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Relationships between spatial and non-spatial preferences and place-based values in national forests

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A B S T R A C T

The management of multiple-use public lands such as national forests in the U.S. is controversial because of the wide range of potential uses and contested public values for these lands. Previous research on national forest values and management preferences examined these relationships non-spatially. The development of public participation GIS (PPGIS) and volunteered geographic information (VGI) systems provide new opportunities to assess spatial relationships between perceived national forest values and preferred uses. This research used empirical data collected from a PPGIS/VGI study for three national forests in California to examine spatial and non-spatial relationships between place-based forest values and preferred uses. The relationships suggest public participants translated some of their non-spatial forest values and preferences into behavioral choices when mapping place-specific values and preferred uses. The empirical relationships between place-based forest values and uses were generally consistent with previous survey research results. Positive, non-spatial attitudes toward extractive uses of national forests were correlated with participant mapping of economic values and related extractive uses, while nonmaterial forest attitudes were correlated with participant mapping of amenity values and conservation-related uses. Further, spatial preferences for extractive forest uses such as timber harvesting were mapped proximate to economic values, while nonmaterial spatial preferences were mapped proximate to amenity-related forest values. PPGIS offers the potential to translate philosophical and ideology-based national forest preferences into place-specific discourse about forest management activities where public accommodation may be more achievable.

Introduction

Over a decade has passed since Brown and Reed (2000) developed and published a typology of forest values in *Forest Science* to measure the relative importance of different forest values held by members of the general public. They concluded that forest values, uses, and policy issues were "logically—even predictably—connected" (p. 247). The novelty of that research was not the typology of forest values which had been conceptually pioneered by Rolston and Coufal (1991) and implemented in general survey questions (Manning, Valliere, & Minteer, 1999), but the recognition that forest values can be operationalized as *place-based* values and applied to public land planning and management in general. A methodological bridge was constructed from traditional survey research to the nascent field of public participation GIS (PPGIS) first described at the 1996 meeting of the National Center for Geographic Information and Analysis (NCGIA). PPGIS became a means to spatially associate public values with public lands (Brown, 2005).

The term "PPGIS" emerged in the United States and developed-country contexts to describe spatially-explicit public participation in land use planning ranging from neighborhoods to regional scales (see Dunn, 2007; Sieber, 2006). In contrast, the term participatory GIS or "PGIS" emerged from participatory planning approaches in rural areas of developing countries (Rambaldi, Kwaku Kyem, Mbile, McCall, & Weiner, 2006). Although the formal definition of PPGIS remains "nebulous" and inconsistent across applications (Tulloch, 2007), PPGIS generally describes the practice of having non-experts or the lay public identify spatial information to augment expert geographic information systems (GIS) data. PGIS is often used to promote the goals of nongovernmental organizations, grassroots groups and community-based organizations that seek to change or influence government policy while PPGIS systems may be sanctioned by government agencies, especially in western, democratic countries as a more effective means to expand public participation and community consultation.

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PPGIS for national forest planning

PPGIS methods using value typologies have been pilot-tested by academics for national forests in Alaska, Arizona, Oregon, and Colorado using both paper-map and Internet-based data collection methods. A PPGIS protocol for use in national forest planning was published following the pilot tests (Brown & Reed, 2009). The Forest Service subsequently requested implementation of PPGIS methods to assist forest planning for up to 15 national forests over three years (Federal Register, April 2, 2010). However, the agency has thus far been blocked by the Office of Management and Budget (OMB) from using PPGIS for national forest planning. OMB must approve federal data collection efforts under the Paperwork Reduction Act.[1]

In anticipation of eventual OMB approval for Forest Service PPGIS data collection, academic researchers, in consultation with the Forest Service, piloted the first Google® maps PPGIS interface for three national forests in California in 2012. These national forests were identified as three of eight national forests that will be the first to revise their forest plans using a new National Forest System Planning Rule after the rule is finalized (Forest Service Press Release, Jan. 30, 2012).

The proposed planning rule (Federal Register, April 9, 2012) does not specifically indicate that PPGIS methods be used in public involvement but does encourage the agency to be "proactive and use contemporary tools, such as the Internet, to engage the public…" (CFR § 219.4) while continuing to require that the agency identify and consider the importance of various physical, biological, social, cultural, and historic resources on the plan area (CFR § 219.7). Thus, the 2012 California national forest pilot study sought to evaluate the Internet PPGIS method and to potentially assist the three national forests in their forest plan revision by providing spatial data on national forest values, and for the first time, place-based forest use preferences. This study is the first to identify and analyze empirical relationships between placed-based forest values and uses collected using PPGIS.

The relationship between national forest values and uses

Public *attitudes* toward national forest management have been measured in several studies (e.g., Shields, Martin, Martin, & Haefele, 2002; Shindler, List, & Steel, 1993) while public forest *values* have been measured in other studies (Steel, List, & Shindler, 1994; Tarrant & Cordell, 2002; Tarrant, Cordell, & Green, 2003). Cognitive *relationships* between national forest values and attitudes toward national forest management were first reported by Manning et al. (1999) for the Green Mountain National Forest in Vermont. They found that survey respondents who rated ecological, esthetic, moral/ethical, scientific, and spiritual values highly were significantly more likely to favor integrated, nonmaterially-oriented forest management, while those who rated economic value highly were more likely to favor dominant-use, materially-oriented management.

Brown and Reed (2000) and Clement-Potter (2006) also examined relationships between national forest values and attitudes toward forest management in Alaska (Chugach National Forest) and Colorado (Pike and San Isabel National Forests) respectively. Clement-Potter (2006) replicated survey questions from the Chugach NF study and the overall results were quite similar. The two studies found statistically significant positive correlations between economic value and material use of national forests including logging, mining, oil/gas drilling, utility siting, commercial outfitting, and motorized recreation. Economic value was negatively correlated with the designation of wilderness. Recreation values were positively correlated with hunting and fishing, motorized and non-motorized recreation, and wilderness, and negatively correlated with extractive activities including logging, mining, and oil/gas development. Learning/scientific and spiritual values were positively associated with wilderness while therapeutic value was negatively correlated with oil/gas development. Thus, although there was variation in the national forest locations and the populations sampled, the value/use relationships reported in Vermont, Alaska, and Colorado were similar. This is not surprising as one would expect general value/attitude relationships toward national forests to be embedded within a regional or even national culture.

