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RESEARCH

Using Canonical Correlation Analysis to Identify Environmental Attitude Groups: Considerations for National Forest Planning in the Southwestern U.S.

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Abstract As public land management agencies pursue region-specific resource management plans, with meaningful consideration of public attitudes and values, there is a need to characterize the complex mix of environmental attitudes in a diverse population. The contribution of this investigation is to make use of a unique household, mail/internet survey data set collected in 2007 in the Southwestern United States (Region 3 of the U.S. Forest Service). With over 5,800 survey responses to a set of 25 *Public Land Value* statements, canonical correlation analysis is able to identify 7 statistically distinct environmental attitudinal groups. We also examine the effect of expected changes in regional demographics on overall environmental attitudes, which may help guide in the development of socially acceptable long-term forest management policies. Results show significant support for conservationist management policies and passive environmental values, as well as a greater role for stakeholder groups in generating consensus for current and future forest management policies.

Keywords Forest policy · National forests and grasslands · Public Land Values · Multivariate analysis

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Introduction

The most recent forest management planning rule marked a significant change in how the United States Department of Agriculture's Forest Service (USFS) develops and validates natural resource management policies (Federal Register 2012). It can be argued that this new planning framework incorporates two conceptual models of natural resource management: (i) a commercial or *multiple-use* model that views resources as commodities to be used for the benefit of humans (Rolston and Coufal 1991); and (ii) a *stewardship of ecosystem services* model, which has a holistic or Leopoldian view of resource management that considers the natural environment and current and future generations as part of the planning process (Kennedy and Koch 2004; Steel et al. 1994). This represents a notable departure from the traditional model of forest management that focused solely on multiple uses (Kennedy and Koch 2004) and is expected to change how the impact of policy is measured (Ruhl 2010).

One possible key to finding balance between the *multiple-use* model and *stewardship of ecosystem services* model is an improved understanding of the full range and complexity of the values and attitudes of the general public, resource users, and other stakeholder groups (Minteer and Manning 1999; Spash 2006). For the USFS, which is required to seek public input for changes in policies or to revise management plans, an improved understanding of the diversity of public values and attitudes can be expected to help shape policy

(Minteer and Manning 1999).[1] For example, it would help minimize objections to planning efforts (Bengston 1994; Tarrant et al. 2003), assess the impact of changes in resource policy, recreation amenities and facilities, and non-use values of public lands (Clement and Cheng 2011; Kotchen and Reiling 2000; Minteer and Manning 1999), or reveal the desirability to changes in policy and willingness to engage in trade-offs for environmental goods and services (Bengston 1994; Dietz et al. 2005; Spash 2006).

For clarification, values represent an ideal measure of attitudes, especially as they relate to resource management planning (Brown and Reed 2000) and a sustainable relationship toward the environment (Dietz et al. 2005). In this investigation, (*forest*) values are defined as an "*enduring conception of the good related to forest and forest ecosystems*" (Bengston and Xu 1995, p. 1). Such values are influenced by the social context in which they are formed and can differ across different population groups (Clement and Cheng 2011; Fischer 2010), but once formed are considered stable over time (Manning et al. 1999; Stern et al. 1995). In the context of resource planning, (*forest*) values are assumed to influence environmental attitudes (Dietz et al. 2005; McFarlane and Boxall 1996) and help predict public reaction to changes in forest policy (Bengston 1994; Tarrant et al. 2003). Therefore, to be useful to policymakers, the analysis must be connected to the set of demographic characteristics that influence the level of agreement for each dimension in held values (Bengston 1994; Stern 2000).

Given a diversity in environmental attitudes, forest managers must take special care in designing plans that ensure the best possible collaboration with local residents to reduce any conflicts with the public (Allen et al. 2009). Long-term policies must also address how changes in demographic characteristics are likely to affect management plans (Larson et al. 2011; Shinew et al. 2006). Thus, developing policies that align with the public's preferences is challenging but necessary, and management plans must reflect national concerns as well as local attitudes (Clement and Cheng 2011; Fischer 2010). Using over 5,800 survey responses to a set of 25 *Public Land Value* statements (developed in prior national surveys), the objective of this investigation is to apply a combination of statistical methods to identify a robust set of general environmental attitudinal groups present in a sample of regional households. This information is an important component in developing socially acceptable forest policy, and the methods described in this analysis may be used to support policy design in other settings in a similar fashion.

Survey Data and Descriptive Statistics

Study Region

This analysis focuses on the Southwestern region of the USFS (Region 3: Arizona, New Mexico, and the Grasslands area in western Oklahoma and Texas—Fig. 1). Our interest in the area is twofold. First, the demographic diversity in the area of study: 6 % of the population is Native American; 30 % of households are Hispanic; and, approximately 14 % of households live in rural areas. Further, in New Mexico and Arizona, the fifth and sixth largest states in the nation, respectively, the USFS land accounts for approximately 11 million acres, or 14 % of the total surface area (USFS 2010). Therefore, changes in forest management policies can be expected to have a significant economic and social effect in the region. Second, as part of a review of Region 3 forest management plans, a unique household, mail/internet survey data set was collected in 2007 in the Southwestern region of the Forest Service that included questions on environmental attitudes.

