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Aggregating high-priority landscape areas to the parcel level: An easement implementation tool

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Abstract

Landscape characteristics and parcel ownership information are often collected on different spatial scales leading to difficulties in implementing land use plans at the parcel level. This study provides a method for aggregating highly resolute landscape planning information to the parcel level. Our parcel prioritization model directly incorporates a Land Trust's conservation goals in the form of a compromise programming model. We then demonstrate the use of our approach for implementation decisions, including parcel selection under a budget constraint and the estimation of a total conservation budget necessary to meet specific conservation goals. We found that these cost constraints significantly alter the composition of the 'best' parcels for conservation and can also provide guidance for implementation. The model's results were integral to a local Land Trust's ability to further define and achieve their goals.

Keywords: Land conservation; Multicriteria analysis; Compromise programming; Geographic information systems

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1. Introduction

Much attention has been focused in the literature on how land use change can affect climate, biodiversity, regional economies, and social well-being (Beinat and Nijkamp, 1998; Watson et al., 2000; Theobald and Hobbs, 2002; Mannion, 2002). Specific conservation plans are needed to guide efforts to protect productive ecological systems, conserve native biological diversity and associated ecological processes, and maintain wild species of interest (Davis et al., 2003). Various conservation planning frameworks have been developed to address these issues at different spatial scales (Noss, 2000; Steinitz, 1990; Kautz and Cox, 2001; Groves et al., 2002; Greer, 2004; Wear et al., 2004; Hulse et al., 2002). In these frameworks and others, the typical approach is to evaluate land use alternatives and conservation targets at broad landscape levels ranging from a county to an entire ecoregion.

At these regional extents, implementation of the alternatives or the conservation targets is often not discussed. For example, Cowling et al. (2003) proposed a framework for protecting biodiversity, but they did not evaluate how to implement their strategies. Hyman and Leibowitz's (2000) framework for prioritizing land for ecological protection and restoration provides important regional perspectives to conservation issues, but it does not address the important issue of implementation at local scales. The Nature Conservancy uses a seven-step conservation planning framework that identifies conservation elements and generates a list of priority sites, but they essentially ignore issues related to the implementation of their framework when selecting specific parcels for protection (Groves et al., 2002). Greer (2004) provides valuable lessons learned from 5 years of implementation of conservation planning to protect endangered, threatened, and other sensitive species at the landscape level but does not discuss how to prioritize properties for conservation at the parcel level.

One of the reasons for few local or parcel level implementation studies is that at the regional extent, the identified areas for conservation are likely to cover or extend over a large number of parcels. In this case, a simple

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spatial overlay in a geographic information system (GIS) can identify the parcels and ownership information for implementation.

When the identified areas for conservation are at a scale that is smaller than parcels, aggregation to the parcel level must be performed. How the aggregation should be done and how to include additional parcel criteria such as size, adjacency, etc. are important questions in implementation. Because higher resolution priority landscape areas have natural or continuous boundaries, they will rarely if ever correspond exactly in size and shape to ownership or other political boundaries such as parcels. As spatial data layers continue to become more available and at finer resolutions, aggregating up to the parcel scale will become even more common.

This paper addresses aggregating highly resolute spatial data to the parcel level when this is the appropriate scale for conservation planning. Our method integrates GIS/spatial analysis, a compromise programming model, and an economic framework as a tool to aid in parcel comparisons. We illustrate our method by applying it to the circumstances of an actual Land Trust in the Cacapon River Watershed of West Virginia. We conclude by evaluating our approach under four main implementation questions: (1) Do high-priority areas identify locations with multifunctional characteristics and represent the land conservation goals and objectives? (2) How successfully were the high-priority areas aggregated to parcels for easement selection? (3) Where are the "best" parcels that fit a conservation budget? (4) How large of a conservation budget is needed to meet a goal of protecting large, contiguous, high-priority areas in the watershed?

2. Method

Our model consists of three components—multicriteria analysis, compromise programming, and cost evaluation (Fig. 1). Parcel level prioritization is essentially a multicriteria analysis problem (Malczewski, 1999). The common procedure for solving multicriteria problems is the integration of an evaluation matrix with a vector consisting of weights corresponding to the assigned priority of the criteria (Jankowski and Richard, 1994; Carver, 1991). The evaluation matrix E and weight vector W can take the following forms:

$$E = \begin{bmatrix} f_{1l} & \cdots & f_{1j} \\ \vdots & & \vdots \\ f_{il} & \cdots & f_{ij} \end{bmatrix}, \tag{1}$$

$$W = (w_1, w_2, \ldots, w_i),$$

where f_{ij} is the evaluation score, J is the set of alternatives, and I is the set of criteria. Each value is expressed with respect to the ith criterion. The basic form of the objective function can be depicted in matrix notation:

$$\begin{bmatrix} A_1 \\ \vdots \\ A_j \end{bmatrix} \text{ function of } \begin{bmatrix} f_{1l} & \cdots & f_{1j} \\ \vdots & & \vdots \\ f_{il} & \cdots & f_{ij} \end{bmatrix} \text{ and } \begin{bmatrix} w_1 \\ \vdots \\ w_i \end{bmatrix}, \tag{2}$$

where A_j is the score for alternative J.

One of the many solving algorithms in the multicriteria literature that can be used to find a possible set of solutions is compromise programming. Compromise programming identifies non-dominated solutions under the most general conditions, allows specified goals, and most important, provides an excellent base for interactive programming (Tecle et al., 1988a). The concept of non-dominance is used in compromise programming to select the best solution or choice of alternative. A solution is said to be non-dominated if there exists no other feasible solution that will cause an improvement in a value of the objective or criterion functions without making a value of any other objective function worse (Tecle and Yitayew, 1990).

The "best" alternative from A_j may not contain the most preferred values for all objectives; it is a compromise solution that is better than all other feasible combinations. In compromise programming, the "best" solution is defined as the alternative that minimizes the distance from a goal point (often the ideal point is used) to the set of efficient solutions (Gershon and Duckstein, 1983; Romero and Rehman, 1989; Zeleny, 1982). Compromise programming algorithms have been used in many different multicriteria evaluation applications, including preference ranking of irrigation technologies (Tecle and Yitayew, 1990), water resource system planning (Duckstein and Opricovic, 1980; Gershon and Duckstein, 1983), developing forest watershed management schemes (Tecle et al.,

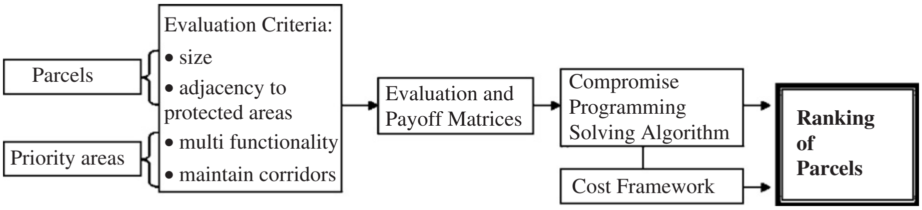

Fig. 1. A parcel prioritization model.