These study results describing the cognitive associations were not spatially explicit as to the location of individual forest values and uses on the national forests. The context of the survey questions in the studies was the entire national forest, a scale that belies most individual experiences with national forests that are place specific. Arguably, the general, non-spatial relationships between values and uses measured in previous studies aren't that helpful to national forest managers that must provide for multiple-use management activities in specific place locations on national forests. The knowledge of general cognitive associations between national forest values and uses may help explain why certain forest uses, especially extractive uses, generate conflict because theyappear at odds with dominant public values for national forests, but they do little to identify place-specific forest management options.

An important research question yet to be empirically addressed is whether general, forest-wide value and use relationships continue to hold when they are measured as place-based forest values and uses. Are there smaller-scale, place-specific relationships that are missed in whole-forest studies of forest value and use relationships? For example, do individuals that value place-specific esthetic values in a national forest also identify spatially-proximate compatible forest uses with these esthetic values? Are place-based economic values spatially related to acceptable locations for extractive forest uses? Are place-based biological values related to acceptable locations for fuels treatment to reduce the risk of wildlife?

The emergence and use of PPGIS methods for engagement with national forest planning and management provide an important opportunity to examine potential spatial relationships between national forest values and uses. In 2012, an Internet-based PPGIS study was undertaken for three national forests in California involving both a random sample of residents proximate to the nationals forests as well as public volunteers. Of relevance to this paper is the analysis of the relationships between placed-based forest values and preferred uses identified by study participants. The analysis seeks answers to three specific research questions:

1) What relationships exist, if any, between national forest use preferences measured using traditional attitudinal survey questions and place-based values mapped by PPGIS participants? Alternatively stated, do placed-based forest values collected using PPGIS exhibit similar relationships to national forest use preferences as previously reported in survey research results?
2) What relationships exist, if any, between the number and type of place-based forest values and the number and type of place-based forest use preferences? This question examines PPGIS participant behavior in the mapping process. For example, is participant placement of esthetic value markers related to the

[1] Federal agency conflict with OMB over information collection review is a common experience leading to, under the best of circumstances, a lengthy approval process. The Paperwork Reduction Act regulations require timely review of agency information collection requests and provide federal agencies with the means to request and receive an automatic one year information collection approval if the OMB review is not timely. However, few agencies are willing to confront OMB over this provision.

number of timber harvesting or fuels treatment markers placed by the participant?

3) What spatial relationships exist, if any, between place-based forest values and placed-based forest use preferences? Do certain types of forest values and uses spatially co-locate on the national forests? This question is examined for four historically controversial national forest uses: timber harvesting, fuels treatment, grazing, and motorized recreation.

Methods

Study location

The PPGIS study location was three national forests located in Region 5 of the USDA Forest Service. The Sierra National Forest (NF) is located on the western slope of the central Sierra Nevada Mountains and is known for mountain scenery, oak-covered foothills, heavily forested middle elevation slopes, and alpine landscapes. The national forest encompasses more than 1.3 million acres ranging between 900 and 13,986 feet in elevation (USDA Forest Service, http://www.fs.usda.gov/sierra). The Sequoia NF is located south of the Sierra NF and is known for its 30 groves of Giant Sequoia trees (*Sequoiadendron giganteum*), granite monoliths, glacier-formed canyons, and whitewater rivers. The forest covers about 1.2 million acres with elevations ranging from 1000 feet in the foothill region to peaks over 12,000 feet in alpine areas (USDA Forest Service, www.fs.fed.us/r5/sequoia/). The Inyo NF is located east of the Sierra and Sequoia National Forests and extends 165 miles near the California and Nevada border. The forest covers about 2 million acres, mostly on the eastern slope of the Sierra Nevada with elevation ranging from 4000 feet in the Owens Valley to 14,495 feet at Mt. Whitney, the highest peak in the contiguous United States (USDA Forest Service). Fig. 1 provides a location map with the national forest boundaries that appeared in the Google® maps PPGIS interface (see also http://www.landscapemap2.org/sierra).

Data collection process

From February to April 2012, we randomly sampled 2343 households located within approximately 20 km of the three national forests. We attempted to distribute the households roughly proportional to the three national forests. The names and addressed were provided by a commercial vendor based on zip codes proximate to the national forests. We mailed letters of invitations to the households inviting them to the PPGIS study website. Each letter of invitation contained a unique access code to be entered by the participant on the website allowing the tracking of responses by sampling group. Because of limited project funding for this pilot study, follow-up reminders to non-respondents were limited to two postcards. The study website also allowed any volunteer member of the public to request a dynamic access code to participate in the study.

The study website consisted of an opening screen for the participant to enter their access code, followed by an informed consent screen for participation, and then a Google® maps interface requesting the participant to drag and drop different digital markers onto a map of the three national forests (see Fig. 1). The markers described 14 forest values, 13 acceptable forest uses, and 13 parallel unacceptable forest uses. The final selection of markers was a result of consultation with Forest Service regional office and national forest-level staff. The Brown and Reed (2009) protocol for PPGIS advocates some flexibility in allowing individual national forests to customize the selection of markers. The forest values used in this study were a slightly modified version of the Brown and Reed (2000) and Clement-Potter (2006) forest value typologies, with the two key differences being the identification of more specific components of *economic* value (i.e., timber, tourism, energy) and the splitting of *recreation* value into day use and camping values. The markers and their operational definitions appear in Tables 1 and 2.