Sampling and Descriptive Statistics

The data come from the survey "*Managing National Forests and Grasslands in the Southwest: What do you think?*" administered by the University of New Mexico on behalf of the US Forest Service. Given the size of the area of study, the data generating process followed a two-stage stratification sampling method. In the first stage, the region was divided into twelve geographical regions, each containing at least one county and a National Forest or Grassland. A total of 12 regions were created, 3 containing the main urban centers of Maricopa (Phoenix, AZ), Pima (Tucson, AZ), and Bernalillo (Albuquerque, NM), 1 containing the counties from Texas and Oklahoma where the Regions' National Grasslands are located. All remaining counties were grouped such that they were next to each other. In the second stage, a random sample was generated based on the number of household in each county to the total number of household in the geographical region. The random sample for each geographical region was generated to ensure the required minimum sample for statistical validity of 384 responses, assuming a 5 % sampling error. Additional households were included in rural counties to ensure the minimum sample of responses was received.[2]

Based on the sampling strategy, a sample frame of 39,200 addresses was purchased from a commercial ven-

[1] The National Forest Management Act (NFMA) of 1976 requires public input in the development and revision of management plans. Plans are reviewed when conditions change, or at least every 15 years, at the Forest, Regional, and National levels.

[2] See McCollum et al. (2008) for a full description of the sampling design and procedures, as well as basic descriptive statistics of the sample.

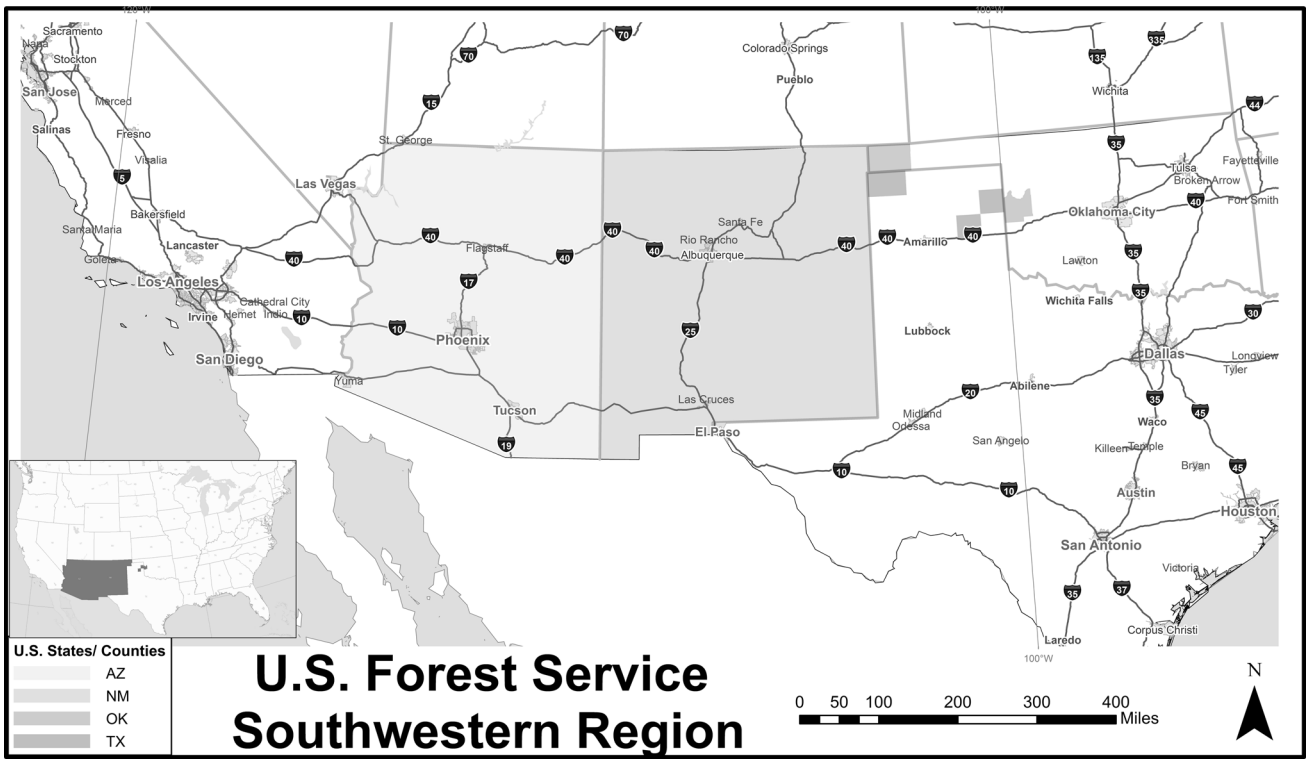

Fig. 1 Region 3 of the U.S. Forest Service

dor. This initial sample was subsequently reduced to 37,804 after removing wrong addresses and deceased from the database prior to mailing the first contact. Of the 37,804 households that were contacted, an additional 2,390 were dropped from the database due to undeliverable wrong addressed and deceased contacts. This resulted in an usable sample of 35,414 households. Data were gathered from June to September, 2007, using up to five mailings via a multiple mode (mail and the internet) and multiple language (English and Spanish) survey instrument, based on Dillman's total design method (Dillman 1978). Given budgetary constraints, the survey achieved the minimum sample requirement in all but one geographical region: the Texas and Oklahoma group received only 358 responses. A total of 7,628 responses were received, resulting in a response rate of 21.54 %. The response rate is on the low end observed in the literature, especially when compared to surveys that target resource-based issues. However, a 20 % response rate is not unusual for mail surveys (Krosnick 1999) and is consistent with a decline in response rate for general population surveys (Connelly et al. 2003; Deaton 1997).

The survey comprised five sections and for this investigation two are used: (i) *Management of National Forests and Grasslands*, and (ii) *Background characteristics*. The first section that is used contains two sets of questions on the value for public lands and management objectives for National Forests and Grasslands, of which this analysis uses the set of statements on the value for public lands (Table 1). These statements are based on an earlier Forest Service national survey, the 2000 National Survey on Recreation and the Environment (NSRE) and adapted to the area of study, Region 3 of the USFS.

