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A reliance on agricultural land values in conservation planning alters the spatial distribution of priorities and overestimates the acquisition costs of protected areas

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ABSTRACT

A common focus for conservation planning is to identify locations for siting potential protected areas, something that requires estimates for the costs of setting up these areas and benefits for biodiversity of doing so. When cost data are not available over relevant scales, conservation planners commonly rely on proxy data that they hope will estimate conservation costs. Here, we assessed how accurately agricultural land values, a commonly used proxy for cost data in conservation planning, estimate the actual acquisition costs of protected areas, focusing on a case study from the central and southern Appalachians. We compared plans based on cost estimates derived from different sources and that involved different levels of spatial aggregation to understand how a reliance on these estimates would impact conservation planning. We found that the average agricultural land value in a county did not accurately predict the acquisition costs of protected areas in that county. This lack of accuracy was a result of choosing agricultural land values as a proxy for acquisition costs, and not spatial averaging. A reliance on agricultural land values risks diverting limited funds for establishing protected areas away from parcels that offer the greatest return-on-investment. It would also lead a conservation organization to overestimate the budget needed to protect a given number of species. Our findings highlight the importance of incorporating data on how much protected areas actually cost in future conservation planning studies.

1. Introduction

Many conservation organizations purchase and set aside land to stem the loss of biodiversity, but are limited in the opportunities they can pursue by budget constraints. In response, they have developed planning tools and guidance to help identify opportunities that offer the greatest return-on-investment (ROI) given spatially explicit estimates of the costs and benefits of protected areas (Amundsen, 2011). This regional planning improves an organization's ability to place a given conservation opportunity in a landscape context (Groves et al., 2002). Given the tradeoff between the spatial extent and grain, or resolution of available cost data (Tobler, 1988), conservation planning studies have generally relied on aggregated cost estimates to prioritize areas for protection (Armsworth, 2014). Our goal in this study is to understand the type, direction, magnitude, and consequences of estimation errors associated with one type of relevant data, conservation costs (Langford et al., 2009).

Conservation planning studies have generally reached a consensus that socioeconomic dimensions of land protection such as economic costs (Naidoo et al., 2006), landowners' willingness to sell (Knight et al., 2011), and even access to greenspace (Miller and Hobbs, 2002) should be factored into the planning process along with other biological objectives (but for a contrasting perspective see Arponen et al., 2010). However, while parcel-level cost estimates may be available within individual municipalities, it can be difficult to collect such fine-grain information across the entire spatial extent of a regional conservation plan (but see Polasky et al., 2008; Torrubia et al., 2014 for examples). As a consequence, conservation planners often estimate costs of protected areas based on costs for other land uses or data on drivers of land use change, such as average agricultural land values (*e.g.* Ando et al., 1998; Ando and Mallory, 2012; Chiozza et al., 2010; Jantke and Schneider, 2010; Jantke et al., 2013; Di Minin et al., 2013; Murdoch et al., 2007; Strange et al., 2006; Withey et al., 2012), average agricultural yields (Carwardine et al., 2008; Naidoo and Iwamura, 2007; Wilson et al., 2011), the value of standing timber (Perhans et al., 2008; Polasky et al., 2008), gross domestic product (Eklund et al., 2011), or human population density (Luck et al., 2003; Williams et al., 2003).

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Moreover, the cost estimates used in conservation planning studies are often spatially aggregated, or averaged within an areal unit such as municipalities. Spatial aggregation has been shown to affect the accuracy of biodiversity data used in conservation planning (Hess et al., 2006; Hurlbert and Jetz, 2007; Rahbek, 2004; Seo et al., 2009) as well as the locations identified as conservation priorities (Arponen et al., 2012; Hermoso and Kennard, 2012; Mills et al., 2010; Shriner et al., 2006; Warman et al., 2004). However, similar issues resulting from the reliance on spatially aggregated cost estimates have received less attention (but see Jantke et al., 2013; Richardson et al., 2006; Sutton & Armsworth, 2014).

In this study we examine how accurately the *ex post* costs of designating protected areas as a land use are predicted by spatially averaged cost estimates derived from an agricultural land use (Fig. 1 — scenario 1). If average agricultural land values do not reliably predict variation in acquisition costs of individual protected areas, this could be due to spatial averaging (Fig. 1 — scenarios 2a and 2b) or to relying on costs based on an alternative land use, in this case being agriculture (Fig. 1 — scenarios 3a and 3b). To distinguish between these possibilities, we quantify the accuracy of cost estimates in five different combinations of data sources and levels of spatial aggregation. However, more important than the accuracy of the estimates given by the proxies per se are the potential consequences for the efficacy of conservation plans. Therefore, we also compare the performance of hypothetical conservation plans based on a subset of the most salient data scenarios (Fig. 1 — scenarios 1, 2b, and 3b).