The PPGIS instructions requested participants to "use the map markers on the left to identify the places you value and your forest use preferences…with your mouse, click on a marker and drag it to the relevant map location…" The different types of markers placed and their spatial locations were recorded for each participant on the web server in a database, along with other information including a timestamp of when the marker was placed, the Google®

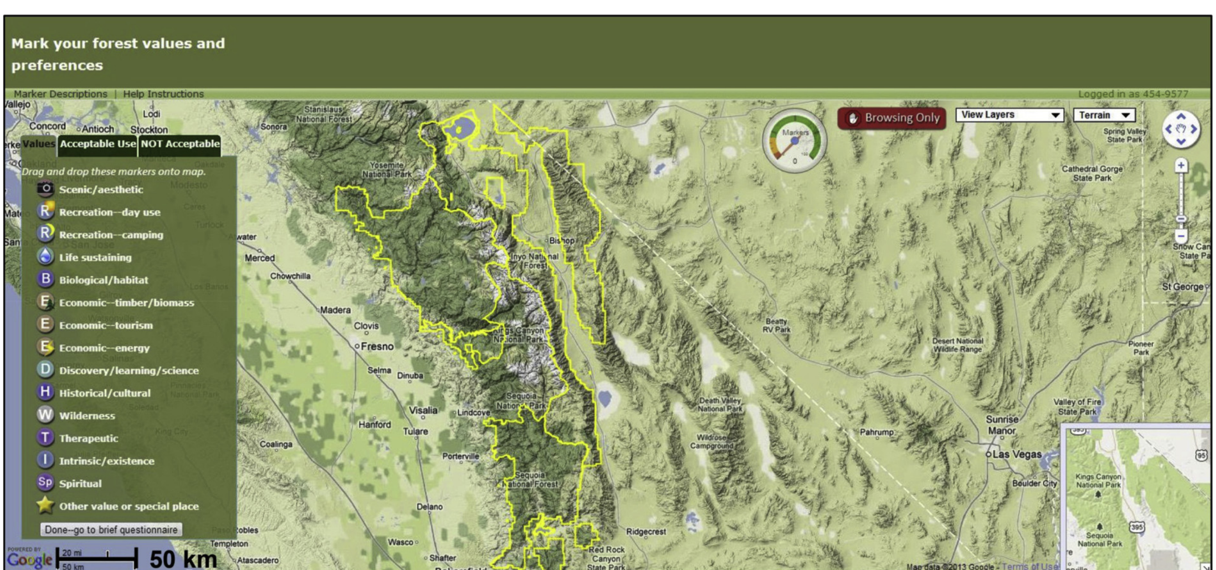

Fig. 1. Google® maps PPGIS interface for collecting national forest values and preferences for three national forests in California. Markers for 14 forest values and 26 forest uses on left panel are dragged and dropped onto the digital map by study participants.

Table 1
Forest value definitions, marker counts, and number of participants placing one or more markers for the value.

Forest values	Operational definition	Marker count	Participants placing one or more markers
Esthetic	These areas are valuable because they contain attractive scenery including sights, smells, and sounds.	527	137
Recreation (day use)	These areas are valuable because they provide day-use or picnicking recreation opportunities.	615	141
Recreation (camping)	These areas are valuable because they provide overnight camping and recreation opportunities	588	142
Biological/habitat	These areas are valuable because they provide for a variety of wildlife and plants.	222	68
Wilderness	These areas are valuable because they are wild, uninhabited, or relatively untouched by human activity	197	76
Life sustaining	These areas are valuable because they help produce, preserve, clean, and renew air, soil, and water.	171	50
Historic/cultural	These areas are valuable because they represent history, cultural identity, or provide places where people can continue to pass down memories, wisdom, traditions, or a way of life.	163	81
Economic (tourism)	These areas are valuable because of their benefit to the tourism industry.	156	64
Economic (timber/biomass)	These are valuable because of their timber and biomass resources.	139	35
Discovery/learning/scientific	These areas are valuable because we can use them to learn about the environment.	101	63
Therapeutic	These places are valuable because they make people feel better, physically and/or mentally.	68	51
Spiritual	These places are valuable because they are spiritually special.	50	42
Intrinsic/existence	These places are valuable because they exist, no matter what I or others think about them or how we use them.	48	28
Economic (energy)	These areas are valuable because of their energy resources.	44	24

map view at time of marker placement, and the Google® map zoom level (scale) at which the marker was placed. Participants could place as few or as many markers as they deemed necessary to express their values and use preferences.

Following completion of the mapping activity (placing markers), participants were directed to a new screen and provided with a set of text-based survey questions to assess general, non-spatial forest management preferences and to measure respondent socio-demographic characteristics. Of relevance to this study was a set of 11 survey questions that asked study participants to identify "what changes in forest use are needed, if any, in future forest plans for these national forests?" The forest use items ranged from commercial logging to residential development and appear in Table 3. Participant responses were recorded on a five-point, Likert scale from strongly increase to strongly decrease the particular forest use.

Analyses

Data preparation

Spatial data collected from the Internet PPGIS needed to be prepared for analysis. We adopted a conservative approach to data quality. The two key data quality issues were markers placed outside the national forest study area and a large number of *acceptable* or *unacceptable* forest use markers placed by a few participants (outliers). We made a judgment to only analyze markers placed within 5 km of the three national forest boundaries to be consistent with the focus of the study on national forest values and uses. The 5 km buffer allows for some imprecision in mapping given the irregular, and in places, concave shape of the national forest boundaries. To limit the potential influence of the mapping effort of a few participants and to account for the

Table 2
Operational definitions for *acceptable* forest uses with marker counts and number of participants placing one or more markers. The operational definitions for *unacceptable* forest uses were identical except the word "NOT" appeared before *acceptable* in the operational definition.

Acceptable use	Operational definition	Marker count[a]	Participants placing one or more markers	Unacceptable use	Marker count	Participants placing one or more markers
Timber harvest	This area is acceptable for timber harvest.	121	38	No timber harvest	125	41
Fuels treatment	This area is acceptable for fuels treatments.	158	33	No fuels treatment	104	10
Grazing	This area is acceptable for grazing livestock.	240	59	No grazing	51	17
Trails	This area is acceptable for installing new trails.	350	80	No trails	4	4
Roads	This area is acceptable for installing new roads.	74	42	No roads	48	19
Motorized use	This area is acceptable for motorized recreational use (e.g., motorcycling, ATVing, motorboating).	242	49	No motorized use	47	30
Non-motorized use	This area is acceptable for non-motorized recreational use (e.g., hiking, canoeing, picnicking).	78	48	No non-motorized use	3	3
Wilderness or wild/scenic river	This area is acceptable for designation as Wilderness or a Wild and Scenic River.	95	49	No wilderness or wild/scenic river	12	5
Urban development	This area is acceptable for new urban development (residential and commercial).	22	10	No urban development	89	32
Rural residential development	This area is acceptable for rural residences with acreage.	72	29	No rural residential development	54	25
Industrial development	This area is acceptable for industrial development including manufacturing, processing, mining (e.g., gravel), or oil and gas development.	9	6	No industrial development	100	33
Energy development	This area is acceptable for installing new commercial wind turbines, photovoltaic panels or thermal solar energy technology, or hydroelectric facilities.	22	17	No energy development	24	20
Other development	This area is acceptable for ANY new development of any type.	8	8	No development any type	100	23

[a] Markers placed within 5 km of national forest boundaries.