The other section consists of demographic characteristics, such as income, education, gender, etc. Based on preliminary diagnostics, a subset of 14 characteristics presented in Table 2 is used. There is a final set of demographic characteristics on the bottom half of Table 2, *membership to a natural resource group*. A question in the survey asked respondents to indicate, among eight general choices, what group they belonged to that had an interest in natural resources and outdoor recreation. Two of the choices, conservationist and environmentalist, were grouped into the *Conservationist* category.

Given the use of the 25 statements, the data required additional cleaning to generate the usable data set. First, of the surveys that were returned, 778 had no responses to any question and are automatically dropped. An additional 1,016 observations are omitted because they contained 5 or more missing value statement observations, resulting in an usable data set of 5,832. For the remaining observations, missing values on the *Public Land Value* statements are

Table 1 Summary statistics of *Public Land Value* statements ($n = 5{,}832$)

Public Land Values		Mean (*SD*)
Personal conservation behavior		
1	People should be more concerned about how public lands are used	4.45 (*0.99*)
2	Natural resources must be preserved, even if some people must do without some products	3.91 (*1.26*)
3	Consumers should be interested in environmental consequences of the products they purchase	4.22 (*1.05*)
4	I would be willing to sign a petition for an environmental cause	3.69 (*1.29*)
6	If we could just get by with a little less there would be more left for future generations	3.95 (*1.17*)
7	Manufacturers should be encouraged to use recycled materials in their manufacturing and processing operations	4.36 (*1.10*)
8	Future generations should be as important as the current one in decisions about public lands	4.29 (*1.12*)
Environmental activism		
10	People should urge friends to limit their use of products made from scarce resources	3.81 (*1.18*)
11	I am glad there are national forests even if I never get to see them	4.49 (*1.03*)
12	People can think public lands are valuable even if they do not actually go there themselves	4.48 (*1.00*)
13	I am willing to stop buying products from companies that pollute the environment even though it might be inconvenient	3.86 (*1.18*)
14	I am willing to make personal sacrifices for the sake of slowing down pollution	4.02 (*1.05*)
15	Forests have a right to exist for their own sake, regardless of human concerns and uses	4.03 (*1.27*)
16	Wildlife, plants, and humans have equal rights to live and grow	3.78 (*1.41*)
Conservationist management values[a]		
18	We should actively harvest more trees to meet the needs of a much larger human population	3.37 (*1.39*)
19	The most important role for public lands is providing jobs and income for local people	3.43 (*1.34*)
20	The decision to develop resources should be based mostly on economic grounds.	3.41 (*1.36*)
21	The main reason for maintaining resources today is so we can develop them in the future if we need to	2.91 (*1.36*)
23	The primary use of forests should be for products that are useful to humans	3.49 (*1.37*)
24	The Federal government should subsidize the development and leasing of public lands to companies	3.92 (*1.38*)
25	The government has better places to spend money than devoting resources to a strong conservation program	3.62 (*1.38*)

Scale: 1 = 'Strongly disagree'; 2 = 'Somewhat disagree'; 3 = 'Neutral': 4 = 'Somewhat agree'; 5 = 'Strongly agree'

[a] Items were reverse coded to ensure higher scores represent pro-environmental attitudes

Table 2 Summary statistics for demographic characteristics ($n = 5{,}832$)

Characteristic	Mean	SD	Min	Max
Household income (000s)	72.63	54.97	30	330
Age	57.20	14.30	19	99
Years living in the area	23.25	19.71	0	90
Hispanic	0.13	0.34	0	1
Male	0.69	0.46	0	1
High school, GED, or less	0.17	0.37	0	1
Some college education	0.26	0.44	0	1
Bachelors or associate degree	0.31	0.46	0	1
Graduate education or degree[a]	0.27	0.44	0	1
Membership to a natural resource group				
Conservationist	0.11	0.31	0	1
Not a member of any group	0.75	0.43	0	1
Producer	0.01	0.11	0	1
Off-highway vehicle	0.02	0.15	0	1
Sportsperson	0.09	0.29	0	1
Hiker/Biker	0.04	0.20	0	1

0 = 'No'; 1 = 'Yes'

[a] Omitted category

replaced using the weighted mean value of each geographical region.[3] Missing income observations are similarly replaced. Education attainment, a categorical variable, is imputed using multiple imputation methods, a simulation-based technique for missing data (StataCorp 2013).

According to the 2000 U.S. Census, Hispanics comprise 30 % of households in the Southwest, compared to 13 % in the data set. Men are over-represented in the data set by a considerable degree, 69 % compared to around 49 %. Households in the sample are also wealthier than the population, and the average age is significantly higher than the 39-year-old average in the 2000 U.S. Census. Finally, the sample over-represents the highest levels of education attainment, especially with respect to individuals with a bachelors or associate degree. A traditional strategy to compensate for over- or under-representation in the sample is to use survey weights. Furthermore, there is an issue of non-response bias due to the relatively low response rate, which is also solved by using survey weights, specifically, post-stratification survey weights that control for both difference in demographic characteristics and non-response (Kish 1992; Little 1986). In this case, however, the nature

[3] We tested the sensitivity of the imputation method by replacing the missing *Public Land Values* with the median, using regression-based predictive values, and by omitting observations with a missing *Public Land Value*. This test revealed that canonical correlation analysis results are sensitive to the method used to replace missing values, and that the method used in our analysis more closely resembles the sample that omits all missing values.

of the statistical instrument, canonical correlation analysis (CCA), does not lend itself to incorporating survey weights into the estimation process. Non-response bias will certainly limit our analysis to the sample, but it does not prevent us from making inferences on it (Deaton 1997). The investigation, therefore, does not make any inferences regarding the proportion of different attitudinal groups back to the larger population (i.e., all results and discussions apply to the resulting sample). Rather, the focus is on identifying distinct attitudinal groups that exist for this sample. As will be shown, a diversity of attitudinal groups is identified, including a mix of environmental attitudes among under-represented groups such as Hispanics and Women.

