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Ecological Economics 57 (2006) 627–639

ECOLOGICAL ECONOMICS

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ANALYSIS

Incorporating stakeholder preferences for land conservation: Weights and measures in spatial MCA

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Received 7 September 2004; received in revised form 8 May 2005; accepted 20 May 2005
Available online 1 July 2005

Abstract

Spatial multicriteria models may provide an equitable and efficient means for incorporating people's preferences in social decisions. However, in order for these tools to be effective, they should include criteria that are locally relevant and measurable in a spatial framework. This paper integrates measures of stakeholder preferences with GIS data in a spatial multicriteria framework for identifying high-priority areas for land conservation. Individual participants' preference weights were measured using the Analytical Hierarchy Process. Individual preferences were aggregated into groups representing outside experts and local stakeholders. Aggregate preferences differed across groups, illustrating an affinity for local knowledge of stakeholders vs. universal broader issues by outside experts. The mapping of priority areas for conservation was relatively unaffected by the weights, mostly due to the lack of spatial measures for locally relevant criteria.

Keywords: Analytic hierarchy process; Experts vs. local stakeholders; Preference weights; Spatial multicriteria analysis

1. Introduction

Land conservation is becoming increasingly important as natural landscapes, agriculture, and rural characteristics are lost to development (Hymann and Leibowitz, 2000; Worldwatch Institute, 2003). To be effective with preservation activities under limited funding, conservation groups must target high-priority lands by focusing on the integration of sound scientific criteria with support from local residents and land owners. Tools that help maximize consensus and minimize conflict among interest groups can lead to better decisions regarding land conservation programs. Multiobjective or multicriteria analysis (MCA) is a framework that can meet this need. The MCA framework enables the integration of goals, objectives, spatial data, and stakeholder preferences in a systematic method. MCAs can facilitate community-based collaborative decision making by considering multiple attributes while avoiding some of the ethical, theoret-

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0921-8009/$ - see front matter
doi:10.1016/j.ecolecon.2005.05.015

ical, and practical shortcomings of conventional economic approaches (Prato, 1999; Munda et al., 1994).

One of the most important aspects of the MCA framework is its integration of people's preferences for attributes with objective measures of those attributes. It is through this integration that knowledge is incorporated in the framework. Several studies have focused on measuring the preferences of different stakeholder groups for alternative land uses (Duke and Aull-Hyde, 2002; Kline and Wilchems, 1996, 1998; Alho and Kangas, 1997), while other studies have focused on the sensitivity of land suitability coefficients to preference weights derived from a variety of methods (Triantaphyllou and Sanchez, 1997; French, 1986; Hartog et al., 1989; Alexander, 1989; Weber et al., 1988). The preference weights used in an MCA can greatly affect the results (Malczewski, 1999). Triantaphyllou and Sanchez (1997) found that the choice of multicriteria method is less important than the influence of weights on the results of an MCA. Prato (2003) recognized the significance of different preference weights by evaluating the effect of four hypothetical attribute-weighting schemes on his MCA outcomes for ecosystem management of a river system.

Preference weights measured for different land management alternatives or conservation criteria can vary significantly across individuals and across groups these individuals represent. For example, Duke and Aull-Hyde (2002) found different rankings of land conservation objectives across Delaware's three counties based on a random sample of residents. Willett and Sharda (1995) showed the variability in rankings of water management objectives was significantly different among interest groups. Even when preferences are measured as group consensus, Cox et al. (2000) found variability in the rankings of development objectives across counties based on local government and business leaders that served as representatives for their respective counties.

This study focuses on the effect of people's preferences in conjunction with measurability of criteria in a spatial MCA framework that identifies and prioritizes areas for land conservation objectives. Community development projects often supplement 'local' knowledge with 'expert' knowledge by inviting experts external to the community to work with stakeholders internal to the community (Fraser and Lepofsky, 2004). Local knowledge is based on a familiarity with the history and geography of a place, whereas expert knowledge transcends the historical–geographic specifics of a place as a form of universal knowledge (Fraser and Lepofsky, 2004). While local knowledge is important to building consensus or identifying compromise, expert knowledge is often treated as having a universal sense of what is best for any place (Fischer, 2000; Skogen, 2003; Wondolleck and Yaffee, 2000). Experts are often more consistent in expressing their preferences for land conservation objectives; however, their rankings of the objectives may significantly differ from non-experts (Kangas et al., 1993; Kangas, 1994).

Another delineation of stakeholder groups is between the institutional members responsible for managing resources and local residents that are affected by their decisions. Planning agencies often consider themselves to be conduits of the voices of local residents (Fraser and Lepofsky, 2004). However, planning agencies may also be a conduit to resources external to a community (Kubisch et al., 2002). Therefore, even though members of an institution and local residents may share the same local knowledge of a place, institutional members' preferences may be significantly influenced by their relationship with the outside world.

