Appl. Spatial Analysis
DOI 10.1007/s12061-011-9072-x

Values Compatibility Analysis: Using Public Participation Geographic Information Systems (PPGIS) for Decision Support in National Forest Management

Greg Brown · Pat Reed

Received: 24 January 2011 / Accepted: 19 October 2011

Abstract Human values are embedded in forest management decisions but are rarely systematically and explicitly included in the decision process. National legislation for public lands often provides conflicting goals but little guidance for agencies such as the U.S. Forest Service to operationalize public value preferences. The historical difficulty of integrating public values into forest management decisions includes the problems of measurement, aggregation, and tradeoff analysis. In this paper, we present a method for measuring and integrating spatially-explicit public values collected using public participation geographic information systems (PPGIS) into a decision support framework we call values compatibility analysis (VCA). We provide a case study to demonstrate how spatially-explicit public values can be used to determine the compatibility of designating ATV/OHV routes on national forest land. The applications and limitations of VCA for decision support are elaborated and we conclude that an effective decision support framework should provide some degree of standardization, be broadly inclusive, and provide the opportunity to engage in systematic place-based value trade-off analyses.

Keywords Public participation GIS · PPGIS · Forest management · Decision support

Introduction

Planning decisions for public lands in general, and forest lands in particular, are inextricably linked to geographic areas that humans identify with, depend on, and often associate multiple values and meanings. Lurking behind each governmental land use decision are important questions about the *people* that were included in the decision, the *process* that was followed, the *information* that was collected, the *decision criteria*

G. Brown (✉)
University of Queensland, Brisbane, QLD 4101, Australia
e-mail: greg.brown@uq.edu.au

P. Reed
USDA Forest Service, Anchorage, AK 99503, USA
e-mail: preed01@fs.fed.us

Published online: 04 November 2011

that were applied, and the specific *rules* for using the decision criteria such as ranking or weighting. Optimistically, some of the answers to these questions may be disclosed in a formal agency record-of-decision. However, public forest decisions often involve deeper, unspoken questions about social and political values. For example, what values should be considered in the decision? Whose values should count? Whose should not? How should different individual and collective values be ranked, weighted, and integrated in the decision? What is the process to adjudicate irreconcilable value differences? Are the preferences of local residents inherently more important than more distant residents or visitors? What are the government's obligations to seek out public values in the decision? Is expert judgment about the forest more important than local or lay experiences with the forest?

Legal statutes regarding forest planning seldom provide responsible decision makers with specific guidance regarding these important questions. In the case of public forest management in the United States, national legislation provide broad, sometimes conflicting goals resulting from political compromise that invariably push down controversial decisions about forest management for administrative agencies to resolve. National legislation imposes some constraints on the decision process such as requiring the development of long-range plans for national forests, providing adequate public notice, and disclosing the potential human and environmental impacts of various forest plan alternatives. But mandating public access, disclosure, and even consideration of the potential impacts of a planning decision by itself provides little guidance on how agencies can or should operationalize that direction to consider the multiple and often competing visions for public forests that are grounded in value hierarchies and preferences. The requirement that administrative agencies use rational-comprehensive or synoptic decision processes to guide decision-making does not avoid the inevitable conflict over decisions that are linked to specific places that people value for variety of reasons. Agency efforts to integrate public values into the forest management process have not been widely successful, and systematic approaches nearly nonexistent. Alternative dispute resolution (ADR) processes may be successful in some forest planning outcomes, but unfortunately, these interventions usually occur later, rather than earlier in the planning process.

Ideally, what is needed to augment current forest planning efforts is a decision support framework that is grounded in the rational-comprehensive model, is broadly inclusive of individuals and groups, and provides guidance regarding the breadth and intensity of public forest values. The historic difficulty for integrating public values into forest management decisions has involved the problems of measurement, aggregation, and tradeoff analysis.

Measurement The measurement of public values for managing national forests has seldom been systematic and is best characterized as ad hoc. Although academic researchers have shown interest in developing and applying forest value typologies and scales (e.g., Rolston and Coufal 1991; Bengston and Xu 1995; Manning et al. 1999; Brown and Reed 2000; Tarrant et al. 2003), there is no widely accepted or adopted forest values scale used by public forest management agencies worldwide.

Aggregation Aggregating forest values through stakeholder groups or other organized interests in a forest planning process can mask important public forest value hierarchies. The rules and rationale for individual aggregation from within or between stakeholder groups in a forest planning process are seldom well-defined or explicit. The problem of aggregation is further compounded with the knowledge that stakeholder groups, attendees at public meetings, and individuals that comment on forest plan decisions in the scoping or impact review planning phases may not be broadly representative of larger populations. While many consider members of the general public to be de facto stakeholders in public forest decisions, there are relatively few examples where public values have been systematically measured in representative samples of regional and national populations. As a result, the natural tendency is to give greater weight to known and vocal interest groups in a decision process rather than the values of the unknown, silent majority of the public.

Trade-off Analysis Although individual preferences for forest management decisions might be logically inferred from forest values, these inferences are seldom made explicit, nor are the rules for weighting or ranking different public forest values in the decision process. For example, an individual that strongly values the diverse native flora and fauna of an area might logically oppose the designation or conversion of the area to plantation forestry. Similarly, an individual that values forest products for their economic contribution could reach the opposite conclusion. Even if the different types of forest values could be measured and aggregated, it is not self-evident that one set of forest values should necessarily trump the other set based on a simple majority principle. Nonetheless, even a majority values approach would be an improvement over existing forest management decisions where decision makers can only speculate about silent majority preferences. The key point is that value tradeoffs should be transparent in the decision process.