Methods

The primary statistical method used and focused here, CCA, considers the multivariate sets of *Public Land Value* statements and demographic characteristics simultaneously. Latent relationships in the data are found by assigning weights to each variable in the multivariate sets that represent the highest level of correlation between them, with each relationship being unrelated to all others. A description of each latent relationship is done by observing the size and sign of the weights of each variable. By applying cut-off thresholds to the weights, the end result is that CCA allows the characterization of distinct attitudinal groups. However, prior to the application of CCA, an exploratory factor analysis is used to facilitate the analysis of the 25 *Public Land Value* statements in summary form. A description of environmental values in summary form is helpful in evaluating the desirability of changes in policy and willingness to engage in trade-offs of environmental goods and services (Bengston 1994; Dietz et al. 2005; Spash 2006).

Exploratory Factor Analysis

Factor analysis is a commonly used statistical method that uses joint variation in a large number of variables to isolate down to a small number of unobserved variable groups, referred to as factors (Afifi and Clark 2004). Because our interest is to obtain easily identifiable factors and not to impose specific constraints, as is the case in confirmatory factor analysis, we conduct exploratory factor analysis (Afifi and Clark 2004). To facilitate the analysis and describe each factor, we use an orthogonal varimax rotation, which maximizes the squared loadings or percent of variance explained by each variable in the factor (Abdi 2003). The benefit of this type rotation method is that it re-expresses the factor loadings so that each factor has a small set of variables with large loadings and a large number of variables with small loadings. Finally, we use the standard cut-off of 1.0 in the eigenvalue to retain all meaningful factors (Afifi and Clark 2004) and a cut-off value of 0.45 on factor loadings to identify the set of variables with the highest loading in each factor. This factor loading cut-off value was selected, in part, because four statements appeared with loadings less than 0.45 and in more than one factor. At this cut-off value, the four omitted statements do not noticeably reduce the reliability score, Cronbach's alpha.[4]

Exploratory factor analysis revealed three factors (or dimensions) of *Public Land Values*. The *environmental attitudes inventory* scale found in Milfont and Duckitt (2010) is used to label and characterize Factor 1 and 3. The statements that comprise Factor 1 (statements 1–4 and 6–8), labeled *personal conservation behavior*, denote "taking care to conserve resources and protect the environment in personal every day behavior" (Milfont and Duckitt 2010). These statements deal with how individuals behave in a passive manner toward the environment and environmental concerns. In contrast, the set of statements that comprise Factor 3 (statements 10–16), *environmental activism*, describes specific actions that individuals are willing to undertake on behalf of the environment. More specifically, *environmental activism* is "personal readiness to actively support or get involved in organized action for environmental protection" (Milfont and Duckitt 2010).

Factor 2 (statements 18–25) contains all but one management statement. *Conservationist management values* are views on how public lands should be managed (Shields et al. 2002, p. 22). For this factor, we use the description found in the 2000 National Survey on Recreation and the Environment, from which we derived the *Public Land Value* statements from our survey (McCollum et al. 2008). The omitted management statement deals with how people perceive the job public land managers are doing to protect natural resources from overuse. The retained statements deal directly with actions taken to either preserve or develop natural resources on public lands. High values denote support for conservationist natural resource policies, while low values denote support for development policies.

Estimated mean values of responses for the three dimensions are shown in Table 3. The range of values

[4] While only summarized here, full exploratory factor analysis results are available upon request from the lead author. The four statements excluded from the analysis are: 5 '*The whole pollution issue has never upset me too much since I feel it's somewhat overrated*'; 9 '*I would be willing to pay five dollars more each time I use public lands for recreational purposes*'; 17 '*Donating time or money to worthy causes is important to me*'; and, 22 '*I think public land managers are doing an adequate job of protecting natural resources from being overused*.'

Table 3 Mean regional and state *Public Land Values*

Public Land Values dimension	Region	Arizona	New Mexico
Environmental activism	4.07 (0.87)	4.06 (0.87)	4.09 (0.86)
Conservationist management values	3.46 (1.04)	3.45 (1.04)	3.46 (1.03)
Personal conservation behavior	4.13 (0.87)	4.13 (0.85)	4.13 (0.89)
Total observations	5,576	2,560	3,016

Excludes observations from Oklahoma and Texas represent 4.39 % of the full sample

Standard deviation in parentheses

follow the range used to measure agreement to each statement, that is 1–5, from 1 'Strongly disagree' to 5 'Strongly agree.' The results are largely consistent with prior national (Shields et al. 2002) and regional (Haefele et al. 2005; Lybecker et al. 2005) NSRE results. Respondents agree with environmental activism and personal conservation behavior, and weakly agree with conservationist natural resource management.

Initially, consideration was given to conducting a state-level analysis on the expectation of underlying differences between the Regional and state samples (Bengston 1994; Johnson et al. 2004; McFarlane and Boxall 1996). However, as can be seen in Table 3, mean values for all three dimensions of *Public Land Values* for the two main state samples, Arizona and New Mexico, are not statistically different from the Regional sample. Thus, the focus of this analysis is on the full Regional sample.