Table 3
Significant bivariate correlations between preferences for national forest uses (from survey questions) and the total number of place-based values mapped by participants.

Forest use preference (survey question)[a]	Mean score[b]	Significant relationships[c] with number of mapped values	
		Positive	Negative
Commercial logging	3.1	Economic—timber (.22**)	Recreation—day (.15*) Life sustaining (.29**) Biological (.21**) Discovery/learning (.19*) Wilderness (.30**) Therapeutic (.17*) Intrinsic/existence (.19*)
Livestock grazing	3.1		Biological (.21**)
Protection of fish & wildlife habitat	2.4	Wilderness (.24**) Life sustaining (.18*) Biological (.18*)	Economic—timber (.20*)
Vegetation management to reduce fire risk	2.4	Intrinsic/existence (.19*)	Economic—timber (.18*)
Commercial mining	3.5		Life sustaining (.21**) Biological (.25**) Discovery/learning (.18*) Wilderness (.19*)
Motorized recreation opportunities (ATV/ORVs or snowmobiles)	3.3		Esthetic (.19*) Recreation—day (.16*) Life sustaining (.18*) Biological (.25**) Historic/cultural (.15*) Wilderness (.29**) Therapeutic (.21**) Spiritual (.16*)
Recreation facilities such as campgrounds, picnic areas, trails	2.4		Therapeutic (.15*)
Energy development (oil, coal, gas)	3.4		Recreation—day use (.17*)
Commercial recreation (e.g., ski areas)	2.8	Economic—tourism (.17*)	Biological (.29**)
Wilderness areas	2.6	Life sustaining (.17*) Discovery/learning (.23**) Historic/cultural (.16*) Wilderness (.28**) Spiritual (.18*)	Economic—timber (.16*)
Residential development	3.5		Recreation—day use (.16*) Life sustaining (.15*) Therapeutic (.16*) Spiritual (.16)

**Significant at ($p \leq 0.001$), *significant at ($p \leq 0.05$).
[a] The forest use question was asked as follows, "What changes in forest use are needed, if any, in future forest plans for these national forests?" Scale (1 = strongly increase, 2 = increase, 3 = no change, 4 = decrease, 5 = strongly decrease).
[b] Mean scores calculated from random sampling group only.
[c] Spearman correlations.

non-normal distribution of the data, we used nonparametric statistical measures of relationship that convert marker counts to rank data.

Relationships between place-based values and non-spatial forest use preferences

To assess significant relationships place-based values and forest use preferences, we calculated Spearman's correlations between the participants' responses to the 11 forest use preference questions (measured on an interval Likert scale) and the number of placed-based values mapped by participants for each of the 14 forest values (see *Analysis 1*, Fig. 2). This method of forest value measurement differs from traditional survey approaches because participants' forest values are measured behaviorally by the number and type of forest value markers placed on the PPGIS website.

Relationships between place-based forest values and place-based forest use preferences

To determine significant relationships between placed-based forest values and place-based forest use preferences, we calculated Spearman's product moment correlations between the number of placed-based values mapped by each participant and the number of place-based forest use preferences (see *Analysis 2*, Fig. 2). This resulted in 346 bivariate correlations (14 values × 26 uses) that were assessed for statistical significance. Similar to the first bivariate analysis, the participants' national forest values were inferred from the number and type of markers placed in the national forests. But in this analysis, forest use preferences were inferred from the

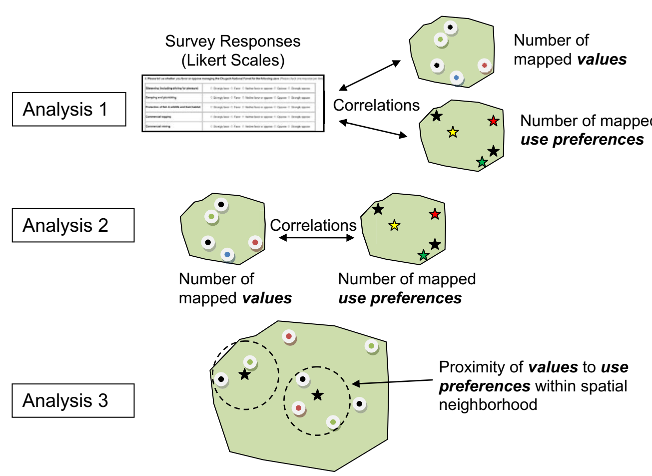

Fig. 2. Overview of the analyses used in the study.

number and type of *acceptable* and *unacceptable* forest use markers placed, not from direct survey questions.

Spatial relationships between place-based forest values and place-based forest use preferences

To measure the spatial relationships between forest values and uses, we used a variation of nearest neighbor analysis that examined the distribution of the 14 forest values that were proximate to four forest uses for which there was the largest number of mapped attributes to analyze—timber harvesting, fuels management, grazing, and motorized recreation (see *Analysis 3*, Fig. 2). We made the assumption that forest uses would most likely influence forest values within 1 km of the forest use. The frequency distribution of the 14 forest values were generated and plotted within this proximity neighborhood. Both *acceptable* and *unacceptable* forest uses were plotted using radar charts to see the contrast in value proportions. As a hedge to the assumption of a 1 km neighborhood, we also plotted the percentage of each of the 14 forest values as a function of distance from the mapped forest uses at two, three, five, and 10 km spatial neighborhoods. In simple terms, the plots show the percentage of forest values "captured" at various distances from the mapped forest uses and reveals the extent to which the value/use relationships are consistent at different spatial scales of analysis.

Results

PPGIS spatial data used in the analyses

Public participants in the study consisted of both a random sample of households proximate to the three national forests as well as a volunteer public. The random household sample participation rate was 7%, a rate that is low but similar to other Internet-based PPGIS methods involving general public random samples (Pocewicz et al., 2012). An in-depth analysis of the similarities and differences between the two sampling groups is provided elsewhere (Brown, Kelly, & Whitall, 2013). For purposes of this study, the spatial and survey data from all public participants ($n = 228$) were combined resulting in 5374 points for analysis within the three national forest study area.