Among wider writings on the effects of accounting for costs in spatial conservation planning (Carwardine et al., 2008; Murdoch et al., 2007; Naidoo and Iwamura, 2007; Withey et al., 2012), the most immediately relevant precursors to our work include two studies that examined the effect of spatial aggregation of cost estimates on conservation plans (Jantke et al., 2013; Sutton and Armsworth, 2014). However, the present study appears to be the first attempt to partition whether conservation plans are affected more by choosing a poor proxy for costs of establishing protected areas or by relying on data that have been spatially aggregated to a coarser resolution than actual conservation measures.

2. Methods

2.1. Choice of case study and cost data

As a case study, we focus on a set of recent transactions made by a conservation nonprofit between 2000 and 2009 to protect hardwood forests within three contiguous ecoregions in the Eastern US (Fig. A1). The Nature Conservancy (TNC) is the largest of the land trusts working in the United States with over $5.4 billion in assets and $950 million in annual revenue (Armsworth et al., 2012; TNC, 2013). Despite this size, their acquisition costs per hectare have previously been shown to be comparable to smaller regional land trusts (Armsworth, 2014). Here our goal to understand how common *ex ante* cost estimates available during the planning stage, such as values derived from other land uses, differ from the *ex post* costs of acquiring land for biodiversity protection. Then, we break down if this disparity between a cost estimate and cost data is a result of the choice of cost estimate or simply the level of spatial aggregation in that cost estimate.

TNC provided data on the actual acquisition cost they paid to protect each parcel of land as well as the cadastral boundaries (Fig. 1 — top right). The property rights of these parcels were all acquired outright

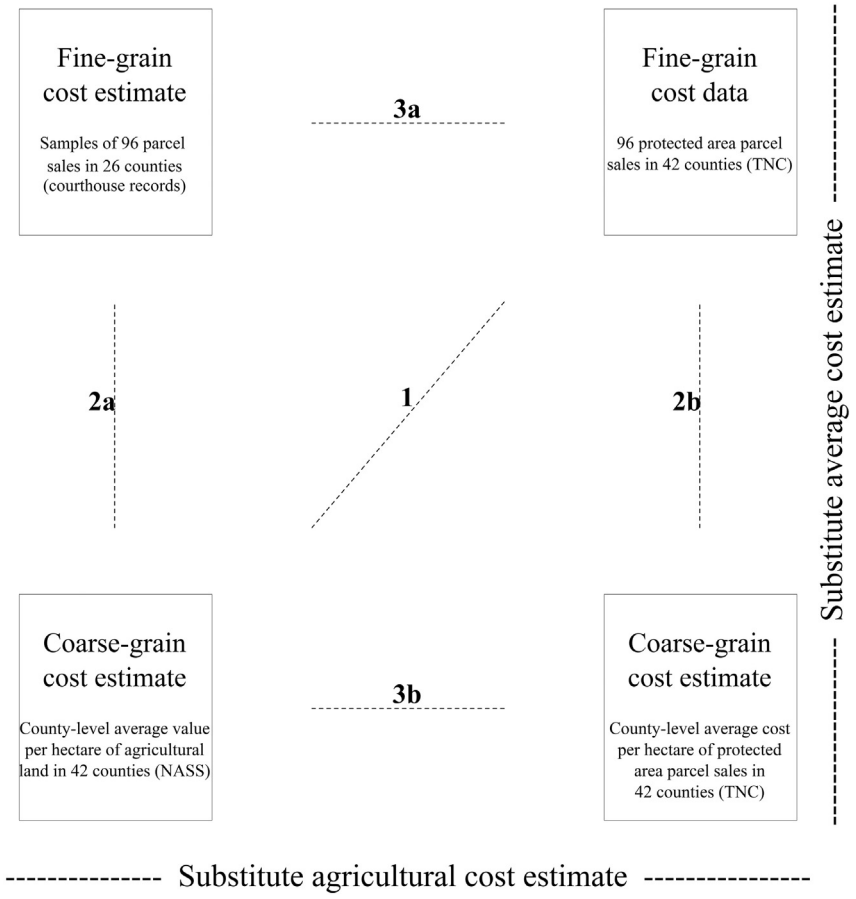

Fig. 1. We compared how accurately three different cost estimates compared to the acquisition costs of protected areas in a case study of recent transactions made by The Nature Conservancy. These estimates were created in two levels of spatial aggregation (rows) and sources of land values (columns).