The empirical problem is how to sort through the large number of value statements and distill down to a set of distinct and statistically significant attitudinal groups. Factor analysis provided the initial step in reducing the dimensionality. To be useful for policymakers, the analysis should relate value statements to demographic characteristics, which influences the level of agreement for each dimension (Bengston 1994; Stern 2000). While a simple correlation analysis was initially considered, this approach would only be capable of estimating the pairwise correlation relationships independently of all other variables in the data. Regression analysis is richer because a group of independent variables may be used to explain one single dependent variable. Regression analysis would, however, result in a cumbersome amount of regressions (e.g., especially with the remaining 21 *Public Land Value* statements), depending on the question of interest. Further, regression analysis assumes that the independent variables explain the dependent variable; this method requires distinguishing between the 'dependent' and the 'independent' variables. In some cases, the direction of causality may not be clear-cut, as is the case with the *Public Land Value* statements. Other techniques that can link value-statements to demographic characteristics include cluster analysis and latent class analysis (Aldrich et al. 2007). However, these methods identify groups in *one* data set with multiple variables based on common response structures and not the relationships between two data sets, each with multiple variables.

Canonical Correlation Analysis

CCA, as introduced by Hotelling (1936), is a multivariate data analysis technique that can handle large number variables on both sides of the relationship. The method does not assume a direction of causality (Clark 1975) and is, therefore, an appealing alternative to identify the diversity of attitudes. By allowing for multiple variables on both the 'dependent' and the 'independent' side of the relationship, CCA allows for a deeper understanding of the connection between environmental attitudes and demographic characteristics than techniques that only have one 'dependent' variable and multiple independent variables.

This investigation uses CCA to analyze simultaneously two multivariate sets of variables: (i) the *Public Land Value* statements and (ii) a set of demographic characteristics. Demographic characteristics are expected to influence the formation of environmental attitudes (Bengston 1994; Stern 2000; Vaske et al. 2001). However, it is uncertain whether characteristics are influenced by or influence individual values, so that we are unsure what set of statements and demographic items best describe each latent relationship.

CCA estimates a coefficient or weight, referred to as the canonical loading, for each variable. A linear combination of variables and associated canonical loadings for each variable set is called a canonical variate, and the associated canonical variates of both variable sets form a canonical function. The canonical loadings in each canonical function are estimated to maximize the canonical correlation ($\rho \in [0,1]$) between the canonical variates, while maintaining orthogonality among all other canonical functions.[5]

Let $\mathbf{U}$ be a $(1 \times p)$ vector associated with $\boldsymbol{X}$ public land value statements and $\boldsymbol{V}$ be a $(1 \times q)$ vector associated with $\boldsymbol{Y}$ demographic characteristics, where p and q are the number of variables in each set. For the first latent relationship (U_1,V_1), CCA seeks the best linear combination of $\boldsymbol{X}$ and $\boldsymbol{Y}$ variables given the weighted sum of variables of each variable set:

[5] The *canonical correlation* is not equivalent to the *coefficient of correlation*, i.e., a measure of variance. The variance can be found by estimating a redundancy index.

$$U_1 = a_1X_1 + a_2X_2 + \cdots + a_pX_p, \quad (1)$$

$$V_1 = b_1Y_1 + b_2Y_2 + \cdots + b_qY_q. \quad (2)$$

The highest correlation is determined by finding the linear combination of the following matrices:

$$\mathbf{U}_1 = \mathbf{a}_1\backslash\Omega_{11}^{-1/2}\mathbf{X}, \quad (3)$$

$$\mathbf{V}_1 = \mathbf{b}_1\backslash\Omega_{22}^{-1/2}\mathbf{Y} \quad (4)$$

that maximizes:

$$\rho_1 = \mathrm{corr}(U_1, V_1) = \max_{a,b} \mathrm{corr}(U_1, V_1) = \frac{\mathbf{a}\backslash\Omega_{12}\mathbf{b}}{\sqrt{\mathbf{a}\backslash\Omega_{11}\mathbf{a}}\sqrt{\mathbf{b}\backslash\Omega_{22}\mathbf{b}}},$$
$$\text{subject to } var(U_1) = var(V_1) = 1, \quad (5)$$

where $\mathbf{\Omega}_{11}$ and $\mathbf{\Omega}_{22}$ is the variance matrix for U and V, respectively, $\mathbf{\Omega}_{12}$ the covariance matrix, and $\boldsymbol{a}$ and $\boldsymbol{b}$ denote the respective vector of weights for each variable set.

The maximization process works stepwise, determining orthogonal canonical functions with descending canonical correlation values. The maximum number of canonical functions is determined by the number of variables in the lowest dimension data set.

The significance of the relationship between the canonical variates of each canonical function is tested using Bartlett's χ^2, which is estimated as:

$$\chi^2 = -\left[(n-1) - \frac{1}{2}(p+q+1)\right] \ln \Lambda, \quad (6)$$

where n is the number of observations, p is the number of variables in the lowest dimension data set, and q is the number of variables in the data set with the greatest dimension. The variable Λ, Wilk's lambda, is estimated as the product of one (full correlation) and the square of the canonical correlation:

$$\Lambda = \prod_{i=1}^{p}(1-\rho_i^2), \quad (7)$$

where ρ_i is the ith canonical correlation.

The null hypothesis is that there is no significant relationship between the canonical variates of each canonical function, that is $\rho = 0$ (Bartlett 1941; Clark 1975). Rejecting the null hypothesis supports the existence of a relationship between the canonical variates, i.e., the canonical function is significant and the set of variables with their respective canonical loadings describe the characteristics of a group (Afifi and Clark 2004). If the first canonical correlation is significant, then the second is tested by excluding the first canonical correlation in (6). Testing continues until the null hypothesis cannot be rejected at a specified level of significance (5 % level of significance is used here).