The counts of individual forest value and use markers placed, as well as the number of participants that mapped one or more of the markers, appear in Tables 1 and 2. The most frequently placed value markers were recreation (day, camping), esthetic, economic (timber, tourism, energy), biological, and wilderness values. The least frequently mapped values were intrinsic, spiritual, and therapeutic. These results are consistent with those reported in previous U.S. national forest studies (Brown & Reed 2000; Clement-Potter 2006), Canadian forest studies (Beverly, Uto, Wilkes, & Bothwell, 2008), and rural counties containing national forest land (Nielsen-Pincus, 2011).

The most frequently placed *acceptable* forest use markers were trails, motorized recreation, grazing, and fuels treatment. The most frequently placed *unacceptable* forest use markers were for timber harvesting, fuels treatment, and development (urban, industrial, and any type).

Relationships between place-based values and non-spatial forest use preferences

Significant bivariate correlations between participants' responses to 11 forest use preference questions and the number of placed-based values for each of the 14 forest values appear in Table 3. Focusing on the highly significant correlations ($p \leq 0.001$), participant preferences for increased commercial logging were positively correlated with the number of markers placed for economic value (timber) and negatively correlated with the number of markers placed for life sustaining, discovery/learning, and wilderness values. Preferences for increased livestock grazing were negatively correlated with the number of biological markers while preferences for increased fish and wildlife habitat were positively correlated with the number of wilderness markers. Preferences for commercial mining were negatively correlated with the number of life sustaining and biological markers. Motorized recreation opportunities were negatively correlated with the number of biological, wilderness, and therapeutic markers placed. As logically expected, preferences for increased wilderness were positively correlated with the number of wilderness markers and discovery/learning markers. Finally, preferences for increased energy development were negatively correlated with the number of biological values placed.

Relationships between place-based values and place-based forest use preferences

Whereas the previous analysis measured the relationships between place-based forest values and general forest use preferences from survey questions, this analysis examined the relationship between place-based forest values and place-based forest use preferences. Significant bivariate correlations between the number of mapped *acceptable* and *unacceptable* national forest uses and the number of place-based forest values appear in Table 4. Focusing on the highly significant correlations ($p \leq 0.001$), participants that mapped *acceptable* timber uses also mapped more economic (timber), economic (energy), and recreation (camping) values while participants that mapped *unacceptable* timber uses mapped more discovery/learning, biological, life sustaining, and wilderness values. Participants that mapped *acceptable* fuels treatment also mapped more economic (timber) values, while participants that mapped *unacceptable* fuels treatment locations mapped more intrinsic, discovery, biological, and therapeutic values. Participants that mapped grazing use as *unacceptable* also mapped more biological, discovery, life sustaining, wilderness, and spiritual values. The mapping of *acceptable* new trail construction was significantly related to the mapping of economic (tourism) values, while *unacceptable* trail construction was related to the mapping of discovery/learning values. The mapping of *acceptable* road construction was related to the mapping of economic (tourism) and discovery values, while *unacceptable* road construction was related to the mapping of life sustaining, biological, discovery, and wilderness values. Generalizing, the mapping of various *unacceptable* development preferences (urban, residential, industrial, energy) was related to the mapping of life sustaining, biological, discovery, wilderness, and therapeutic values.

In general, these PPGIS participant mapping results appear logically consistent across the forest use and value categories in the sense that few values were significantly related to the mapping of forest uses as both *acceptable* and *unacceptable*. A notable exception was use related to forest access (i.e., trails and roads). Participants that placed *acceptable* use markers for road construction and trails mapped more discovery/learning value markers as did participants that mapped these same uses as *unacceptable*. This result suggests that increased forest access through roads and trails may be perceived by the public as both an enabler, and a detractor, of certain forest values.

Spatial relationships between place-based forest values and place-based forest use preferences

The spatial relationships between the four most frequently mapped forest uses and the 14 forest values were analyzed using a

Table 4
Significant bivariate correlations between the number of mapped ***acceptable*** and ***unacceptable*** national forest uses and the number of mapped place-based values.

Acceptable use	Place-based value	*R* value[a]	Unacceptable use	Place-based value	*R* value
Timber harvest	Economic—energy	.26**	Timber harvest	Discovery/learning	.28**
	Economic—timber	.31**		Biological	.24**
	Economic—tourism	.18*		Life sustaining	.20**
	Recreation—camping	.25**		Wilderness	.23**
				Therapeutic	.16*
				Spiritual	.13*
Fuels treatment	Economic—timber	.22**	Fuels treatment	Intrinsic/existence	.24**
				Discovery/learning	.21**
				Life sustaining	.15*
				Biological	.19**
				Therapeutic	.23**
Grazing	Economic—energy	.14*	Grazing	Esthetic	.15*
				Life sustaining	.18**
				Biological	.26**
				Discovery/learning	.25**
					.20**
				Wilderness	.16*
				Therapeutic	.17**
				Spiritual	
Trails	Economic—tourism	.17**	Trails	Biological	.17*
	Discovery/learning	.15*		Discovery/learning	.20**
				Wilderness	.15*
				Therapeutic	.14*
				Intrinsic/existence	.14*
Roads	Esthetic	.14*	Roads	Life sustaining	.20**
	Economic—tourism	.23**		Biological	.26**
	Discovery/learning	.22**		Discovery/learning	.25**
	Therapeutic	.13*		Wilderness	.29**
Motorized use	None		Motorized use	Life sustaining	.15*
				Biological	.26**
				Discovery/learning	.27**
				Therapeutic	.14*
				Intrinsic/existence	.20**
				Spiritual	.15*
Non-motorized use	Esthetic	.14*	Non-motorized use	Life sustaining	.16*
	Life sustaining	.14*		Biological	.17*
	Wilderness	.14*		Economic—tourism	.14*
	Spiritual	.19**		Wilderness	.18**
Wilderness	Life sustaining	.18**	Wilderness	Economic—timber	.18**
	Discovery/learning	.17*			
	Wilderness	.30**			
	Therapeutic	.17**			
	Spiritual	.21**			
Urban development	None		Urban development	Life sustaining	.17**
				Biological	.27**
				Economic—tourism	.15*
				Discovery/learning	.26**
				Wilderness	.20**
				Therapeutic	.22**
				Spiritual	.18**
Rural residential development	Esthetic	.16*	Rural residential development	Life sustaining	.14*
	Life sustaining	.15*		Biological	.21**
	Biological	.14*		Discovery/learning	.15*
	Economic—tourism	.27**		Wilderness	.21**
	Discovery/learning	.25**		Therapeutic	.18**
	Historic/cultural	.15*			
	Therapeutic	.15*			
Industrial development	None		Industrial development	Recreation—camping	.14*
				Life sustaining	.33**
				Biological	.36**
				Economic—tourism	.17**
				Discovery/learning	.58**
				Historic/cultural	.19**
Energy development	None		Energy development	Life sustaining	.14*
				Biological	.26**
				Discovery/learning	.18**
				Wilderness	.18**
				Therapeutic	.31**
				Intrinsic/existence	.32**
				Spiritual	.17**