We test for differences in preferences by separating participants into various groups, including outside experts vs. stakeholders and board members vs. local residents. The sensitivity of land prioritization to group aggregate preference weights is tested by comparing suitability indexes across the various groups using an integer mathematical program. We found significant differences in preference weights between outside experts and local stakeholders. However, the spatial MCA outcomes (rankings) were relatively insensitive to these weight differences. This was primarily due to the lack of objective, spatial measures for criteria representing local knowledge of place.

2. Methods

2.1. Model development

Multicriteria analysis (MCA) is the integration of attribute measures for criteria relevant to decision-makers' objectives and measures of decision-makers' preferences. A common aggregation function that combines preference weights (w_i) and criterion scores (x_i) is known as the suitability index S. Weighted linear combination is a common means of calculating the suitability index (Eastman et al., 1995):

$$S = \sum w_i x_i. \tag{1}$$

MCA consists of two primary steps: formulation of an evaluation matrix E consisting of $I*J$ standardized criterion scores (e) for I criteria across J alternatives and a group preference weight vector W consisting of preference weights (w) for each criterion i (Jankowski and Richard, 1994):

$$E = \begin{bmatrix} e_{11} & \cdots & e_{1J} \\ \vdots & \ddots & \vdots \\ e_{I1} & \cdots & e_{IJ} \end{bmatrix}; \tag{2}$$

and

$$W = (w_1, w_2, \ldots, w_I), \qquad \sum_{i=1}^{I} w_i = 1. \tag{3}$$

The basic form of the weighted linear combination model can be expressed as

$$\begin{bmatrix} s_1 \\ \vdots \\ s_I \end{bmatrix} = \begin{bmatrix} e_{11} & \cdots & e_{1J} \\ \vdots & \ddots & \vdots \\ e_{I1} & \cdots & e_{IJ} \end{bmatrix} * \begin{bmatrix} w_1 \\ \vdots \\ w_I \end{bmatrix}. \tag{4}$$

The weighted linear combination method is a straightforward application and can easily be integrated spatially in a geographic information system (GIS) by using raster-based map algebra.

In Eq. (2), E can be measured within a GIS by raster- or grid-based spatial analysis techniques. Typically, all criterion scores are standardized to a common numeric range such as 0–1 or 0–100 before aggregation. Eastman et al. (1995) recommends that all grid layers be represented on an equal range scale aided by representing the presence/absence of a criterion value as 0, 1 or as a range from using a fuzzy membership function (Weerakoon, 2002; Malczewski, 1999). With values represented in equal scales, the GIS grid layers can be used to represent each of the criteria I in a spatial context. The alternatives J comprise the cell locations for the extent of a study area and the values from Eq. (4) represent the suitability S for a location.

To derive values for criteria weights W for Eq. (3), we used the Analytical Hierarchy Process (AHP) as the weight solicitation technique in this study. Our choice of AHP was based on the following reasons:

- The number of criteria made many of the other weighting methods infeasible.
- The AHP method allows for many criteria to be simplified to individual comparison choices.
- The time constraints required each participant to take the test (i.e., perform comparisons) at the same time. AHP could be administered as an individual test.
- AHP has one of the strongest theoretical foundations and the ability to easily incorporate the normalized weights into a GIS ranking model.
- The availability of AHP software made calculations easy and provided many display tools to quickly view results.
- Group and individual comparisons could be made to identify trends and potential trade-offs.

As in Duke and Aull-Hyde (2002), this study extended the use of AHP from a single decision maker to a group of N people. Because of this, the geometric mean is used in place of individual ratings. Obviously it was not possible to sample all watershed residents. Therefore, the issue is not whether there are enough samples to use AHP but whether there are enough samples to accurately represent the watershed's residents.

The following AHP conceptual model is adopted in form and notation from Duke and Aull-Hyde (2002), Kangas (1994), and Triantaphyllou and Mann (1989). The hierarchy used in this study consisted of four main land conservation objectives. From the objectives, criteria were defined and assembled as one matrix for participants to perform pairwise comparisons. The matrix can take the following form:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \tag{5}$$

where a_{mn} is the pairwise comparison rating for criterion m and criterion n. For the pairwise comparisons, Duke and Aull-Hyde (2002) and Saaty (1987) note the axioms of theoretical validity of the comparison matrix A:

- Reciprocal comparison: If $a_{mn}=x$, then $a_{nm}=1/x$ where $x\neq 0$.
- Homogeneity: If characteristics m and n are judged to be of equal relative importance, then $a_{mn}=a_{nm}=1$ for all m.
- Independence: When expressing preferences under each criterion, each criterion is assumed to be independent of the properties of the decision alternatives.
- Expectations: When proposing a hierarchical structure for a decision problem, the structure is assumed to be complete.