Once the model is estimated, and significant canonical functions are identified, the size and sign of canonical loadings are used to interpret the results. CCA does not yield a t test, so it is common to assign a cut-off value for the canonical loadings (Barcikowski and Stevens 1975; Clark 1975; Lambert and Durand 1975). While there is no standard rule, a cut-off value of 0.10 in absolute value is used here to focus on the most important statements and characteristics for each group.

Table 4 Bartlett's χ^2 test of canonical function significance

Description	χ^2	d.f.	p-value
Group 1	2,171.20	294	0.000
Group 2	1,463.90	260	0.000
Group 3	835.84	228	0.000
Group 4	532.51	198	0.000
Group 5	373.37	170	0.000
Group 6	242.39	144	0.000
Group 7	154.55	120	0.018
Group 8	109.81	98	0.195
Group 9	76.00	78	0.543
Group 10	45.60	60	0.916
Group 11	29.96	44	0.948
Group 12	15.95	30	0.983
Group 13	8.04	18	0.978
Group 14	3.01	8	0.934

The null hypothesis is that there is no significant relationship between the canonical variates

Empirical Results of the CCA

Initial Diagnostics

CCA results from Eq. (6) are presented in Table 4 for the 14 possible latent relationships—labeled here as Group 1 through Group 14, by ascending order of the size of the canonical loading—indicate the first seven groups are statistically significant.[6] To confirm these results, the stability of the canonical loadings for each statistically significant group was verified using a split-sample validation process discussed in McGarigal et al. (2000). The process involves randomly splitting the sample into sub-samples (60/40), and then conducting CCA on each split sample. The correlation between the canonical loadings of each split sample with respect to the full sample is then estimated to determine the stability of the results. If the loadings are highly correlated, close to 100 % in absolute value, then the results of the full sample are stable. Overall, the groups are generally stable for both sub-samples splits, except for

[6] The 21 public land values statements represent the larger set of variables, compared to the 14 demographic characteristics; therefore, the total number of possible relationships is 14.

Table 5 Estimated canonical loadings

Value/characteristic	CCA groups						
	1	2	3	4	5	6	7
Environmental activism (statements 10–16)[a]	*0.5049*	*−0.2890*	*−0.1756*	−0.0778	0.0346	*0.2307*	*0.1463*
Personal conservation behavior (statements 1–8)[a]	*0.5317*	*−0.1710*	*−0.1969*	−0.0525	0.0200	0.0571	*0.1699*
Conservationist management values (statements 18–25)[a]	*0.4084*	*0.2258*	*−0.4934*	*−0.2285*	0.0370	0.0465	0.0670
Household income	*−0.1322*	*0.4386*	0.0555	−0.0226	0.0763	*0.2567*	*0.2805*
Age	0.0270	*−0.3992*	*−0.6376*	*0.3474*	*0.3865*	−0.0026	0.0876
Hispanic[b]	0.0552	*−0.5102*	*0.6704*	−0.0534	*0.3495*	*0.3601*	0.0013
Male[c]	*−0.6089*	*0.1220*	−0.0441	*0.2327*	*0.4533*	0.0675	*−0.4228*
High school, GED, or less[d]	*−0.1695*	*−0.5894*	0.0286	*−0.3206*	−0.0613	*−0.3227*	*−0.1094*
Some college education[d]	−0.0727	*−0.1961*	0.0741	0.0597	0.0711	*−0.3519*	*0.2832*
Bachelors or associate degree[d]	−0.0554	*0.3124*	0.0536	0.0916	*−0.2193*	*0.4815*	*−0.2258*
Years living in the area	*−0.1327*	*−0.5060*	*−0.4316*	*−0.3868*	−0.0417	*0.5512*	−0.0155
Conservationist	*0.6214*	*0.2870*	*−0.1294*	*−0.3554*	*0.4619*	−0.0347	*−0.1655*
Not a member of any group	−0.0976	*−0.3350*	*0.1459*	*0.5064*	*−0.5559*	*0.1791*	*−0.1643*
Producer	*−0.2664*	0.0989	0.0268	*−0.3997*	0.0862	*−0.1177*	*−0.1455*
Off-highway vehicle	*−0.2207*	*0.1306*	−0.0366	*−0.3278*	*0.1979*	*−0.1387*	*−0.2731*
Sportsperson	*−0.4116*	*0.2590*	−0.0172	*−0.3259*	*0.3964*	0.0432	*0.5103*
Hiker/biker	*0.1982*	*0.1190*	−0.0922	−0.0939	*0.1639*	*−0.1878*	−0.0118

Canonical loadings with an absolute value greater than or equal to 0.10 are given in italics

[a] Calculated as the average canonical loadings of the corresponding public land value statement. Positive values represent greater agreement with the *Public Land Value* dimension

[b] Positive values denote Hispanic, negative non-Hispanic

[c] Positive values denote male, negative female

[d] Graduate education is the reference category

Group 6 in the 40 % split. As each sub-sample was generated based on random sampling without replacement, some deviation between the full sample and each sub-sample is expected.

CCA Empirical Results

Table 5 presents mean values for each of the seven identifiable CCA latent relationships (Group 1 through Group 7), by each of the three value dimensions of *Public Land Value* statements and demographic characteristics.[7] Mean values are calculated by taking the average value of the canonical loadings of the statements corresponding to each *Public Land Value* dimension. Positive values represent agreement with the value dimension. For example, the mean value of *environmental activism* for Group1 is positive, while for Group 2 it is negative. Therefore, the latent relationship that is described by Group 1 agrees with *environmental activism*, while the latent relationship that is described by Group 2 disagrees. Prior to a more general discussion, each of the seven groups (1–7) identified are briefly summarized.

