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Social-Value Maps for Arapaho, Roosevelt, Medicine Bow, Routt, and White River National Forests, Colorado and Wyoming

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Cover. Photograph showing Maroon Bells at Sunrise, Aspen, Colorado, by K. Scott Jackson, U.S. Geological Survey (front). Photograph showing scenic view of Roosevelt National Forest, Colorado, by John J. Mosesso, U.S. Geological Survey (back).

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Abbreviations

AUC	Area under the curve
DEM	Digital elevation model
GIS	Geographic information system
HDNR	Human Dimensions of Natural Resources
NVUM	National visitor use and monitoring
SolVES	Social Values for Ecosystem Services

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Executive Summary

The continued pressures of population growth on the life-sustaining, economic, and cultural ecosystem services provided by our national forests, particularly those located near rapidly growing urban areas, present ongoing challenges to forest managers. Achieving an effective assessment of these ecosystem services includes a proper accounting of the ecological, economic, and social values attributable to them. However, assessments of ecosystem goods and services notably lack information describing the spatial distribution and relative intensity of social values—the perceived, nonmarket values derived particularly from cultural ecosystem services. A geographic information system (GIS) tool developed to fill this need, Social Values for Ecosystem Services (SolVES; http://solves.cr.usgs.gov), now provides the capability to generate social-value maps at a range of spatial scales. This report presents some of the methods behind SolVES, procedures needed to apply the tool, the first formal map products resulting from its application at a regional scale, and a discussion of the management implications associated with this type of information.

In this study, we use SolVES to identify the location and relative intensity of social values as derived from survey responses gathered from residents living in counties adjacent to Arapaho, Roosevelt, Medicine Bow, Routt, and White River National Forests. The results, presented as a series of social-value maps, represent the first publicly available spatial data on social-value intensity for the southern Rocky Mountain region. Our analysis identified high-value areas for social values including aesthetic, biodiversity, and life sustaining within wilderness areas. Other values, like recreation, show high-value areas both within wilderness and throughout the general forest areas, which can be attributed to people using the forests for a diverse set of recreational activities. The economic social-value type was lower within wilderness areas, which was an expected outcome because of the restrictions inside wilderness areas that preclude resource extraction, development, and motorized or mechanized recreation.

Providing spatially explicit social-value information collected from residents in counties adjacent to these national forests can assist in facilitating the U.S. Department of Agriculture Forest Service's Multiple-Use Sustained-Yield Act of 1960 (16 U.S.C. 528) note and the 2012 Forest Service Planning Rule (36 CFR Part 219), which encourage public participation in planning and management. By making these maps available to the public, we hope to encourage exploration of potential uses of these data for resource management and planning

Introduction

As the U.S. population continues to grow, so too will the importance of managing our national forests so that future generations continue to benefit from the natural resources and recreational opportunities they provide through their wide array of ecosystem services. Comprehensive ecosystem service assessments offering a full accounting of their ecological, economic, and social values would assist forest managers in their efforts. However, as the Millennium Ecosystem Assessment (2005) reported, limited information exists at the local and national level for many ecosystem services and even less information exists for nonmarket services. Furthermore, information describing the spatial distribution and relative intensity of social values, the perceived, nonmarket values ascribed by the public particularly to cultural ecosystem services such as aesthetic, recreation, and spiritual (Sherrouse and others, 2014), has been notably lacking from assessments of ecosystem goods and services (Carpenter and others, 2006; Tyrväinen and others, 2007; Raymond and others, 2009; Chan and others, 2012). In this study, we present maps for 13 social values—aesthetic, biodiversity, cultural, economic, future, historic, intrinsic, learning, life sustaining, recreation, spiritual, subsistence, and therapeutic. National forests that are adjacent to large urban areas with rapidly growing populations, like the three examined in this study, can benefit greatly from the identification of social values to help support management decisions.