The a_{mn} values represent the relative degree of importance of criterion m over criterion n. To combine the responses, the geometric mean has been proven to be an effective method to calculate an overall rating (Benjamin et al., 1992; Schmoldt et al., 1994). With a survey of p respondents, a composite judgment of their a_{mn} values, is the geometric mean of the a_{mn} values which is defined as

$$a^*_{mn} = p\sqrt{\prod_{k=1}^{p} a^k_{mn}} \quad (6)$$

With the geometric averaged a^*_{mn} values, a set of numerical weights $w_1, w_2, \ldots w_i$ may be computed to represent the relative degree of importance assigned to each criterion. The numerical weights sum to 1, a useful outcome when combining the spatial data layers in a GIS (Eastman et al., 1995).

3. Application

3.1. Objectives and criteria

The Cacapon River Watershed in West Virginia (Fig. 1) is under development pressure from the nearby metropolitan Washington, DC, area. The natural features and rural character of the watershed are threatened by urban sprawl and subdivision of land. The Cacapon Land Trust (Land Trust) is a local land conservation group interested in prioritizing areas in the watershed for future easements. From the overall goal to preserve lands in the Cacapon Watershed, the

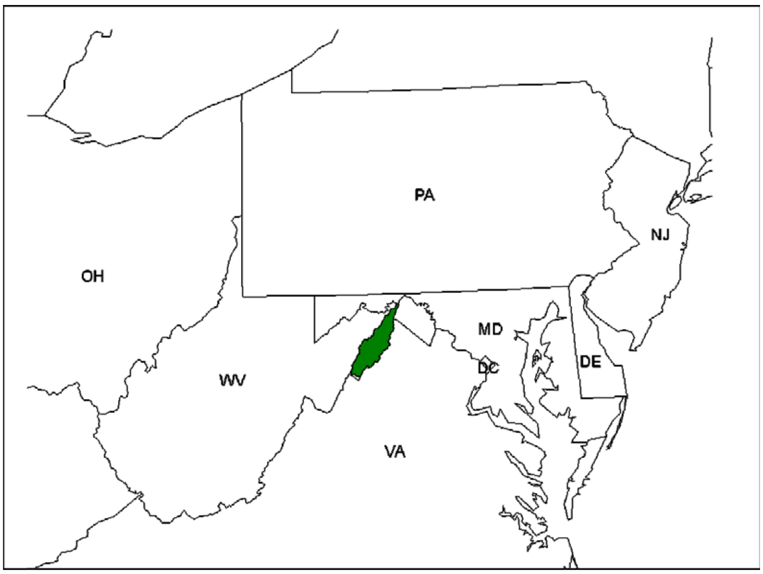

Fig. 1. Cacapon River Watershed in West Virginia.

Land Trust crafted the following mission statement; "The Cacapon Land Trust will assist landowners and their communities to maintain healthy rivers, protect forests and farms, and preserve rural heritage for the enjoyment and well being of present and future generations." This mission statement (goal) led to the resource values (objectives) the Land Trust wanted to protect. These included protection of agriculture (AG), forests (FOR), water quality (WQ), and rural heritage (RH). These four objectives provided a holistic view of land stewardship that includes biological, social, and economic interests.

Evaluation criteria for the objectives were derived from an organized meeting of Land Trust board members, residents from the targeted watershed, and outside experts. The outside experts consisted of regional professionals in related fields and included resource managers, biologists, and scientists. The meeting focused on defining evaluation criteria for each of the four objectives (AG, FOR, WQ, RH). Regardless of their affiliation, participants worked under the objective that best represented their interests, specialty or expertise. Brainstorming and nominal group techniques (Schmoldt et al., 1994; Taylor, 1984) were used to help develop a list of criteria for prioritizing lands for protection. The MCA hierarchy of the goal, objectives, and criteria are summarized in Table 1.

3.2. Weight solicitation

Using the complete list of criteria, a survey was administered to each individual. In order to minimize problems with path dependency (Saaty, 1987), the criteria were presented to participants in a randomly ordered, abbreviated pairwise comparison format. In an abbreviated format, all possible pairings of the criteria are not presented to the participant. Instead, pairs are sequentially assigned as A–B, B–C, C–D, etc., where the initial criterion and the second criterion in each subsequent pair are randomly assigned. A complete ranking of criteria is based on the actual choices made and assuming transitive preferences. Peterson and Brown (1998) show people are transitive in their preferences revealed through a method of paired comparison. Consistency ratios, as measures of consistent (transitive) preferences, are redundant when transitivity is assumed as in the case of the abbreviated pairwise comparison format.