[7] The canonical loadings for the corresponding *Public Land Value* statements are available upon request to the lead author.

Group 1 is comprised predominantly by women, members of a conservationist group, which have earned a degree higher than high school or GED. They hold strong personal conservation behavior values, and agree with environmental activism and conservationist management values. They belong to households that earn a lower income than average, have not lived long in the area, and are not likely to be members of a Sportsperson, Producer, or Off-highway vehicle groups, but are likely to be a member of a Hiker/Biker group.

Group 2 is predominantly young, male, non-Hispanic, more likely to have earned a higher degree than high school or GED, have not lived long in the area, and more likely to live in a households that earns a higher than average income. They disagree more with environmental activism than with personal conservation behavior, and agree with conservationist management values. They are likely members of a natural resource group, for example, Conservationist, Off-highway vehicle, Sportsperson, or Hiker/Biker group.

Individuals from Group 3 are women, young, Hispanic, have recently arrived to the area and are not likely to be a member of any natural resource group. Their environmental attitudes are influenced by their general disagreement with all three *Public Land Values*. They more strongly disagree with conservationist management values

and personal conservation behavior, indicating more passive attitudes toward the environment.

Group 4 is mostly defined by not being a member of any natural resource group, for example, Conservationist, Producer, Off-highway vehicle, or Sportsperson group; and their environmental attitudes are defined by disagreement with conservationist management values. They are likely male, older, have lived in the area for a short time, and have likely earned a degree higher than high school or bachelors.

Membership to a natural resource group is very important to Group 5, especially to a Conservationist group. The group is predominantly male, Hispanic, and likely to have earned a degree higher than Bachelor's. They are also likely to be members of either an Off-highway vehicle, Sportsperson, or a Hiker/Biker group. Unlike all other groups, the three *Public Land Value* factor dimensions are not strongly related to demographic characteristics. Of the three, they weakly agree more with conservationist management. It appears that for this group, the interest in any natural resource group leads to weak environmental attitudes.

Group 6 have lived in the area for some time, and are more likely to have earned a bachelor's degree than any other degree. They belong to households that earn a higher than average income, are Hispanic, and their environmental attitudes are influenced by environmental activism. Group 6 is not likely to hold membership in any natural resource group, especially a Sportsperson or a Hiker/Biker group.

Group 7 are likely members of Sportsperson group, female, and who agree more with personal conservation behavior than with environmental activism. They are more likely to either have some college education or a higher than a bachelor's degree, live in a household that earns a higher than average income and are not likely to be members of a Conservationist, Producer, or Off-highway vehicle group.

Turning to more general observations, Hispanics are the second largest group in the Western part of the United States (Campbell 1996) and are expected to see their share of the population continue to grow over the next couple of decades (Ortman and Guarneri 2009). Despite being under-represented in the sample, being Hispanic is an important characteristic for five of the seven groups; women, another under-represented group in the sample, is represented in three of the seven groups.

Groups, 1, 3, and 7, are comprised primarily of women and Hispanics. Group 1 is better educated and is more likely to be a member of a conservationist group than Groups 3 and 7. Group 3 is likely to be younger than Groups 1 and 7. A key difference among these groups is membership to a stakeholder group, specifically to a Conservationist group. Group 1 has stronger pro-environmental attitudes and is more likely to belong to Conservationist group than Group 7, which is more likely to belong to a Sportsperson group. These differences affect the level of agreement with respect to the *Public Land Values*, and thus the attitudes toward their environment. Groups 1 and 7 agree with the two individual values and hold conservationist management values; Group 3 disagrees with all three values. Personal conservation behavior is a stronger determinant of environmental attitudes for Groups 1 and 7.

Groups 5 and 6 primarily characterize Hispanic males. Group 6 is better educated and more likely to live in a household that earns a higher income. Group 5 is likely older and more likely to be a member of natural resource group, especially a Conservationist or Sportsperson group. In terms of environmental attitudes, both hold have positive values toward the environment, but Group 6 has stronger individual values, due in part to having lived in the area longer. The weaker attitudes for Group 5 are due, in part, to the greater likelihood of belonging to all or some natural resource groups. They likely belong to groups that can be described as mechanized groups, Off-highway vehicle and Hiker/Biker, one that can be characterized as extractive, Producer. Each group has slightly different views in terms of the extent to which humans may or should impact the environment, and these dissimilar views lead to contradictory views with respect to how public lands are managed (Clement and Cheng 2011).

Discussion

The articulated goals of the US Forest Service include achieving sustainability by "integrating environmental, social, and economic issues and values" (USFS 2007). CCA identified seven statistically distinct attitudinal groups across the Southwestern Region, connected to both *Public Land Value* statements and demographic characteristics. In contrast to CCA, a simple regression analysis, or even the use of correlation tables, would not identify the nuances that can impact public responses to forest management and planning. Results are largely consistent with changes in Forest Service policy toward supporting both sustainability of ecosystem services and multiple uses of natural resources (Federal Register 2012). As Table 5 shows, most groups hold pro-environmental attitudes, with a greater agreement for development management values, followed by personal conservation behavior and environmental activism.

The analysis also yields insights on the relative importance of different stakeholder groups to management plans. For example, women, who have been traditionally characterized as having strong pro-environmental attitudes (McGarigal et al. 2000; Mobley et al. 2010; Steel et al.

