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Implementing efficient conservation portfolio design☆

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Modern tools for cost-effective conservation reserve site planning require the planner to have information about spatial distributions of conservation costs and benefits. Climate change creates unprecedented uncertainty about future land values and species habitat ranges, such that conservation scientists cannot map costs and benefits with certainty anymore. This paper contributes to the literature on the economics of conservation in the face of climate change uncertainty. It advances a new method for using modern portfolio theory to choose lands to protect that yield total conservation returns with less uncertainty. It explores the implications for portfolio recommendations of variation in the correlations between ecological and land-value responses to climate change. It also tests the robustness of the method to shortcuts that might be taken to simplify analysis, identifying problems that arise if conservation costs are ignored in portfolio analysis and demonstrating when portfolio recommendations are sensitive to how ecological benefits are quantified.

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1. Introduction

A large body of sophisticated work has developed methods for cost-effective conservation reserve site planning. However, modern conservation planning tools require the planner to have information about spatial distributions of conservation costs and benefits. Climate change creates unprecedented uncertainty about future land values and species habitat ranges, such that conservation scientists cannot map costs and benefits with certainty anymore. Ando and Mallory (2012) pioneered the use of Modern Portfolio Theory (MPT) for spatial conservation planning, showing how this methodology from finance can be used to choose portfolios of land for conservation that reduce overall uncertainty about the benefits that will flow from future reserves. This tool is promising, but extensive data are needed to carry out a MPT analysis correctly. Conservation planners might in practice face data or time limitations that make shortcuts tempting. This paper further develops the MPT approach to conservation planning in the face of climate uncertainty by demonstrating baseline features of the MPT approach to conservation reserve diversification and investigating whether the technique is robust to common shortcuts (e.g., neglecting costs or using benefit indexes rather than true measures of conservation benefits).

Previous work developed cost-effective spatial strategies for choosing conservation investments. Conservation biologists and ecologists use biophysical information to target conservation at places to gain the highest total conservation benefit (Wilson et al., 2006). Economic research has shown the importance of considering variation in other factors such as costs (Ando et al., 1998) and development threat (Costello and Polasky, 2004); economists have also studied dynamic elements of conservation planning such as endogenous future land prices (Dissanayake and Önal, 2011), endogenous future threat (Armsworth et al., 2006), and responses of one set of conservation agents to policy or actions taken by another (Albers et al., 2008; Lichtenberg et al., 2007).

All this research is based on a foundation of information: the ability to measure factors influencing the costs and benefits of conservation across space that arise under climate change uncertainty. Only a few papers have grappled with the problem of conservation planning in the absence certain information about the spatial distribution of conservation benefits and costs, which will be influenced by a changing climate. However, that work (Polasky et al., 2000; Arthur et al., 2004) simply allows for species occurrence in a portion of the landscape to be uncertain in a manner that reflects lack of knowledge. This type of uncertainty does not capture the spatial patterns of uncertainty in future ecological benefit and conservation costs that are associated with climate-change induced uncertainty.

Ecologists and conservation biologists have made many suggestions for changing conservation planning practice to cope with climate change uncertainty, (Williams et al., 2005; Hannah et al., 2007; Hodgson et al., 2009; Beier and Brost, 2010) but most of that work does not employ decision tools that grapple with uncertainty directly (Ando and Hannah, 2011). Spatial conservation diversification under uncertainty was developed by several authors, but none used information about the covariance in outcomes across space that would be necessary to accomplish efficient risk management (Anderson and Ferree, 2010; Pyke and Fischer, 2005; Strange et al., 2011 are some notable examples). Work such as Hannah et al. (2002), Regan et al. (2005), Carroll et al. (2010), and Kujala et al. (2013) considers conservation prioritization that is robust or resilient (variously defined) to a number of different possible climate outcomes without explicitly using the MPT framework. These methods are useful, but do not produce full menus of conservation portfolios that efficiently reduce uncertainty in overall conservation outcomes as does MPT.

Climate change uncertainty introduces a problem of deep uncertainty (Knight, 1921) since it is difficult to estimate the probability distribution over future climate outcomes (Weitzman, 2009). Decisions made based on miscalculated probabilities can misallocate resources and produce poor conservation outcomes. The problem of deep uncertainty is difficult to account for in a standard decision framework (Weitzman, 2010). Gilboa and Schmeidler (1989) present *max–min* control (optimizing over conditions given the least favorable prior) to guide decisions under deep uncertainty. Alternatively, as Lempert et al. (2004) note, identifying conservation strategies that avoid relying on all or nothing investments can mitigate some of the risk associated with deep climate uncertainty; thus, MPT could serve as an alternative to the *max–min* approach. MPT planning recommendations split conservation investment based on a (perhaps imprecisely measured) probability distribution, and hence diversify investment.