Table 1
MCA hierarchy for prioritizing lands

Goal	The Cacapon Land Trust will assist landowners and their communities to maintain healthy rivers, protect forests and farms, and preserve rural heritage for the enjoyment and well being of present and future generations.			
Objectives	Agriculture	Forest	Water Quality	Rural Heritage
Criteria	• Farms within viewsheds	• Large contiguous forested land	• Riparian forested areas	• Valuable farm lands
	• Prime farmland soils	• Single ownership (private) of forested land	• Lands in proximity to protected areas	• Sustainable timber lands
	• Farms with unique features	• Forest biodiversity and condition	• High-quality floodplains, wetlands, and streams	• Significant plant and wildlife habitats and special natural areas
	• Size of farms	• Forests threatened to conversion	• Groundwater recharge areas	• Scenic viewsheds and scenic corridors
	• Contiguity with other farmlands	• Economic viability and sustainable forests	• Grassy riparian buffers	• Historic and prehistoric sites
	• Working family farms		• Headwater streams	• Culturally significant places
	• Farms with economic sustainability			• Encouraging stewardship by community
	• Farms threatened to development			• Rural lifestyles and traditions
	• Farms that use best management practices			• Natural streams, high-quality water
	• Farms with sustainable practices			• Scenic places
				• Recreational land use

A relative importance scale for measuring intensity of preferences was used in this survey. However, we employed a reduced form of the traditional nine nominal values to reduce the cognitive burden of participants. Table 2 crosswalks the nine traditional values to the four intensity of preference nominal values used in our survey, including "equal, " "somewhat prefer," "prefer," and "strongly prefer." Fig. 2 shows an example of the abbreviated pairwise survey used in this study.

Criterium Decision Plus (Info Harvest, 2000) software was used to summarize the pairwise comparisons from each participant. Criterium Decision Plus provided a complete ranking of criteria with preference weights.

The participants in this study were treated as the decision makers. Their aggregated individual weights would serve as the criteria weights for the analysis. Traditionally, AHP is applied on a single decision maker or a small decision making group. The participants in this study represent a small, but not random, sample of stakeholders and outside experts.

3.3. Tests of statistical differences

The weights from the AHP test were analyzed to determine if the individuals could be grouped based on their affiliations, and if so, whether the groups' preferences were substantially different from each other, on which criteria they differed, and the spatial implications of these differences. If the variation in individual responses is too great within a group, the median value should not be used to represent the group (Bantayan and Bishop, 1998).

We defined the groups based on participants' affiliation as either an outside expert or a stakeholder. As mentioned previously, outside experts consisted of regional professionals who worked in the fields of agriculture, water quality, rural heritage, or forestry as resource managers, biologists, or scientists. Stakeholders consisted of landowners or full-time residents of the watershed. The stakeholder group is comprised of both board members and local residents.

Friedman's Q statistic (a nonparametric, two-way analysis of variance by ranks statistic) (Siegel, 1954) is used to test for statistical differences of intra-group and inter-group preference weights. Bantayan and Bishop (1998) applied this statistic to test for intra-group differences among their decision makers. The null hypothesis for the intra-group comparisons states that the preferences of members i in a group (y) represent a population (P_y). The alternative hypothesis states that intra-group members are not from the same population (i.e., preferences significantly differ across the group members). Formally, this hypothesis test may be written as

$$\begin{aligned} H_0 &: \; y_i = P_y \quad \forall i \in P_y \\ H_1 &: \; y_i \neq P_y \quad \forall i \in P_y \end{aligned} \tag{7}$$

The inter-group comparisons test whether the preferences comprising a group (P_y or P_z) are from the same population P. Formally, this hypothesis test can be written as

$$\begin{aligned} H_0 &: \; P_y = P_z \quad y_i \in P_y; \; z_i \in P_z; \; y \neq z \\ H_1 &: \; P_y \neq P_z \quad y_i \in P_y; \; z_i \in P_z; \; y \neq z. \end{aligned} \tag{8}$$

The inter-group comparisons are restricted to the pairs of outside experts vs. stakeholders and board members vs. local residents. Membership in a group is mutually exclusive within the inter-group comparisons (e.g., an individual is either an outside expert or a local stakeholder, and within the stakeholder group, an individual is either a board member or a local resident).

Friedman's Q statistic is

$$Q = 12/[Nk(k+1)]^* \sum_{i=1}^{k} R_i^2 - 3N(k+1) \tag{9}$$

where N is the number of individuals, k is the number of criteria and R_i^2 is the square of the rank sum asso-

Table 2
Traditionally pairwise intensities and simplified choices used in this study

Traditional pairwise intensities	Simplified choices[a]
Equal	Equal
Barely prefer	
Weakly prefer	Somewhat prefer
Moderately prefer	
Definitely prefer	
Strongly prefer	Prefer
Very strongly prefer	
Critically prefer	
Absolutely prefer	Strongly prefer

[a] The simplified choices were used in this study based on the difficulty test respondents experienced in distinguishing between intensities with the 9-point traditional scale. The 4-point scaling system was adopted to reduce the cognitive burden.