(*continued on next page*)

Table 4 (*continued*)

Acceptable use	Place-based value	*R* value[a]	Unacceptable use	Place-based value	*R* value
			No development any kind	Life sustaining	.18**
				Biological	.21**
				Discovery/learning	.23**
				Wilderness	.23**
				Intrinsic/existence	.14*

**Significant at ($p \leq 0.001$), *significant at ($p \leq 0.05$).
[a] Spearman correlations.

variant of neighborhood (proximity) analysis. We operationalized a neighborhood as the circular area contained within a specified radius of a preferred use marker (see *Analysis 3*, Fig. 2). The proportion of forest values falling within a 1 km spatial neighborhood for *acceptable* and *unacceptable* timber harvesting and fuels treatment is plotted in Fig. 3a and b respectively, while grazing and motorized use proportions are plotted in Fig. 4a and b. The percentage of forest values falling within larger neighborhoods of increasing radii (2, 3, 5, and 10 km) is also plotted for *acceptable* timber harvesting (Fig. 3c), fuels treatment (Fig. 3d), grazing (Fig. 4c), and motorized use (Fig. 4d).

Where timber harvesting was identified as *acceptable*, economic values (timber, energy, tourism) were most abundant within the 1 km neighborhood, followed by recreation and biological values (Fig. 2a). Where timber harvesting was *unacceptable*, the most proximate values were spiritual, discovery/learning, intrinsic, recreation, and wilderness. In other words, economic values for national forests tend to be mapped near where timber harvesting is viewed as *acceptable*, while nonmaterial forest values were mapped where timber harvesting was identified as *unacceptable*. These spatial relationships tend to hold for *acceptable* timber harvest at different proximity neighborhoods (Fig. 3c), i.e., consistently more

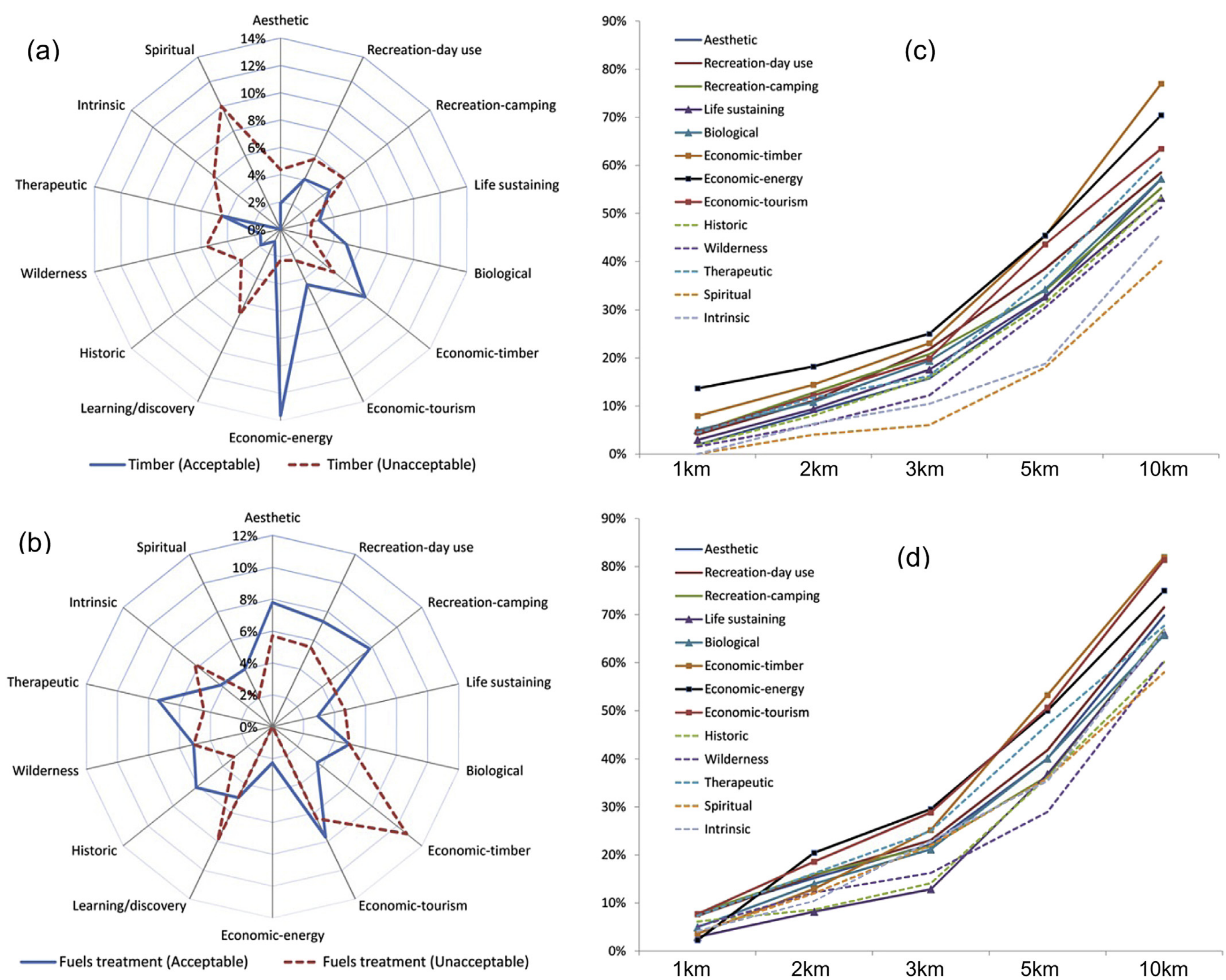

Fig. 3. The percentage of forest values for each value type falling within a 1 km spatial neighborhood of ***acceptable*** and ***unacceptable*** uses for (a) timber harvesting, and (b) fuels treatment. The percentage of forest values falling within neighborhoods of different radii (1, 2, 3, 5, and 10 km) for *acceptable* (c) timber harvesting, and (d) fuels treatment.

