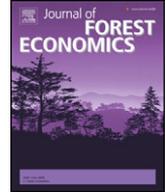




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Adaptive management decision of agroforestry under timber price risk

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ABSTRACT

In an effort to increase wood production and mitigate environmental problems, agro-forestry practices have emerged as a viable strategy in the Northern Plains of China, where one popular form of the agro-forestry system consists of fast-growing and high-yield plantation of poplar (*populus*) trees and the underwood planting of button mushroom (*Agaricus bisporous*). This paper examines adaptive management decision-making with stochastic dynamic programming under risk of timber price. Under the assumption of risk neutral preferences of the investors, the results suggest that the reservation price strategy remains optimal for the harvesting decision of agro-forests: when the timber price is higher than the reservation price, poplar trees should be harvested to end agro-forestry; otherwise, the trees should be retained. Numerical results are presented for sample agro-forest stands, which show that, with underwood planting, the reservation price for timber harvesting will be higher than that in pure forest.

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Introduction

Agroforestry, in a broad sense, refers to intensive land management that optimizes the benefits (physical, biological, ecological, economic, social) arising from biophysical interactions created when trees are deliberately combined with crops or livestock; while in a narrow sense focuses on the intentional mixing of trees and crops or animal production systems to create environmental, economic, and social benefits (Rambo, 1997; Rasul and Thapa, 2003; Sharawi, 2006).

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Stimulated by the development of economy and society, agro-forestry has emerged as a viable strategy in recent years, for example in the Northern Plains of China which includes Shandong, Jiangsu, Hebei, and neighboring provinces. There are large areas of fast-growing, high-yield plantations of poplar trees for wood production. They offer enough space and opportunity to plant underwood crops and the most popular underwood crop is button mushroom because of its good market potential. Moreover, several studies have shown that growing mushrooms in poplar plantations contributes to maintain soil fertility and moisture, and improve land productivity (Rule et al., 1994; Fang et al. 2005; Gotoh and Yokota, 2009; Bruhn et al., 2010).

With the increasing popularity of agro-forestry, a substantial body of literature has been developed in recent decades. One of the main focuses is the ecological and physiology aspects (Yao and Wang, 1997; Li et al., 1999, 2000; Zhang et al., 2003; Zhao et al., 2006; Peng et al., 2009), as well as the conception and structure of agro-forestry (e.g. Bruhn, 2008; Newman, 1996). Another major focus is the evaluation of the benefits of agro-forestry (Meng et al., 2001; Wu et al., 2002; Luckert, 2005; Palma et al., 2007; Gao et al., 2009). There are also a considerable number of studies about the adoption of agro-forestry (Rogers, 1995; Franzel et al., 2001; Keil et al., 2005; Benítez et al., 2006). In contrast, there are relatively few studies of optimal harvest of the trees in agro-forestry systems (Lu and Li, 1999).

With respect to optimal forestry decisions under risk, one of the primary research focuses is the optimum time for forest thinning and final-felling. Shi and Song (1999) studied the optimum harvest time of timber stands under timber price risk. Xu and Song (2004) studied forest investment and optimum time of final cutting with real option, and there was also other research on forest investment and forest property evaluation with real option (Ge, 2004; Wei et al., 2006; Liu et al., 2006). Moreover, there are many researchers who tried many different optimization methods to assist management decision-making of forestry including: optimal control theory, dynamic programming, nonlinear programming, stochastic dynamic programming, etc. (Chappelle and Nelson, 1964; Näslund, 1969; Brodie and Kao, 1979; Roise, 1986; Solberg and Haight, 1991; Brazee and Bulte, 2000; Van Kooten, 2000; Sohngen and Mendelsohn, 2003; Lu and Gong, 2003, 2005; Benítez et al., 2006; Lu and Lohmander, 2009).

From the management decision-making viewpoint; however, an agro-forestry system should not be regarded as a simple combination of some forest with some crops/livestock. It generally is improper to analyze the tree harvest decision separately from decisions concerning crops growing and/or livestock raising in an agricultural system, because of the interactions between trees and crops/animals in the system.

The objective of this paper is to examine the effects of underwood crop growing on the optimal forest harvest decision under conditions of uncertainty in timber price, and develop adaptive management strategies for an agro-forestry system composed of poplar (*populus*) and button mushroom (*Agaricus bisporus*). The methodology for an adaptive management decision under stochastic timber price is based on stochastic dynamic programming. We will demonstrate that the reservation price strategy remains optimal and planting button mushroom under poplar makes the reservation price for tree harvest higher than that in pure forest.

The paper is organized as follows. In method section, the decision method is presented. In Application section, the specific mathematic function and necessary data used to fit the model are presented, followed by a description of the sample agro-forestry site. The result section contains a comprehensive collection of the numerical results of the model for the sample site. Finally, discussion and conclusion section discusses the implications of our results, and summarizes conclusive remarks and possible future research direction.

Methods

The sample agro-forestry system we studied here is poplar-button mushroom inter-plantations in Shandong province, where poplar is a major and popular tree species (Fang et al., 2005) due to its fast growing character. To make full use of growth space above the ground, many people choose to plant button mushroom under wood. The main reasons for choosing button mushroom as the underwood crop are (1) it has good market price so as to enhance the income for manager, (2) poplar can provide shade environment for its growth, and (3) it can accelerate the annual volume growth of poplar (Sha

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