Name____________________________________

For each paired choice below, fill in the circle to indicate which criteria is more important (or equal) in preserving lands in the Cacapon River Watershed

criteria	strongly prefer	prefer	somewhat prefer	equal	somewhat prefer	prefer	strongly prefer	criteria
Farms threatened for develment	O	O	O	O	O	O	O	Farms that use best mgmt prac
Farms that use best mgmt prac	O	O	O	O	O	O	O	Large contiguous forested land
Large contiguous forested land	O	O	O	O	O	O	O	Community stewardship land
Community stewardship land	O	O	O	O	O	O	O	Sustainablity/econ/viabile forests
Sustainablity/econ/viabile forests	O	O	O	O	O	O	O	Farms within viewsheds
Farms within viewsheds	O	O	O	O	O	O	O	Single owners of forested land
Single owners of forested land	O	O	O	O	O	O	O	High quality floodplns, wetl, strms
High quality floodplns, wetl, strms	O	O	O	O	O	O	O	Lands that maintain rural lifestyle
Lands that maintain rural lifestyle	O	O	O	O	O	O	O	Headwater (1st,2ndorder) streams
Headwater (1st,2ndorder) streams	O	O	O	O	O	O	O	Historic / prehistorical sites
Historic / prehistorical sites	O	O	O	O	O	O	O	Prime farmland soils
Prime farmland soils	O	O	O	O	O	O	O	Lands near protected areas
Lands near protected areas	O	O	O	O	O	O	O	Grassy riparian buffers
Grassy riparian buffers	O	O	O	O	O	O	O	Size of farms
Size of farms	O	O	O	O	O	O	O	Farms practicing sustainablity
Farms practicing sustainablity	O	O	O	O	O	O	O	Threatened forest lands
Threatened forest lands	O	O	O	O	O	O	O	Economic sustainability
Economic sustainability	O	O	O	O	O	O	O	Contiguity of farms to other farms
Contiguity of farms to other farms	O	O	O	O	O	O	O	Scenic places
Scenic places	O	O	O	O	O	O	O	Groundwater recharge areas
Groundwater recharge areas	O	O	O	O	O	O	O	Culturally significant places
Culturally significant places	O	O	O	O	O	O	O	Sustainable timber lands
Sustainable timber lands	O	O	O	O	O	O	O	Riparian forested areas
Riparian forested areas	O	O	O	O	O	O	O	Working family farms
Working family farms	O	O	O	O	O	O	O	Lands with recreational uses
Lands with recreational uses	O	O	O	O	O	O	O	Valuable farm lands
Valuable farm lands	O	O	O	O	O	O	O	Scenic corridors
Scenic corridors	O	O	O	O	O	O	O	Significant plant and wildlife habi
Significant plant and wildlife habi	O	O	O	O	O	O	O	Farms with unique features
Farms with unique features	O	O	O	O	O	O	O	Forest biodiversity

Fig. 2. Abbreviated pairwise test administered to each participant.

ciated with the kth criterion (Siegel, 1954). Friedman's Q statistic is distributed as a Chi-squared with $k-1$ degrees of freedom. The data for Eq. (9) are extracted from the ranks of the criteria among the participants that made up each of the four groups (outside experts, stakeholders, local residents, board members). We adjusted the ranks for ties by performing the RANK function option in EXCEL (Microsoft, 2002).

Friedman's Q statistics provide information on whether group members comprise a homogeneous unit or group and whether the groups differ from each other. However, the statistic does not provide information on which criteria the group members' preferences may differ. Therefore, the nonparametric Mann–Whitney U-test is used to test for statistical differences of preference weights for each criterion across groups (Kachigan, 1986; Siegel, 1954). The null hypothesis of Eq. (10) states that the aggregated preference weight for individuals i in group y are equal to the aggregated preference weight for individuals i in group z for criterion k. The alternative hypothesis (Eq. (10)) states they are not equal.

$$\begin{aligned} H_0 &: \; w_{iy}^{k} = w_{iz}^{k} \quad \forall i \in (y,z);\; y \neq z \\ H_1 &: \; w_{iy}^{k} \neq w_{iz}^{k} \quad \forall i \in (y,z);\; y \neq z. \end{aligned} \tag{10}$$

The Analyse-IT (General and Clinical Laboratory Statistics, 2000) software for Microsoft Excel aided computation of the Mann–Whitney U statistics.

4. Results

4.1. Intra-group differences

Friedman's Q statistics for the intra-group comparisons are reported in Table 3. Three out of the four groups failed to reject the null hypothesis of similar preferences. These groups included the stakeholders, board members, and local residents. Only the outside expert group statistic rejected the null hypothesis of similar preferences. This result was expected in that the outside experts were selected for their expertise in one of the four categories of agriculture, forestry, water quality or rural heritage. Their areas of expertise were reflected in their preference weights for the various criteria. Therefore, individual assignments to the stakeholder, board member, and local resident groups were confirmed based on homogeneity of preferences. Outside experts were assigned as a group more for who they represented than the homogeneity of their preferences.