The essential qualities of a decision support framework for forest planning should therefore include valid measures of public forest values, an expansive and inclusive public involvement process, the use of spatial technology to geo-reference forest values, and a set of decision heuristics that explicitly link public forest values to prospective forest plan decisions.

The Forest Management Context—National Forest Planning in the U.S.

The National Forest System (NFS) in the United States comprises about 193 million acres (approximately 78 million hectares) divided into 155 national forests and 20 national grasslands. These public lands hold multiple values and meanings for American society and the uses of these lands have been contested historically since their inception as forest reserves. Multiple generations of Native Americans and immigrants have forged special, deep, and often conflicting values for these national forests. As a result, national forest management has been a process marked by conflicting values and ambiguous or contested goals at multiple scales of analysis, from the individual national forest to the NFS as a whole.

The traditional rational-comprehensive forest planning model that locates primary planning and management activity at the national forest unit has not often performed well under these conditions, and particularly when multiple forest values have no ready means of quantification and aggregation. For a variety of reasons, many related to value differences, every one of the 96 national forest plans completed through 1996 had been appealed (Kaiser 2006). The U.S. Forest Service (Forest Service), the administrative agency responsible for developing and implementing national forest plans, currently lacks formal protocols to cope with these “wicked” value-related management issues. Since inception of the requirement to develop forest management plans under the 1976 National Forest Management Act (NFMA), there has been little, if any, practical advancement in (1) systematic inventory and mapping of place-specific forest values the public attaches to national forests, or (2) rigorous and replicable analysis of place-specific forest value data to assess forest plan decisions for consistency with public values—much less in a manner that is helpful to forest planners and capable of withstanding legal challenges in the 1970 National Environmental Policy Act (NEPA) process. All national forest plans are subject to the disclosure of environmental impacts under NEPA.

Place-Based Values and Special Places With national forest conflict centered on conflicting forest values from individuals and groups, national forest planning provides an important but challenging opportunity to develop a decision framework for integrating place-based forest values to help diffuse conflict. Substantial funds are spent on forest planning, but the primary source of information about public values and preferences for land management planning outcomes comes from the NEPA public review process that is not scientifically rigorous nor statistically representative of public values. A preponderance of comments to forest planners and managers may come from a vocal few who represent their own interests, or the interests of a specific user group, to the exclusion of the interests of other, potentially conflicting uses. In lieu of reliable, scientific data about public values, forest managers will sometimes make erroneous assumptions about public values leading to suboptimal forest plan decisions.

Forest Values Operationalization An important premise of a place-based, forest plan decision support system is that the concept of value provides a natural connection between place and decision-making. The human valuing process is complex with multiple meanings of the “value” concept. Brown (1984) classified the realm of values into three categories: held values, assigned values, and relationship values, with preference relationships providing the linkage between held and assigned values. Brown (1984) defines value as the feeling or experience that emerges from a person’s preference for an object in a given context.

In the earliest national forest planning application that explicitly examined forest values, Brown and Reed (2000) asked individuals to identify the spatial location of forest values in the Chugach National Forest (Alaska). The starting point for the selection of a forest value typology was based on conceptual work by Rolston and Coufal (1991), who identified 10 basic forest values: life support, economic, scientific, recreation, aesthetic, wildlife, biotic diversity, natural history, spiritual, and intrinsic. This values typology was modified and expanded from 10 values to 13 values by including subsistence, cultural, and therapeutic values, the latter 2 based upon earlier “taxonomies” described by Roslton (1988). The forest values and their definitions used are broad enough to cover a wide range of geographic settings and spatial scales, and to date, all have been used by at least some respondents in survey research. In subsequent national forest applications of the values mapping method, a category of "special places" was added to identify place-based values that individuals did not feel were expressed in the pre-defined values typology or alternatively, to emphasize multiple values in a given location. An additional benefit of mapping special place locations separately is that it provides a means to examine inter-rater reliability in the placement of predefined forest values.

To operationalize the measurement of forest values, individuals are provided with electronic or paper sticker dots (points) representing the different values and a map of the national forest. In the cognitive process of selecting one of the values and spatially locating the value on the forest map, individuals are expressing preference relationships that link their held values with the place-based context in the national forest. This operationalization appears consistent with Brown's (1984) conception of the human valuing process that links held values to object values through relationship or felt values in the process of mapping the values. This method also appears consistent with the transactional concept of human-landscape relationships (Zube 1987) where humans are active participants in the landscape—thinking, feeling and acting—leading to the attribution of meaning and the valuing of specific landscapes and places. When an individual places a value marker on a place location, the relationship between the individual and place becomes explicit. In the measurement of forest values, we have not attempted to parse the influence of held values (based on life experiences) from assigned values (based on object attributes) as the process of mapping landscape values and special places is best viewed as relational and holistic. Further, the difference between held and object values is likely indistinguishable to the public for the purposes of forest planning.

Public Participation Geographic Information Systems The linking of geographic information systems (GIS) technology with public participation processes for national forest management is a type of public participation geographic information system (PPGIS). In the late 1990's, social researchers developed PPGIS methods to capture place-based information for land use planning (see Sieber 2006; Sawicki and Peterman 2002; and Brown 2005 for a review of PPGIS applications). For example, landscape values were mapped in marine and coastal areas in Prince William Sound (Alaska) to assist nongovernmental organizations in developing a conservation strategy for protection of the Sound by identifying conservation "hotspots." Subsequent analysis of the values data provided opportunities to compare "expert" with "lay" or public conservation priorities (Brown et al. 2004).