Our study area includes Arapaho, Roosevelt, Medicine Bow, Routt, and White River National Forests, located in the southern Rocky Mountains of Colorado and Wyoming (fig. 1). These national forests rank as some of the most visited in the

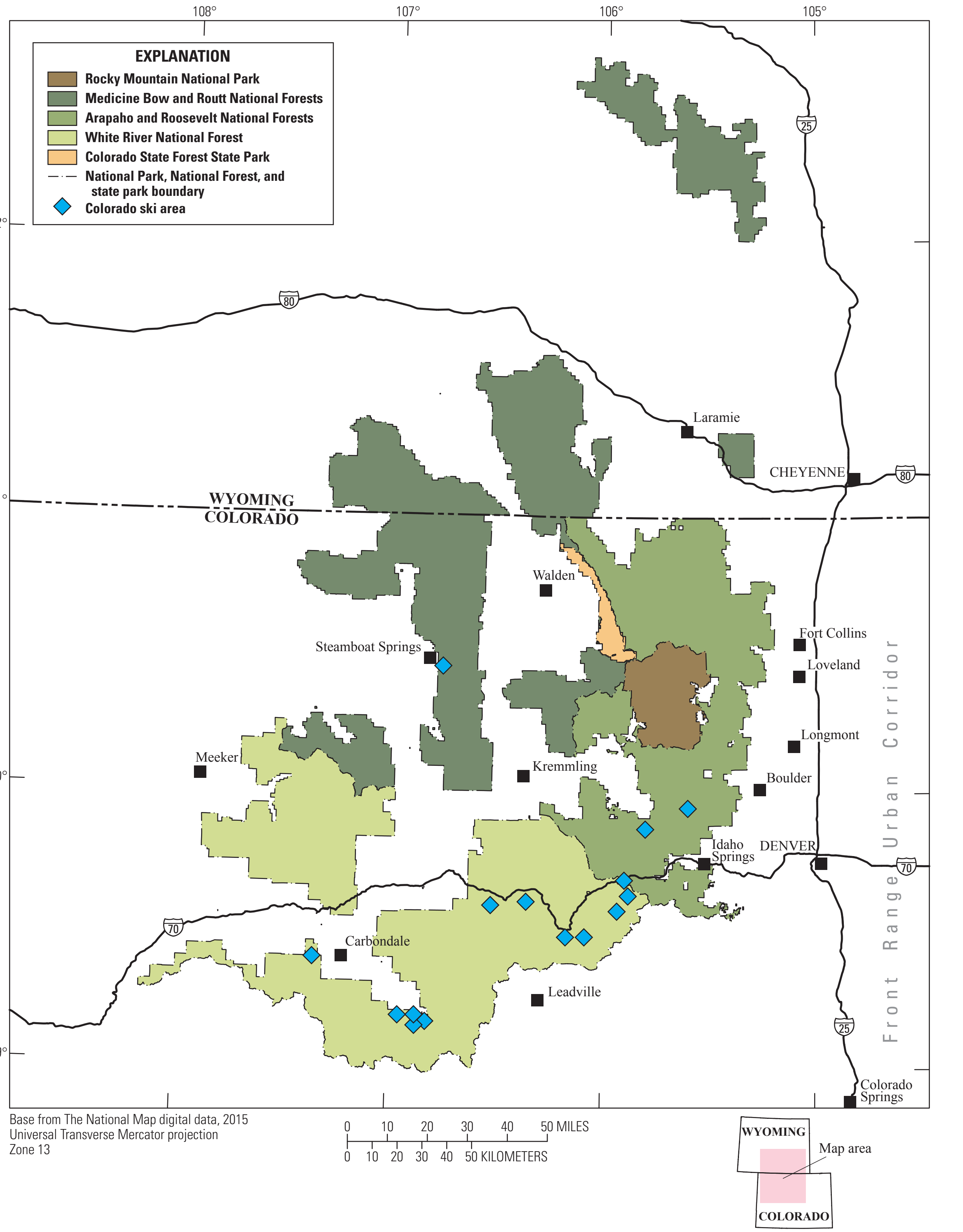

Figure 1. Study area map showing the location and boundaries of the public lands included in our analysis.