4.2. Inter-group differences

Inter-group differences tests are also reported in Table 3. Based on Friedman's Q statistics, we reject that outside experts and local stakeholders are from the same population. However, we fail to reject that board members and local residents are from the same population based on their individual members' preference weights because they share local knowledge. The board members vs. local residents test is redundant to the intra-group preferences test for stakeholders given that the former two groups comprise the latter. This result is not surprising since board members are also local residents. Their official capacity as board members does not seem to override their personal knowledge of the issues as local ones.

4.3. Criterion weight differences

Table 4 provides the results of the Mann–Whitney U-tests of statistical difference across group for each criterion. Only those criteria that are statistically dif-

Table 3
Summary of Friedman's Q statistics

	Intra-group comparison				Inter-group comparisons	
	Stakeholders	Outside experts	Board members	Local residents	Stakeholders vs. outside experts	Board members vs. local residents
Statistic	41.756	14.127	42.343	28.853	183.512	41.756
Significance	0.235	0.000	0.216	0.790	0.000	0.235
N	11	20	6	5	31	11

The test statistic is distributed as a Chi-squared with 36 degrees of freedom for each test. Stakeholders and Board Members vs. Local Residents tests are identical given that Stakeholders is equivalent to the sum of Board Members and Local Residents.

Table 4
Statistically different criteria and the aggregated group weights

Criterion	Outside experts	Local stakeholders
Scenic places or corridors*	0.0107	0.0100
Culturally significant places**	0.0138	0.0027
Lands that maintain a rural lifestyle*	0.0049	0.0154
Lands that encourage stewardship by community*	0.0115	0.0202
Farms threatened for development**	0.0096	0.1144
Size of farms*	0.0063	0.0098
Single owners of forested land*	0.0051	0.0115
Sustainable economic viable forests*	0.0108	0.0209
Farms with unique features**	0.0178	0.0074
Forest biodiversity*	0.1071	0.0345
High-quality floodplains, wetlands, streams*	0.0187	0.0384
Farms within viewsheds**	0.0031	0.0134
Prime farmland soils*	0.0070	0.0204
Lands near protected areas*	0.0184	0.0237
	Board members	Local residents
Lands near protected areas*	0.0330	0.0126
Contiguity of farms to other farms*	0.0165	0.0044
Grassy riparian buffers**	0.0608	0.0108

H_0: $w_{ik} = w_{jk}$; * and ** refer to statistical differences significant at $\alpha = 0.1$ and 0.05, respectively.

ferent are reported in Table 4. In total, 14 out of the 32 total criteria were statistically different in their aggregate preference weights expressed by the outside experts group and the local stakeholders group. Four of the 14 criteria were statistically different at the 0.05 level and 10 were statistically different at the 0.10 level. Most notably, out of the statistically different aggregate preference weights for the two groups, outside experts gave a high weight to forest biodiversity while local stakeholders weighted the farms threatened by development criterion high.

For board members vs. local residents, 2 out of the 32 criteria were statistically different at the 0.10 level with an additional criterion being statistically different at the 0.05 level. The three criteria that were significantly different between the board members and local residents were all considered to be more important to prioritizing lands by the board members than by the local residents on average.

4.4. Spatial effects of preference weights

Many of the defined criteria were difficult to measure and therefore incorporate into a spatial prioritization model. Examples of these criteria include those that are subjective (i.e., socially and culturally defined) in nature such as features that are “scenic”, “culturally significant”, “rural lifestyle”, or “encouraging stewardship”. In addition, some of the criteria are also very site-specific in scale and cannot be measured without parcel level data or land ownership information. Examples of site-specific criteria include size of farms and single owners of forested land. From the original list of thirty-two criteria, eleven were included in the final GIS ranking model. Seven of these eleven criteria also resulted in statistically different preference weights across the outside expert vs. local stakeholder groups and/or the board member vs. local resident

Table 5
Criteria and weights used in ranking model

Criterion	All participants	Outside experts	Stakeholders	Board members	Local residents
Large contiguous forested land	0.2257	0.2364	0.2150	0.2367	0.1890
Riparian forested areas	0.1143	0.1308	0.0977	0.0603	0.1426
Forest biodiversity[a]	0.0708	0.1071	0.0345	0.0355	0.0334
Significant plant and wildlife habitat	0.0492	0.0595	0.0389	0.0275	0.0526
Prime farmland soils[a]	0.0440	0.0443	0.0437	0.0445	0.0428
High quality floodplains, wetlands, streams[a]	0.0285	0.0187	0.0384	0.0382	0.0386
Lands near protected areas[a,b]	0.0210	0.0184	0.0237	0.0330	0.0126
Grassy riparian buffers[b]	0.0205	0.0029	0.0381	0.0608	0.0108
Contiguity of farms to other farms[b]	0.0195	0.0280	0.0110	0.0165	0.0044
Headwater streams	0.0161	0.0126	0.0196	0.0223	0.0164
Farms within viewsheds[a]	0.0082	0.0031	0.0134	0.0135	0.0132

[a] Aggregated preference weights statistically different between Outside Experts and Local Stakeholders.
[b] Aggregated preference weights statistically different between Board Members and Local Residents.

groups (Table 4). Only 5 of the 14 significantly different criteria weights between the outside experts and local stakeholders were included in the prioritization model. The lack of objective, spatial measures of these criteria prohibited their integration in the model. All three of the statistically differently criteria weights between the board members and local residents were included in the model.