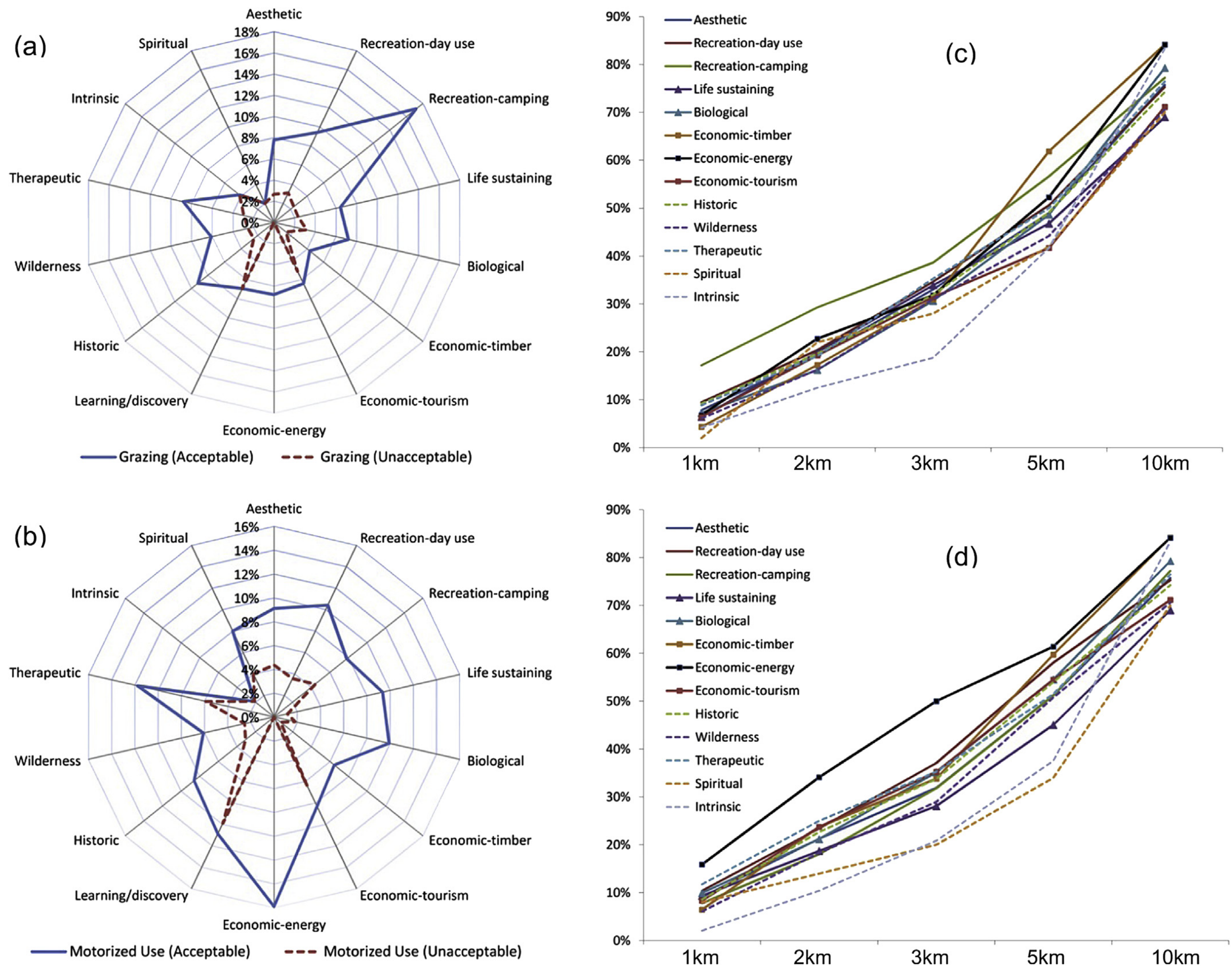

Fig. 4. The percentage of forest values for each value type falling within a 1 km spatial neighborhood of ***acceptable*** and ***unacceptable*** uses for (a) grazing, and (b) motorized use. The percentage of forest values falling within neighborhoods of different radii (1, 2, 3, 5, and 10 km) for acceptable (c) grazing, and (d) motorized use.

economic values are captured in spatial neighborhoods at varying distances from *acceptable* timber harvesting while consistently fewer nonmaterial forest values are captured.

The spatial relationships between fuels treatment and forest values are more complex as shown in the radar plot (Fig. 3b). Where fuels treatment is *acceptable*, proximate forest values are more evenly distributed as indicated by the shape of the polygon in the radar plot. This distributional pattern is similar for *unacceptable* fuels treatment with the notable exception of the higher proportion of economic (timber) values within 1 km, suggesting spatial incompatibility between timber harvesting for economic value and fuels treatment. The complexity and variability of fuels treatment and its potential impact on forest values is also reflected in the distribution of forest values at increasing neighborhood distances. Visually, this is reflected in the value percentage lines crossing at increasing neighborhood distances from *acceptable* fuels treatment (Fig. 3d).

The spatial relationships between *acceptable* and *unacceptable* grazing and motorized uses with national forest values depicted in Fig. 4, reflect, in part, the much greater abundance of *acceptable* use markers compared to *unacceptable* markers. Hence, the spatial relationships between *acceptable* forest uses and forest values are more trustworthy for interpretation. Acceptable grazing use tends to be proximate to recreation values, especially camping, and more distant from spiritual and intrinsic values, as well as economic (timber) value (see Fig. 4a). These relationships hold at varying neighborhood distances (Fig. 4c).