Additional applications of the PPGIS methods identified the location of highway corridor values in Alaska to assist in the designation, planning, and management of national scenic byways (Brown 2003); the measurement of landscape values and special places in Kenai Peninsula coastal areas in Alaska to identify "coupled social-ecological" hotspots where human and biophysical systems are closely linked (Alessa et al. 2008); the measurement of preferences for tourism and residential development on Kangaroo Island, a popular tourism destination in South Australia (Brown 2006); the identification of priority areas for conservation in the Otways Region of Victoria, Australia (Raymond and Brown 2007) and the Murray River corridor in Australia (Zhu et al. 2010); the measurement of park and open space values in Anchorage, Alaska for the purposes of park and open space planning (Brown 2008); and to inform national park planning in Australia (Brown and Weber

2011). Additional PPGIS studies that mapped forest values in the U.S. based were completed by Nielsen-Pincus (2011) and Clement and Cheng (2011).

Using the Brown (2005) landscape value spatial mapping method as a model, researchers with the Canadian Forest Service designed and developed the first internet-based participatory mapping application to collect data on the locations of forest values across a 2.4 million ha study area in the province of Alberta, Canada (Beverly et al. 2008). Three additional internet-based PPGIS landscape value and special place mapping studies were completed for the Coconino, Deschutes, and Mt. Hood National Forests in the western United States in 2006 and 2007 (Brown and Reed 2009).

While PPGIS methods that map values and special places are best characterized as applied research, the method has also contributed to theory development and validation. For example, the method has been used to validate the presence of spatial discounting of environmental resources (Brown et al. 2002), the development of a theory of urban park geography (Brown 2008), the development of proxy measures and indices for place attachment (Brown and Raymond 2007), and the assessment of risk associated with climate change (Raymond and Brown 2010).

From PPGIS Data Collection to a Decision Framework

The value maps from aggregated public responses exhibit some degree of collective, spatial consistency despite a high degree of spatial variation and error on an individual basis. The analogy of Surowiecki's (2004) "wisdom of crowds" may be appropriate here in observing that that a diverse collection of independently-deciding individuals in the PPGIS process can produce collective spatial information that is better than individuals or even experts for certain types of values.

The sampling design used in the forest planning public involvement process establishes the limits for population inference in the decision support system. If the process is broadly inclusive and utilizes scientific random samples of regional populations, these representative results can be compared with non-representative stakeholder, interest group, and convenience samples. A scientific random sample of the regional population, while not required for decision support by regulation, is arguably essential to provide baseline public value data for comparison. In addition to the regional sample, the values data collection process may include individuals on a national forest's mailing list, individuals that attend forest planning meetings, and those that learn of the forest planning process through the Federal Register notice.

The termination of the values data collection process is followed by the generation of forest value maps in GIS for use in decision support. The normative, guiding principle behind national forest decisions is that in lieu of specific legislative direction to the contrary, forest management should be consistent or compatible with public values for the forests. The degree to which decisions reflect actual public values and preferences will depend on the sampling design (whose values are included?) and the validity of interpreting the relationships between values and prescriptive national forest decisions.

The Values Compatibility Analysis (VCA) Process The overarching goal of the VCA methodology is to explicitly integrate place-based forest values in forest planning decisions. The simplified VCA process for providing decision support in national forest planning consists of: 1) identifying a typology of place-based values relevant to the planning purpose, 2) querying the general public and optional subgroups about the distributions (i.e., location and relative importance) of the identified values through an inclusive and representative participatory process, 3) compiling and preparing the value data for analysis, 4) modeling the compatibility of proposed management activities or decisions with the values, and 5) using the modeled results to promote collaborative learning opportunities through discourse with those affected by the plan outcomes.

The validity of the methodology rests upon the following set of assumptions:

- the general public and various stakeholder groups hold multiple, diverse, and discoverable values for national forests;
- individuals can and will express place-based forest values in a public involvement process;
- forest values have identifiable spatial (place-based) locations, although the scale and resolution of the values will vary by individual and method of collection;
- reasoned judgments can be made about the compatibility of potential forest management actions with forest values based on both logical inference and experience.

The analysis of forest values can be schematically mapped into at least five domains: 1) the relationship between different forest values; 2) the relationship between values and individual forest management activities and/or policies; 3) the relationship between values and existing or prospective forest plans (i.e., plans represent multiple management activities and/or policies); 4) the relationship between values and biophysical forest attributes and conditions, and 5) the relationship between forest values and public uses/activities. While a comprehensive decision support system for forest management should ultimately engage each of these analytical domains, the VCA decision system described in this paper is concerned with the second domain—assessing the compatibility of forest values with prospective forest plan policies.

Aggregation and Trade-Off Analyses Forest plan decisions represent a series of choices about forest allocation for particular uses (or non-uses). The complexity of forest planning, especially with public lands, requires a multi-criteria decision approach that we argue should include place-based values as a key criterion. One of the traditional weaknesses of forest planning is the lack of commensurate measures that allow meaningful comparisons of the relative merits of plan alternatives. Because value data is collected systematically for a region or population using the same value definitions, the data is commensurate across the planning area. Forest plan alternatives can be compared for their relative compatibility with forest values (e.g., whether or not to designate ATV/OHV use in a particular area, as described below).