Seven maps of high-priority locations were created by integrating different preference weights with the GIS data layers using the weighted summation technique (Eq. (1)). High priority is defined as the top third of the mapped locations. Different preference weights were used across the seven maps, including one for each of the four groups (outside experts, local stakeholders, board members, and local residents), an aggregate of all participants' weights, and two weighting schemes testing the sensitivity of the model to preference weights (no weights and inverted aggregate participants' weights). Table 5 reports the aggregate preference weights for each of the four groups and all participants group. The last three map comparisons were designed to determine how sensitive high-priority areas were to having any weights in the model and the sensitivity of the high-priority areas to the weights from all individuals.

Table 6 provides a summary of the spatial comparison between the various weighting schemes. The high-priority locations were compared across the various weighting schemes. A comparison of no weights or inverted weights vs. all participants' aggregate weights show that weights matter; i.e., the spatial MCA without weights or with inverted weights is inaccurate. In a spatial MCA, specification of weights is an important and necessary component of the model. Basically, the maps only have 9% of the high-priority locations in common depending on how weights were (or were not) incorporated into the model. The insensitive areas to preference weights could be attributed to several spatial layers at that location or to limitations in the linear weighted model from numerous combined data sets (Fig. 3).

There are various methods of combining data including a weighted sum of normalized input layers with associated weights, maximization models that note the most important characteristic at a spatial location by cell, or a goal achievement algorithm (Pettit, 2002). Based on the method used, errors can be introduced that limit the usefulness of results for implementation (Chrisman, 1987; Veregin and Hargitai, 1995; Lodwick et al., 1990; Huevelink et al., 1989; Yoon, 1989). It is quite possible that our sensitivity results would differ depending on the method used to combine the data layers. Further examination of the comparisons should be done with a different weighted summation model such as the goals achievement method (Hill, 1968) and part/whole percentaging (Nagel and Long, 1989).

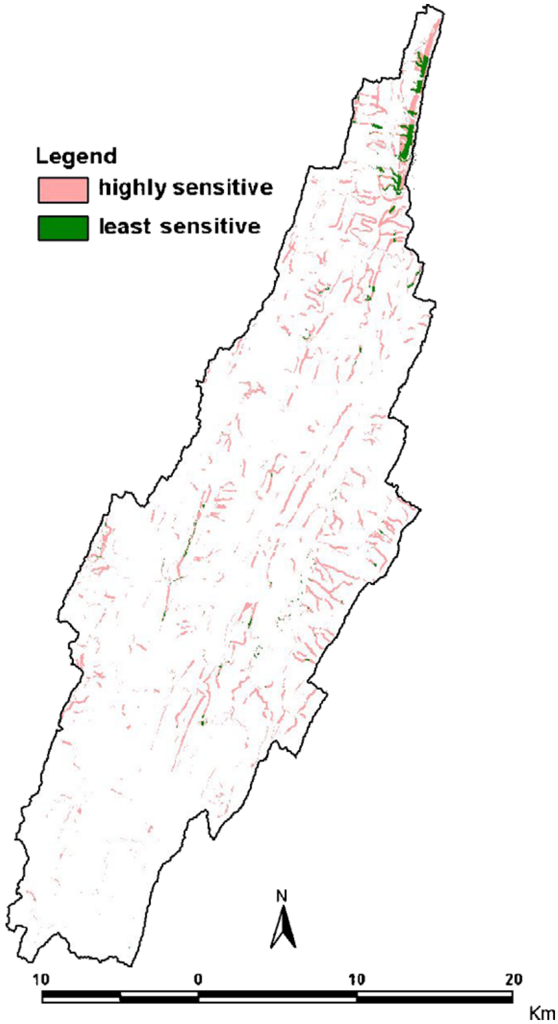

Fig. 3. Spatial sensitivity to preference weights.

Even though the outside experts' vs. local stakeholders' aggregate preferences were statistically different for 4 of the 11 criteria, it still resulted in 76% of the same high-priority locations. Conversely, even though

Table 6
Comparison of mapped high-priority areas

	Outside experts vs. stakeholders weights	Board members vs. local residents weights	All participants vs. no weights	All participants vs. inverted weights
Areas in common				
%	76	47	9	9
Hectares	10,554	9095	1041	1042
Different				
%	24	53	91	91
Hectares	3244	10,155	10,299	10,173

there was strong agreement between the board members and local residents preferences, they only had about half of the high-priority locations in common.

