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Cost-effective biodiversity restoration with uncertain growth in forest habitat quality

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ABSTRACT

This paper develops a dynamic model for cost-effective selection of sites for restoring biodiversity when habitat quality develops over time and is uncertain. A safety-first decision criterion is used for ensuring a minimum level of habitats, and this is formulated in a chance-constrained programming framework. The theoretical results show; (i) inclusion of quality growth reduces overall cost for achieving a future biodiversity target from relatively early establishment of habitats, but (ii) consideration of uncertainty in growth increases total cost and delays establishment, and (iii) cost-effective trading of habitat requires exchange rate between sites that varies over time. An empirical application to the red listed umbrella species – white-backed woodpecker – shows that the total cost of achieving habitat targets specified in the Swedish recovery plan is doubled if the target is to be achieved with high reliability, and that equilibrating price on a habitat trading market differs considerably between different quality growth combinations.

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Introduction

The global rate of biodiversity loss is alarming; it is estimated that the global rate of species extinction rate has increased by approximately 1000 times over the background rates (MEA, 2005). An international agreement was reached in 2010 in order to combat this loss, an important component of which was to protect 17% of terrestrial land, and 10% of coastal and marine areas by 2020 (CBD, 2011). Such protection of existing habitats can slow biodiversity loss, but active restoration of habitats is regarded as essential for improving biodiversity, in particularly in human dominated regions (e.g. Wilson et al., 2011).

However, unlike protected areas which usually are biodiversity rich and therefore chosen for protection, restoration occurs at degraded areas offering the potential to be biodiversity rich. The realization of this potential is uncertain and may take many years to deliver. This implies, in turn, a risk. The risk is that targets expressed in terms of provision of habitats with sufficient quality may not be achieved, threatening the persistence of species. Another request for certainty in target achievement is raised by national policy-makers who are usually concerned with the choice of abatement portfolio and the ability to achieve targets in order to maintain trust in international cooperative agreements (e.g. Barrett and Stavins, 2002). Although there are a few studies in economics analyzing optimal biodiversity provision under uncertainty (Costello and Polasky, 2004; Newburn et al., 2006; Strange et al., 2006; Drechsler et al., 2009; Vardas and Xepapadeas, 2010; Billionet, 2011; Adams et al., 2011), relatively strong risk aversion with respect to non-attainment of targets has not been included. The purpose of this paper is to present a numerical model for optimal selection of restoration sites when habitat quality is uncertain and policy makers are risk averse with respect to not achieving targets. This is made with a dynamic cost effectiveness approach with safety-first decision criterion in the framework of chance constrained programming.

The ecological and economic literature on optimal site selection for protected areas is relatively large (e.g. Kirkpatrick, 1983; Costello and Polasky, 2004; Newburn et al., 2006; Carwardine et al., 2008; Lewis et al., 2009) but there are, to the best of our knowledge, no economic studies of biodiversity restoration with uncertainty in growth of habitat quality. Instead, studies accounting for uncertainty and dynamic aspects are applied to conservation of species (Costello and Polasky, 2004; Newburn et al., 2006; Strange et al., 2006; Drechsler et al., 2009; Vardas and Xepapadeas, 2010; Billionet, 2011; Adams et al., 2011). Some of these studies approach uncertainty by sensitivity analyses, where robustness in the optimal solution is explored by changing key parameter values (e.g. Drechsler et al., 2009; Adams et al., 2011). Other studies enter uncertainty into the decision problem with explicit consideration of attitudes towards risk or uncertainty. Several of these studies regard the supply of suitable land for conversion as stochastic (Costello and Polasky, 2004; Strange et al., 2006; Vardas and Xepapadeas, 2010; Billionet, 2011). Costello and Polasky (2004) develop a dynamic model and apply stochastic programming for optimal site selection under given budget constraint when the supply of reserve sites of sufficient quality is random. The acquisition of a site increases the probability of species survival, whereas the non-protected sites face a risk of irreversible exploration conversion. Strange et al. (2006) use the same model but add an option of selling protected sites in later periods, which increases expected species survival for a given budget restriction. Similarly, Billionet (2011) allows for restriction on size and number of sites and weighting of species. Vardas and Xepapadeas (2010) develop a theoretical model using another approach, robust control, for analyzing conditions for optimal site selection under uncertainty with respect to irreversible conversion of habitats into commercial land uses. Robust control allows for incorporating non-measurable uncertainty, or ambiguity, in a Knightian setting where it is not possible to assign probabilities to different outcomes (Knight, 1921).

The switch in focus in our study from conservation to restoration of habitats has at least two implications for uncertainty analysis. One is the perception of the uncertainty as such. Whereas much of the current literature in the economics of conservation with uncertainty in the decision rules regards habitat quality as given and the number of sites at each time period as random, the opposite is the case for restoration. The reason is that, in practice, suitable restoration sites are often selected based on their potential ability to provide attractive habitat opportunities for a target species (e.g. Wilson et al., 2011). The number and characteristics of sites are therefore relatively certain at the time of establishment, but their development during time with respect to critical quality parameter is uncertain. Another

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