Case Study—Travel Management Planning on the Mt. Hood National Forest

All-terrain-vehicle and off-highway-vehicle (ATV/OHV) use on NFS lands is one of the most contentious issues facing forest managers. In 2005, the Forest Service published a rule in the Federal Register requiring the designation of roads, trails, and areas that are open to motor vehicle use. Motor vehicles will be prohibited off the designated system of routes. To implement the rule, each NFS unit or Ranger District will need to designate roads, trails, and areas open to motor vehicle use. Thus, the travel management planning process in national forest planning consists of identifying areas where ATV/OHV use may occur on national forest land and the policies that regulate or otherwise enable or restrict off-highway vehicle use. With the increasing popularity of ATV/OHV use on public lands and the potential for conflict with other national forest uses, decisions regarding travel management can be controversial. For some individuals, the use of ATV/OHVs enhances their forest values through easier access while for others, the presence of ATV/OHVs may negatively impact forest values.

In 2007, we completed an internet-based PPGIS project that mapped forest values and special places for the Mt. Hood National Forest (Oregon, U.S.). Approximately 180 individuals from a general public random sample and individuals from the Mt. Hood National Forest mailing list participated in the project and indentified 4,614 value locations and special places on the national forest. Individuals were asked to map the values and special places indentified in Table 1 resulting in the distribution of values appearing in Fig. 1.

Independent of the PPGIS data collection process, the Mt. Hood National Forest planning staff had tentatively identified 6 proposed areas for ATV/OHV use on the forest (see Fig. 1). They inquired whether the PPGIS values data could be used to validate the designations and to identify potential problems with the designations. We indicated the VCA process could provide decision support by answering the following questions: 1) What are the public values that characterize these proposed ATV/OHV areas? 2) Are the designated areas unique or similar in their value distributions? 3) Is the designation of ATV/OHV use in these areas consistent with these public values? and 4) Are there other areas on the national forest where ATV/OHV use designation would be more compatible with public values?

Some observations were made about the distribution of mapped values in the proposed ATV/OHV areas on the Mt. Hood National Forest. For example, the Rock Creek area had the highest number of mapped value points, and contained about 43% of all value points mapped in the six proposed ATV/OHV areas, with approximately 2.5 times more value points than the average number of mapped values per area. The Rock Creek area also had the highest density of mapped value points per acre on average, dominated by primitive recreation value. The Peavine proposed ATV/OHV area had the highest diversity of values suggesting the greatest potential for value conflict within the area. Developed recreation value was the dominant mapped value in 3 out of the 6 proposed units.

Some logical suppositions can be made from the spatial distribution of values within the proposed ATV/OHV areas. Areas where *primitive* (non-motorized) recreation values dominate (Gibson and Rock Creek) could present a problem for ATV/OHV designation as primitive recreation values appear *prima fascia* incompatible with ATV/OHV recreation. However, this conclusion must be considered tentative, at least for the Gibson area because primitive recreation value is not highly dominant among other values expressed in the area. A closer look reveals that the second most frequently mapped value in the Gibson area is *developed* (motorized access okay)

Table 1 Value typology used in the Mt. Hood PPGIS project

Aesthetic—I value these areas for their scenic qualities.
Economic—I value these areas because they provide income and employment opportunities through industries like tourism, forest products, mining or other commercial activity.
Developed Recreation—I value these areas because they provide for recreation activities such as hiking, camping, fishing, skiing, or wildlife viewing with motorized access and some facilities.
Primitive Recreation—I value these areas because they provide for primitive recreation activities such as backpacking and horsepacking without motorized access and facilities.
Life Sustaining—I value these areas because they help produce, preserve, and renew air, soil, and water.
Learning/Scientific—I value these areas because they provide opportunities to learn about the natural environment through activities like nature interpretation and scientific study.
Biological diversity—I value these areas because they provide places that support a variety of plants, wildlife, or other living organisms.
Spiritual—I value these areas because they are sacred, religious, or spiritually special places.
Intrinsic/Existence—These areas are valuable for their own sake, even if I or others don't use or benefit from them.
Historic or Cultural—I value these areas because they have features that represent history, or provide places where people can continue to pass down wisdom, traditions, and a way of life.
Therapeutic/Health—I value these areas because they make me or others feel better, physically and/or mentally.
Wilderness—I value these areas because they are wild, uninhabited, or relatively untouched by human activity.
Special Places—I value these places because they are special to me. Please double click on the Special Place marker to indicate the reason why the place is special to you.

recreation value which may be considered *prima fascia* compatible with ATV/OHV use. It is also possible for apparently incompatible forest uses to harmoniously coexist within an area. In the case of ATV/OHV use, natural corridors, topography, and vegetation can provide natural separation or zoning to minimize value conflict.

Compatibility Modeling There are multiple ways to approach compatibility modeling for a prospective forest plan decision such as the designation of an ATV/OHV area. The method briefly described herein uses assumptions about the relationship between the different forest values and ATV/OHV activity in general and uses these assumptions to generate an indexed compatibility score for ATV/OHV activity based on the spatial distribution and composition of public values for the forest.

Specifically, the VCA process for travel management planning decision support is a multiple-step process consisting of the following: 1) converting value point data (vector) into density-based data (raster data with grid cells), 2) assigning quantitative compatibility scores to the relationship between each forest value and ATV/OHV activity, 3) mathematically aggregating and classifying grid cells based on the forest value and ATV/OHV compatibility scores, 4) overlaying and displaying the resulting compatibility maps on the proposed travel management units, and 5) modifying or adjusting designated travel management areas (as needed) based on the compatibility scores.