5. Discussion and conclusions

The Analytical Hierarchy Process is an efficient and effective means at measuring people's preferences for land conservation criteria. Thirty-one participants were able to convey their preferences for 37 criteria in a short amount of time while maintaining a strong theoretical foundation over other ranking or rating methods (Malczewski, 1999). Integration of measured preferences as weights in a spatial multi-criteria analysis framework fostered a strong sense of ownership in the decision making process for participants in this study (N. Ailes, personal communication, 2003).

However, whose preferences count is a debatable issue. Outside experts bring universally relevant knowledge to decisions (Fraser and Lepofsky, 2004), but these experts often lack place-specific knowledge (Fischer, 2000; Skogen, 2003). Factors of local relevance or importance are often overlooked or not recognized by outside experts. We found that outside experts' aggregate preferences were significantly different than local stakeholders' aggregate preferences. Outside experts rated broadly relevant criteria significantly higher than local stakeholders. This indicates a potential education or information gap in which the outside experts could inform the stakeholders of the importance of these criteria in land prioritization.

Conversely, local stakeholders rated several criteria that are generally place specific in nature higher than outside experts. It is through local residents' intimate knowledge of certain characteristics or features that motivates their expression of relative worth. Outside experts rated these locally relevant features low either because they were unaware of them or the features did not correspond to their universal knowledge base.

We found 14 significantly different criteria between outside experts and local stakeholders but only four of the criteria had objective, measureable features that could be represented in the spatial MCA model. This limitation contributed to a lack of spatial sensitivity when comparing the preferences from the outside experts and local stakeholders. Consequently, since all three of the statistically different criteria between the board members and local residents were represented in the spatial MCA model, we found more spatial sensitivity of the high-priority areas.

The unmeasurable criteria for this study were either subjective characteristics that are hard to measure (e.g., culturally significant places, lands that encourage stewardship by community, and lands that maintain a rural lifestyle) or physical characteristics that lacked GIS data (e.g., size of farms, sustainable economic viable forests, farms with unique features, and farms on prime soils). It is believed that if the difficult to measure criteria were used as inputs in the ranking model, the mapping of high-priority areas would take a different form. The objective, yet unmeasured criteria likewise would have affected the spatial sensitivity to preference differences. Data collection efforts, including the use of tools and techniques for quantifying subjective (i.e., socially and culturally defined) characteristics of land, would greatly improve the validity of a spatial multicriteria analysis model.

These results demonstrate the gaps in information that may be critical to identifying high-priority areas through implementation of a spatial multicriteria analysis. We believe we would have seen more spatial difference if the objective features for the criteria were represented specifically between the outside experts and the local stakeholders. It should be noted that this result is highly likely to be observed elsewhere. Criteria matter to local stakeholders and are not easily measured; e.g., place attachment, sense of place, local knowledge. These are often the most important criteria (but overlooked by an outside expert's preferences) in satisfying local needs/preferences.

Utilities can be developed that allow decision makers to have direct input into the goals, objectives, criteria, and attributes in spatial MCA models; i.e., a 'bottom–up' approach to decision making that empowers local stakeholders. However, an important question is how best to measure or represent criteria that are important to stakeholders and should be included in spatial MCA studies? The answer is not an easy one. Our study design specifically allowed an open listing of criteria for conserving lands by the participants regardless if the GIS data set would be available or measurable in the watershed. We did not want to miss the opportunity to capture a landscape characteristic for conservation that a participant may have conveyed if they were required to only consider currently available or mappable data sets.

Another reason we took this approach was to help define appropriate future data needs or studies. One important local data need or study is to identify farms that are threatened by development or conversion from agriculture to residential land use. Other important criteria are the objective features of where the landscape provides especially scenic qualities or culturally significant characteristics.

Spatial MCA can simplify complex decisions; however, it is equally important to identify limitations to the method to prospective users. Changes in rankings are a function of unmeasured criteria that are important to local stakeholders, an issue that outside experts cannot adequately address. Second, consensus is meant to be an educational tool to raise awareness of local stakeholders to universal, broader issues. Only through local stakeholders can those things most important to them be accounted. Thus, we are really talking about a form of discursive democracy in which people's preferences for local and universal knowledge are explored and refined (Sagoff, 1998). Spatial MCA provides just as much insight with the process as it does with final rankings. It is best when used to aid in the decision-making process and not as the only or final approach. With more insight into the landscape factors and processes that influence priority rankings, time and effort can be directed to using data and preferences to aid in planning and decision making for conservation.

Acknowledgements

We acknowledge the funding support for this study that was provided by the West Virginia University Agriculture Experiment Station and the Canaan Valley Institute. In addition, we owe gratitude to the Cacapon Lands Trust and the many participants who provided the information for this study. The paper also benefited from comments by anonymous referees.

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