Acceptable motorized use in national forests tends to be spatially proximate to economic (energy) value and more distant from intrinsic value. However, motorized use affects a wide range of proximate forest values as indicated by the more evenly-shaped radar plot in Fig. 4b. These spatial relationships are consistent at varying neighborhood distances (Fig. 4d). A noteworthy spatial relationship exists between motorized use and therapeutic value suggesting that individuals that engage in motorized recreation may receive therapeutic benefit from this activity, or alternatively, that less mobile people need motorized transport to be able to access the forest in order to enjoy therapeutic benefits.

Discussion

This study examined the relationships between national forest values and preferred uses by asking whether these relationships manifest spatially in place-specific national forest contexts. This line of inquiry is made possible by the development of PPGIS applications that can collect place-based public preferences and values for national forests. This study found that non-spatial forest use/value relationships previously reported in public survey research are also present in place-based relationships collected using PPGIS methods. PPGIS participants manifest their non-spatial national forest management preferences and values in behavioral choices when identifying and mapping place-specific values and preferences in PPGIS.

This is good news for national forest planners that have pondered what to do with general, ideology-based public comments submitted during the development of new or revised national forest plans. If public values and uses of national forests can be translated into place-specific locations on the national forests, there is at least the potential to bound national forest value/use conflicts to place-specific locations where viable alternatives to forest management may be more apparent, for example, though spatial or temporal zoning of forest management activities. Brown and Donovan (2013) describe how PPGIS methods can improve national forest planning processes by identifying areas of potential forest conflict and by assessing the compatibility of proposed forest plan allocations or prescriptions. Thus, PPGIS has the potential to translate ideology-based natural resource preferences (i.e., utilization vs. preservation) into place-specific discussions about potential management activities where compromise and accommodation may be achieved.

Historically, conflict over logging in national forests fueled appeals and lawsuits in the first round of national forest plans required under the National Forest Management Act (1976) to the point where every one of the 96 national forest plans completed through 1996 had been appealed (Kaiser, 2006). This study suggests that timber management is one national forest use where public value trade-offs appear reasonably well-delineated, both spatially and non-spatially. Where timber harvesting is deemed *unacceptable*, nonmaterial forest values such as biological, life sustaining, spiritual, intrinsic, wilderness, and recreation values dominate. Where timber harvesting is identified as *acceptable*, economic values (timber, energy) dominate.

With the dramatic decline in commercial timber harvesting from national forests following litigation in the 1990s over endangered species, controversy in national forest management shifted to a debate over healthy forests and managing the risk from wildfires. For national forest management activities such as fuels reduction (e.g., tree thinning, prescribed burns), the forest value/use relationships and associated trade-offs are less obvious. Similar to other published survey results in Oregon (Shindler & Toman, 2003), Arizona (Ostergren, Lowe, Abrams, & Ruther, 2006), and California (Winter, 2003), this study also found majority public support for vegetation management to reduce fire risk. However, where fuels treatment was identified as spatially *acceptable* in PPGIS, a wide range of forest values are also present. Forest Service activities to reduce fire risk in California have, and will continue to confront, a diverse, multi-valued landscape. Continued agency support for fuels management will require nimbleness to navigate the panoply of place-based values that are present in the Sierra Nevada national forests and elsewhere. The Forest Service strategy under these conditions should include an expanded and "more active role in communication and involvement" (Ostergren et al., 2006, p. 381). PPGIS is a relatively new engagement method that can facilitate public involvement while acknowledging and communicating the range of place-based values the public holds for national forests.

Motorized recreation on national forest lands with all-terrain-vehicles and off-highway-vehicles (ATV/OHV) is one of the more controversial issues in national forest management. In 2005, the Forest Service published a rule in the Federal Register formalizing a *travel management* planning process requiring the designation of roads, trails, and areas that are open to motorized use, with the remaining areas to be closed. The contentious nature of this planning process was predictable given the value/use findings of this study. Preferences for motorized recreation were negatively correlated with the identification of nonmaterial forest values including biological, discovery/learning, wilderness, and therapeutic values. These relationships were also reflected in the forest values mapped proximate to the *unacceptable* locations for motorized recreation. Brown and Reed (2011) provide an example of how forest use/value relationships can be used for forest planning decision support to identify place-based suitability of ATV/OHV use. In that study, Forest Service employees (rather than the public) were surveyed on the perceived compatibility of the various forest values with motorized recreation. With the findings from this PPGIS study, there is now the possibility to develop an expanded compatibility model that integrates both Forest Service "expert" judgments with public perceptions of forest use/value compatibilities.

Limitations

This study was one of the first to analyze national forest value/use relationships from an explicitly spatial, place-based perspective. As such, it has limitations. Although the data included ($n = 228$) PPGIS participants and the mapping of over 5000 spatial locations, the three national forests comprise a relatively large area with the amount of data quite sparse and patchy in places. The spatial dataset was adequate for exploring relationships between place-based values and preferences, but the response rate was insufficient to conclude general public representativeness for purposes of national forest planning. The low random sample household participation rate (7%) using the Internet-only PPGIS method is a concern shared by all survey researchers with response rates showing declines across all modes of delivery (Curtin, Presser, & Singer, 2005; de Leeuw & de Heer, 2002). Replication of the methodology for a single national forest with a larger number of participants is needed to increase confidence in the putative results. Further, this study examined national forest value/use relationships in the context of California national forests. Are these national forests and participants sampled representative of national forests across the country? Some might argue that California is exceptional on many social and economic variables that could influence the forest value/use relationships identified in this study. There would be benefit in replicating this type of study and analysis in a different region of the country.

Finally, this study combined responses from a random household sample (PPGIS) and responses from a volunteer public (VGI) for the purpose of exploring the relationships between mapped forest values and preferred uses. As described by Brown et al. (2013), there were differences in the types of values and preferences mapped by the two sampling groups and their study provides a cautionary tale about the potential consequences of special interests mobilizing for participatory mapping processes. The volunteer public expressed stronger utilitarian values and consumptive forest use preferences while the random household sample preferred national forest amenities. The variability in attitudes, values, and preferences of participants toward national forests was beneficial to this study which sought to understand how individual differences in these variables manifest in PPGIS mapping behavior. However, understanding individual PPGIS mapping behavior is a very different purpose from collecting and analyzing PPGIS data to inform national forest management decisions. As a general rule, spatial data from PPGIS and VGI sampling groups should not be combined and presented as "public" values and preferences for national forests.

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