The important step of assigning compatibility scores to each forest value and ATV/OHV activity relationship can be accomplished a number of different ways—by asking key forest management personnel about the relationship, by using "expert" panels such

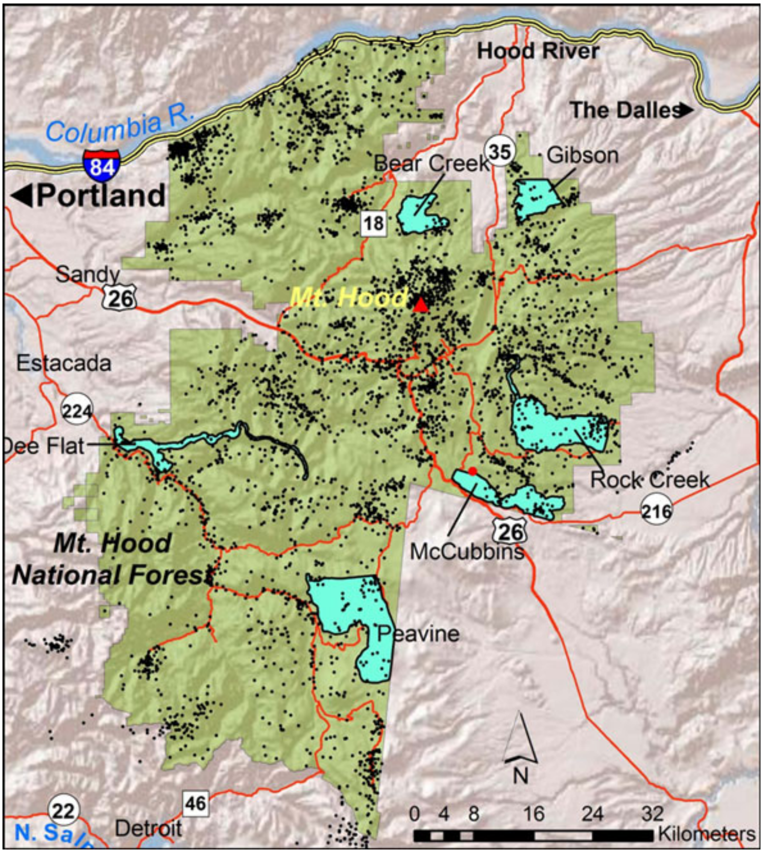

Fig. 1 Distribution of mapped forest values (n=4,614) on the Mt. Hood National Forest (Oregon). The six proposed ATV/OHV areas appear in *blue*

as a group of District Rangers, or by a survey of the general public. Value/activity compatibility is assumed to be on a continuum ranging from highly compatible to highly incompatible. Value/activity compatibility scores can be modified or weighted to assess the sensitivity of the overall compatibility results to the assigned general value/activity relationship score. The resulting maps show areas on the national forest where ATV activity appears compatible or incompatible with public forest values.

To model ATV/OHV compatibility for the Mt. Hood National Forest, we assigned forest value/activity scores based on survey responses from a convenience sample of 28 Forest Service employees (primarily District Rangers) attending Forest Service workshops in 2007. Forest Service employees were asked to assign a compatibility score for each value/activity relationship on a scale that ranged from −5 (the forest value and ATV/OHV use are highly incompatible) to +5 (the forest value and ATV/OHV activity are highly compatible) based on the definition of the forest value and the likely effects of the activity. An assigned score of 0 would indicate no apparent or obvious relationship between the forest value and ATV/OHV activity. Each of the value/activity relationship scores represents a subjective judgment on the part of the rater but consistent relationships emerge with increased polling of individuals.

Figure 2 shows the frequency distribution of responses for each forest value and ATV/OHV combination as well as the mean score on the 10 point scale.

The value/activity frequency distributions can be used as input to compatibility modeling in a number of different ways. One simple method, illustrated here, used the mean scale score of the respondents. This method has the advantage of capturing the direction and magnitude of the perceived compatibility relationship. Alternative methods could include collapsing the compatibility scale to dichotomous variables or using the modal value of the scale. In this illustration, we used the mean value/activity scores as shown in Fig. 2 which ranged from −2.18 (Wilderness value) to +3.32 (Developed recreation value).

The next step is to translate the compatibility judgments to the value locations on the forests. Each value was mapped on the Mt. Hood National Forest as a point location. These point locations are converted to raster data (cells) through a point density function. In this example, the density of points that fall within each cell (500 m) and within a search radius around the grid cell (2,000 m) were calculated using GIS software. The output of this process was a set of 12 raster data layers representing each forest value with each grid cell containing the point density for the value. The raster data can be visualized as data layers draped on the forest landscape.