1994), in fact have heterogeneous environmental attitudes, characterized by age, membership to a natural resource group, and for whom individual values matter most. Younger women (Group 3) tend to disagree with all three *Public Land Values,* with attitudes are driven primarily by management values. In contrast, older women (Groups 1 and 7) tend to agree with all three *Public Land Values* and their attitudes are driven primarily by individual values.

Hispanics is a group that has been traditionally characterized as having weak pro-environmental attitudes, with differences usually discussed in terms of foreign- and US-born Hispanics (Cordell et al. 2002; Johnson et al. 2004). Our analysis shows Hispanics are indeed not one homogenous group with respect to environmental attitudes. Of the five groups that are characterized as Hispanic, two describe Hispanic men (Groups 5 and 6), both of which have pro-environmental attitudes. Of the remaining three groups, one describes young women with anti-environmental attitudes (Group 3) and two older women with pro-environmental attitudes (Groups 1 and 7). Most importantly for policymakers, most groups tend to have weak conservation management values and at least one group is likely to disagree with this management value. The implication for policy is a relatively stronger support for conservationist policies than for development policies.

Higher levels of education are associated with stronger pro-environmental attitudes (Cottrell 2003; Mobley et al. 2010). However, education attainment seems to be a weak indicator of *Public Land Values*, consistent with empirical evidence of the weak association of education and environmental concern (McFarlane and Boxall 2000; Olli et al. 2001). Most groups tend to have a higher level of education than High School, consistent with the distribution in the data set. The one distinguishing characteristic among most groups is membership in a natural resource group, which has been found to be an indicator for environmental attitudes (McFarlane and Boxall 2000).

In this respect, there are some summary points that can be distilled. Most groups appear to derive environmental attitudes from conservationist management values and from personal conservation behavior (Groups 1, 3, 4, and 7). This set of groups has a common element in the role that stakeholder groups have in defining the key underlying values that affect attitudes. Passive environmental behavior and support for conservationist policies across most groups is at least suggestive that policymakers should implement low-impact resource development policies. Groups that derive their attitudes from environmental activist (Groups 2 and 6) values tend to be better educated, which is an important outcome for resource planners, as the average level of education is expected to increase over the coming decades (Day and Bauman 2000). This appears to explain the variability in the general attitudes among all identified groups and implies some concern for how resources are being managed, but not enough to encourage greater participation in environmental issues.

One of the benefits of using CCA to identify and characterize latent attitudinal groups is to make clear or explicit the full multiplicity of environmental attitudes using demographic characteristics. Since long-term policies must also address how changes in demographic characteristics are likely to affect future management plans (Larson et al. 2011; Shinew et al. 2006), we can match census projections to the environmental attitudes identified in CCA results in Table 5. For policymakers, this type of analysis is important in allowing them to consider the impact on resource plans due changes in attitudes toward the environment and associated changes in how public lands are used (Cordell et al., 2002; Johnson et al., 2004). Over the long-run, plans should focus on policies that control resource development, which are favored by groups that represent young and old individuals, or Hispanics. These groups that are expected to have greater impact on the overall values of the Region, which will have an impact on regional environmental attitudes and visitation patterns to National Forests and Grasslands (Chavez and Olson 2009; Cordell et al. 2002).

In a broader policy application, this approach can be used to develop resource and environmental policies that align with the values the public places on the environment, as well as reducing the possibility of conflict with stakeholder groups and other interested agents. A key requirement is the collection of environmental attitudes, which can then be used to compare and contrast overall attitudes across different regions or countries. Further, the strategy used in this investigation can be used in other resource planning settings, such as developing hydropower energy. In such a context, environmental attitudes would help inform policymakers how the public hopes current environmental needs are met and how to design long-term development or conservations strategies.

One weakness in the analysis is the inability to discuss the results in the context of a population-wide analysis. However, as discussed in the "Survey Data and Descriptive Statistics" section, the data generating process suffered from a low response rate, which is not unexpected in general population surveys (Connelly et al. 2003; Deaton 1997). An identified reason for the low response rate is the lack of saliency in the survey instrument, which was due to having several important features removed from the original questionnaire during the design stage. It is also possible that many contacted individuals were not available during the sampling period, summer, which may have also contributed to the low response rate (McCollum et al. 2008 for details). Given the importance of stakeholder groups in the results, prior contact with them may have resulted in

greater awareness among a group of individuals that would be more directly impacted by changes in forest management policy. Future research should involve stakeholder groups, both at the development phase of the survey, and in generating interest about the research project.

Conclusions

A shift in natural resource management planning by the US Forest Service toward greater consideration of ecosystem services requires an understanding of the environmental attitudes in the public. In addition of helping define the direction of resource management policies, such analysis is helpful in designing socially acceptable management plans. We use CCA to relate a set of *Public Land Value* statements and demographic characteristics to identify environmental attitudes and discuss their implication toward forest management in the Southwest United States.

Forest planners must design resource management guidelines that address local concerns and a complex mix of values and attitudes. Ideally, conservation programs must accompany natural resource development policies, with an understanding of the benefits to the public. What is clear is that planners must engage in greater outreach to local communities and stakeholder groups and engage in an on-going discussion about the effect of policy on the environment.

But most basically, perhaps the key message is that there are no simple characterizations to the seven distinct, identifiably attitudinal groups from this analysis. What is clear is that simple bifurcations or single dimension stereotypes (e.g., along gender or race and ethnicity) do not exist. On the other hand it is clear that planners should never fall into the trap that there are somehow an infinite or countless number of attitudinal groupings. The number of statistically distinct attitudinal groups in Region 3 is a little more than a handful (seven), but it is a complex mix.

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