harvested after the first event, then forest damage and subsequent growth would depend critically on the arrival timing of events.

Rotation age decisions under risk have been studied extensively, but there have been three basic and nearly universal assumptions underlying all of this work. First, most of the work utilizes an ongoing rotations model similar to Faustmann (1849). Second, only one damaging event is assumed to arrive during a rotation when the risk exists. Third, and related to the second, if the event arrives before a planned rotation age is reached, the landowner is assumed to salvage harvest what he can and replant to begin a new rotation immediately. Even in more dynamic models, the second and third assumptions typically have been employed. Early studies of these problems in forest economics include discussion in Samuelson (1976), initial simulations in Martell (1980) and Routledge (1980), later theoretical work conducted by Reed (1984, 1987), Reed and Apaloo (1991), Yin and Newman (1996), Englin et al. (2000), and more recently Stainback and Alavalapati (2004), Yoder (2004), and Amacher et al. (2005) among others.

Reed (1984) has emerged as one of the most highly-cited articles in forest economics. He investigates the relationship between risk of fire arrival during a rotation and the optimal harvest age, assuming the arrival rate of fire follows a time-independent Poisson process and that the forest is destroyed (or randomly salvageable) and the rotation ended upon the occurrence of fire, or the rotation age is reached and the stand is 'destroyed' through harvesting. There are only two exceptions of which we are aware where the stand is not assumed to be necessarily harvested after the first event arrives (Goodnow et al., 2008; Susaeta et al., 2014), however, these studies only allow for a single disturbance during any future rotation.

Reed and the related literature develop one basic result: a forest should be cut at time T when the marginal benefit from harvesting now equals a marginal cost of continuance that depends on the probability (arrival rate) of a (first) damaging event that is capitalized into the interest rate factor.[1] We revisit this basic result and approach, but relax three basic assumptions that make sense in light of forest management realities. First, we consider and allow for sequential disturbances during a rotation using the same framework as Reed and others use, but also allow the landowner the choice to harvest or wait after a first disturbance. We develop our problem for two disturbances that may arrive in any future rotation, although the modeling of more than two is straightforward and follows along the lines of the model we develop here.[2] Second, we allow the landowner a choice to harvest the stand at the first event, at the second event, or at a planned rotation age. In other words, we allow the landowner a choice of continuance strategies along with the rotation age choice. Third, our harvesting strategy is more flexible than those studied in the current literature, giving a stand can be continued after the

[1] Some later studies relax the assumption of total damage upon arrival of a catastrophic event, and indeed Reed (1984) also allowed for random survival once an event strikes. In this work, it is possible that the landowner can employ costly protection effort during a rotation in order to reduce forest damage should a fire arrive before the rotation age is reached, thereby not always leading to rotations as short as Reed-based models predict. However, the usual assumptions remain omnipresent.

[2] Although we can prove that our results hold for any number of disturbances that might arise during a rotation (details available upon request), the two disturbance or less case we consider in this paper is the most likely one for planted softwood stands that are normally harvested within a window of 20–40 years. For boreal forests that may be grown for more than 80 years, it is conceivable that there could be a third or fourth potential event that would not dictate the automatic harvesting assumed in the literature.