The final step in the compatibility modeling process is to associate the activity/value compatibility scores with the spatial distribution of values represented by the raster layers. A composite compatibility score or index is calculated for each grid cell through the selection of a mathematical function. There are multiple ways to combine the compatibility scores with the density values from the grid cells, but a simple method described here is to assume each forest value is equally important (no weighting). Each activity/value compatibility score is multiplied by the density of the value for each grid cell and then summed into a single composite compatibility score for each grid cell. The

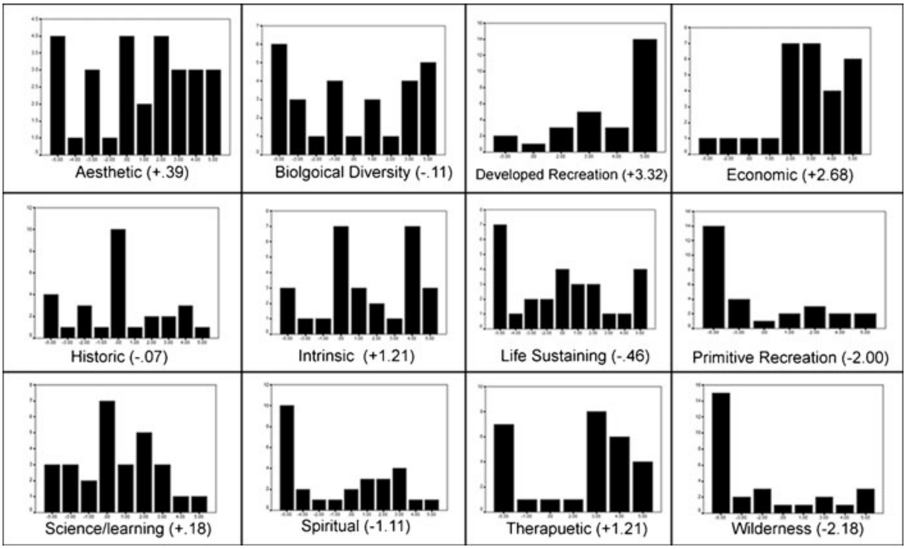

Fig. 2 Frequency distribution of compatibility scores for 12 forest values with ATV/OHV use (n=28 Forest Service employees). Scale scores ranged from −5 (highly incompatible) to +5 (highly compatible). Negative scale values appear on the left and positive values on the right. The mean scale score appears in *parentheses*

composite compatibility score will be negative if a particular grid cell contains more forest values that are perceived to be incompatible with ATV/OHV use while the score will be positive where a grid cell contains values that are perceived compatible with ATV/OHV use. In the Mt. Hood National Forest, this method yielded composite compatibility scores ranging from −5.8 to +9.3. The composite scores indicate both the direction of the relationship (positive or negative compatibility) and the magnitude of the compatibility relationship (stronger or weaker compatibility). The compatibility scores were color-coded (reds-incompatible, greens compatible) and displayed for the forest in Fig. 3. Color ramping is useful as a visual guide to show the direction and magnitude of the compatibility relationship.

Using the Model for Decision Support Each of the 6 proposed ATV/OHV areas was examined in detail to determine individual value compatibility. If compatibility scores are positive (green) in the proposed area, the public value data would appear to support ATV/OHV activity. Where compatibility scores are negative (reds), the data suggest incompatibility with ATV/OHV activity. Figure 4 provides enlarged map images for two of the proposed ATV/OHV areas, Rock Creek and McCubbins. The model indicates general value compatibility with ATV/OHV designation for the McCubbins area (the area is dominated by positive, green-shaded grid cells), but potential problems with designation of the entire Rock Creek area. Within the Rock Creek area, there are significant incompatible areas (red grid cells) in the western half of the unit, while the eastern half appears compatible (green cells). This finding should prompt the forest planning team to more closely examine the specific quantity and mix of public values in the western reach of the unit that resulted in the negative composite compatibility scores.

The compatibility model described here is intended to provide decision support, not actual decisions. The compatibility maps generated by the process should not mechanistically determine a decision, but rather provide the foundation for further public involvement or stakeholder processes to explore more specific value conflicts, to present value tradeoffs with proposed actions, and to discuss ways to ameliorate value conflicts. It is important to caution that the value/activity scores, in effect, treat every area as if they were homogeneous across the entire forest. Compatibility modeling at the scale of the entire forest may mask place-specific attributes areas and should not substitute for detailed, site level project analysis.

Assumptions about the forest value/forest activity relationships used in the decision support system can be easily changed to perform sensitivity analysis to show how widely the model results may—or may not—vary by value/activity assumptions, by geographic area, community, population demographic, or management unit of analysis. The VCA decision framework can operate at multiple spatial scales provided there is sufficient value point data at smaller scales.

Applications and Limitations of VCA as a Decision Framework

Compatibility modeling based on the systematic, spatial mapping of forest values provide forest planners, local communities, first nations, special interest groups, and

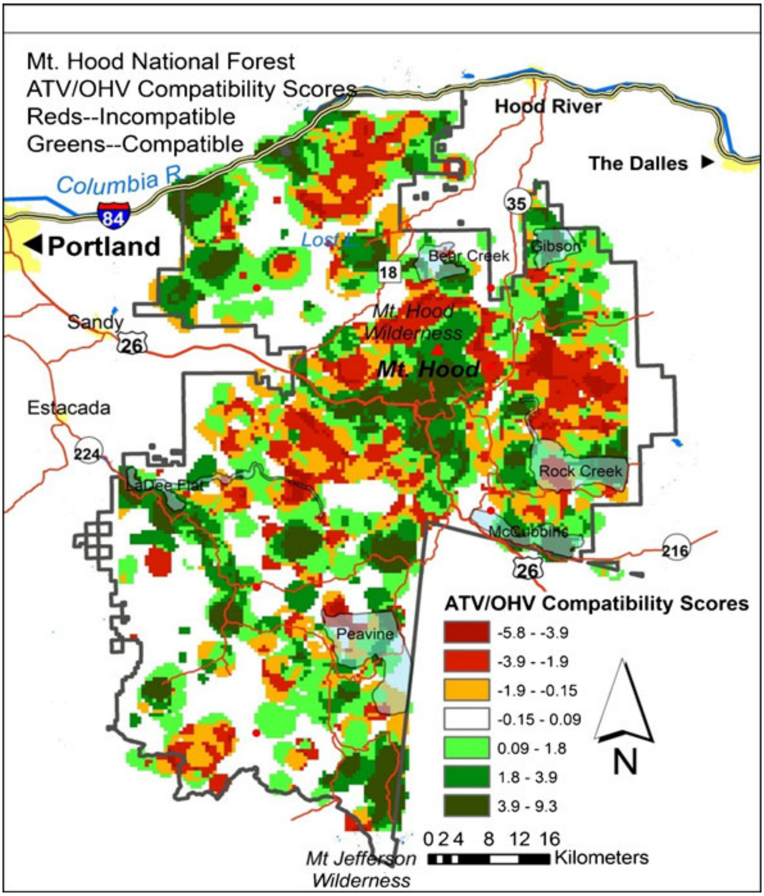

Fig. 3 Model of ATV use compatibility with mapped forest values on Mt. Hood National Forest (Oregon). Compatibility scores range from compatible (*dark green*) to incompatible (*dark red*)

other stakeholders with a useful starting point for a participatory planning process to develop and revise forest plans. Because the VCA decision framework includes data that is place-specific, includes both tangible and intangible forest values, and accounts for local and regional values, it offers significant advantages over the historic system of soliciting values indirectly through a scoping or impact review process that is non-systematic, non-spatial, voluntary, and consequently likely to be non-representative of the multiple publics that have an interest in national forest management outcomes.

But the development and implementation of a NFS-wide protocol for mapping forest values faces some formidable constraints that appear more administrative and political than technical. The list of constraints includes the lack of specific agency directives, the cost of developing and implementing the VCA protocol, the Office of Management and Budget (OMB) review process for collecting public data, the lack of significant agency experience working with value and special place data, the public acceptability of using this type of data for forest planning decisions, and the uncertain legal implications of planning decisions that explicitly reference public value data (Brown and Reed 2009). In addition, a general fear by government officials to engage the public in planning

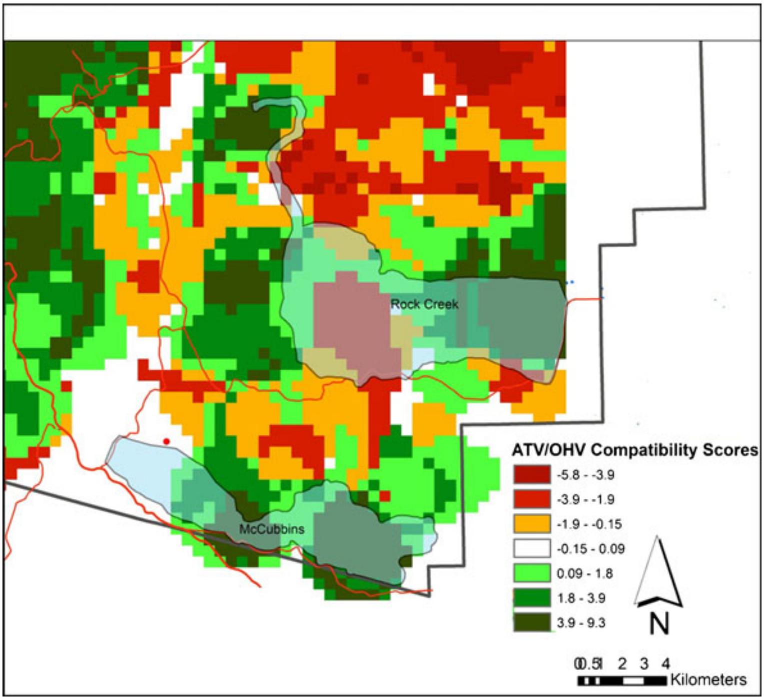

Fig. 4 Model of ATV use compatibility with mapped forest values on Mt. Hood National Forest (Oregon). Overlay of compatibility scores on two proposed ATV/OHV management areas—McCubbins and Rock Creek. Compatibility scores range from compatible (*dark green*) to incompatible (*dark red*)

and the discounting of lay knowledge relative to expert knowledge has hampered the uptake of PPGIS applications in regional and environmental applications (Brown in press). There does not appear to be a single, simple solution to increased agency adoption of the methods described herein. Brown (in press) has suggested that NGOs can assist agencies in overcoming some of the structural barriers (e.g., OMB review) through partnerships, but ultimately, the greatest need is a change in agency culture toward more sincere, rather than token engagement of the general public in planning processes irrespective of the technology involved.

Conclusion

Beierle (1999) presents five goals to evaluate the quality of public participation in environmental decision-making. Does the process educate and inform the public? Incorporate public values into decision making? Improve the substantive quality of decisions? Increase trust in institutions? Reduce conflict? Although not perfect, we argue that the values compatibility analysis process increases the likelihood of achieving these goals by explicitly integrating public values to improve the substantive quality of forest management decisions.

Even the best conceived participatory process for measuring and integrating public values into decisions must consider institutional priorities, existing planning practices, organizational norms, and public comprehension. Unless a decision framework can be translated into a standard operating procedure (SOP) for the agency leading the planning effort, the method is unlikely to be widely used or adopted. Qualitative research on forest values, while providing contextually rich data, has yet to be systematically included into a decision support system. For better or worse, qualitative research on forest values has not achieved the same "science-based" status of other quantitative research within public management agencies.

There is a clear need to meaningfully translate public values into agency decision support systems. But how to best achieve this outcome remains a work-in-progress. We believe that analyzing forest values identified through PPGIS offers considerable promise. To be effective, values must be attached to the geography of place, provide some degree of standardization, and provide the opportunity to engage in systematic trade-off analysis. Values compatibility analysis, while offering complex options for decision support, is intuitively simple at the highest and most important level for public and agency acceptance: forests should be planned and managed for activities and allocations that are consistent with public values.

References

Alessa, N., Kliskey, A., & Brown, G. (2008). Social-ecological hotspots mapping: A spatial approach for identifying coupled social-ecological space. *Landscape and Urban Planning, 85*(1), 27–39.

Beierle, T. (1999). Using social goals to evaluate public participation in environmental decisions. *Policy Studies Review, 16*, 75–103.

Bengston, D., & Xu, Z. (1995). *Changing national forest values: A content analysis*. USDA For. Serv. Gen. Tech. Rep. NC-323. 29 p

Beverly, J., Uto, K., Wilkes, J., & Bothwell, P. (2008). Assessing spatial attributes of forest landscape values: An internet-based participatory mapping approach. *Canadian Journal of Forest Research*. doi:10.1139/X07-149.

Brown, T. C. (1984). The concept of value in resource allocation. *Land Economics, 60*(3), 231–246.

Brown, G. (2003). A method for assessing highway qualities to integrate values in highway planning. *Journal of Transport Geography, 11*(4), 271–283.

Brown, G. (2005). Mapping spatial attributes in survey research for natural resource management: Methods and applications. *Society and Natural Resources, 18*(1), 17–39.

Brown, G. (2006). Mapping landscape values and development preferences: A method for tourism and residential development planning. *International Journal of Tourism Research, 8*, 101–113.

Brown, G. (2008). A theory of urban park geography. *Journal of Leisure Research, 40*(4), 589–607.

Brown, G. (in press). Public Participation GIS (PPGIS) for regional and environmental planning: Reflections on a decade of empirical research. *URISA Journal*.

Brown, G., & Raymond, C. (2007). The relationship between place attachment and landscape values: Towards mapping place attachment. *Applied Geography, 27*, 89–111.

Brown, G., & Reed, P. (2000). Validation of a forest values typology for use in national forest planning. *Forest Science, 46*(2), 240–247.

Brown, G., & Reed, P. (2009). Public participation GIS: A method for national forest planning. *Forest Science, 55*(2), 166–182.

Brown, G., & Weber, D. (2011). Public participation GIS: A new method for use in national park planning. *Landscape and Urban Planning, 102*(1), 1–15.

Brown, G., Reed, P., & Harris, C. C. (2002). Testing a place-based theory for environmental evaluation: An Alaska case study. *Applied Geography, 22*, 49–76.

Brown, G., Smith, C., Alessa, L., & Kliskey, A. (2004). A comparison of perceptions of biological value with scientific assessment of biological importance. *Applied Geography, 24*(2), 161–180.

Clement, J. M., & Cheng, A. S. (2011). Using analyses of public value orientations, attitudes and preferences to inform national forest planning in Colorado and Wyoming. *Applied Geography, 31*, 393–400.

Kaiser, B. (2006). The national environmental policy act's influence on USDA forest service decision-making, 1974–1996. *Journal of Forest Economics, 12*(2), 109–130.
Manning, R., Valliere, W., & Minteer, B. (1999). Values, ethics, and attitudes toward national forest management: An empirical study. *Society and Natural Resources, 12*(5), 421–436.
Nielsen-Pincus, M. (2011). Mapping a values typology in three counties of the Interior Northwest, USA: Scale, geographic associations among values, and the use of intensity weights. *Society and Natural Resources, 24*(6), 535–552.
Raymond, C., & Brown, G. (2007). A spatial method for assessing resident and visitor attitudes toward tourism growth and development. *Journal of Sustainable Tourism, 15*(5), 520–540.
Raymond, C., and Brown, G. (2010). Assessing spatial associations between perceptions of landscape value and climate change risk for use in climate change planning. *Climatic Change*. Online First. Available from http://www.springerlink.com/content/100247 [Accessed 25 July 2010].
Rolston, H., & Coufal, J. (1991). A forest ethic and multivalue forest management. *Journal of Forestry, 89*(4), 35–40.
Roslton, H. (1988). *Environmental ethics*. Philadelphia: Temple University Press.
Sawicki, D., & Peterman, D. (2002). Surveying the extent of PPGIS practice in the United States. In W. J. Craig, T. M. Harris, & D. M. Weiner (Eds.), *Community participation and geographic information systems* (pp. 17–36). London: Taylor & Francis.
Sieber, R. (2006). Public participation geographic information systems: A literature review and framework. *Annals of the Association of American Geographers, 96*(3), 491–507.
Surowiecki, J. (2004). *The wisdom of crowds*. New York: Doubleday.
Tarrant, M. A., Cordell, H. K., & Green, G. T. (2003). PVF: A scale to measure public values of forests. *Journal of Forestry, 101*, 24–30.
Zhu, X., Pfueller, S., & Whitelaw, P. (2010). Spatial differentiation of landscape values in the Murray River Region of Victoria, Australia. *Environmental Management, 45*(5), 896–911.
Zube, E. (1987). Perceived land use patterns and landscape values. *Landscape Ecology, 1*(1), 37–45.