Nation and are used by the public for many activities such as: hiking, camping, boating, horseback riding, snowmobiling, skiing, fuelwood collection, hunting, fishing, ATV riding, and many others. White River National Forest has the highest visitation of any national forest in the country at an estimated 9.7 million people annually with approximately 6.5 million of these visits attributed to the forest's 11 major ski areas (U.S. Department of Agriculture [USDA], 2005). Arapaho and Roosevelt National Forests, with approximately 6 million combined visitors annually, have one of the highest visitation rates but much less of a contribution from the forest's three ski areas at approximately 1.8 million (USDA, 2005; Colorado Department of Transportation, 2010). Medicine Bow and Routt receive less visitation than the adjacent forests with approximately 2.9 million combined visitors annually (USDA, 2007). However, Medicine Bow and Routt National Forests are some of the top snowmobile destinations in the United States with over 325 miles of snowmobile trails in Medicine Bow alone (Keinath and McCumber, 2007).

The human population along the eastern flank of the southern Rocky Mountains in Colorado and Wyoming from Cheyenne to Colorado Springs (the Front Range urban corridor) is expected to grow over the next 5 years from 4.4 million to 5 million residents and is likely to further increase visitation to the national forests in the region (Colorado Department of Local Affairs, 2014). In 2013, Colorado's population was estimated at approximately 5.4 million with approximately 83 percent of the population residing in 12 counties of the Front Range (Colorado Department of Local Affairs, 2014). The populations in the Denver metro area and Front Range counties are expected to grow by 1.9 percent per year with a total state population exceeding 6.1 million by 2020 (Colorado Department of Local Affairs, 2003; U.S. Census Bureau, 2014). With the continued dependence of a rapidly growing regional population on the array of services the Arapaho, Roosevelt, Medicine Bow, Routt, and White River National Forests provide, along with visitation rates being among the highest in the Nation, it is informative to forest management to consider which locations in the forests are highly valued by whom and why.

National forest management is guided by the USDA's Forest Service (Forest Service) multiple-use mandate as "an act to authorize and direct that the national forests be managed under principles of multiple use and to produce a sustained yield of products and services, and for other purposes" (Multiple-Use Sustained-Yield Act of 1960, 16 U.S.C. 528 note). The Forest Service originally envisioned forest management as a way "to improve and protect the forest, to secure favorable watershed conditions, and to furnish a continuous supply of timber for the use of citizens of the United States" (USDA, 2013). Over time, the description of forest management has evolved to include "assessing ecological situations at the local and landscape levels, establish [sic] management objectives based on ecological, social, and economic information, and utilize [sic] the best tools available to achieve established vegetation objectives" (USDA, 2014). The 2012 Forest Service Planning Rule, incorporated into existing forest management objectives, emphasizes providing meaningful opportunities for public participation early and throughout the planning process, increases the transparency of decision making, and provides a platform for the agency to work with the public and across boundaries with other land managers to identify and share information and inform planning (USDA, 2012).

Our study focuses on developing relevant, spatially explicit social-value information gathered from the public that will support management objectives of the five national forests to further their productivity and maintain enjoyable and meaningful visitor experiences in the face of pressures on resources driven by regional population growth and increasing visitation. The addition of social-value information can directly address the five components of the 2012 Forest Service Planning Rule (desired conditions, objectives, standards, guidelines, and suitability of lands) and allow the public to be more involved in the planning process of their national forests.

To develop the systematic, quantitative, and spatially explicit information necessary to properly consider social values in forest management, the Social Values for Ecosystem Services (SolVES) tool (http://solves.cr.usgs.gov/) was applied to data obtained from responses to a value and preference survey randomly distributed to residents around the Arapaho, Roosevelt, Medicine Bow, Routt, and White River National Forests. SolVES—developed as an Esri ArcGIS® custom toolbar—was designed to assess, map, and quantify social values (Sherrouse and others, 2014). The resulting social-value maps, rendered with a 10-point value index (VI), are presented here to illustrate the differences in the spatial distribution and relative intensity of various social values across the landscape. Social values ascribed to cultural ecosystem services have been difficult to include in management decisions for national forests because of the limited information available to decision makers. Recent studies have identified, through the use of SolVES, where these values exist on the landscape by using responses to value and preference surveys for these five national forests in Colorado and Wyoming (Sherrouse and others, 2011, 2014; Sherrouse and Semmens, 2014; Bagstad and others, 2015).

In this report, we explore the general utility of this type of social-value information for national forest management and planning rather than informing any particular management decisions in progress. The maps presented in this report represent some of the first publicly available geospatial data generated by SolVES for social values at a regional scale in the southern Rocky Mountain region. In addition to the maps included in the appendix, raster datasets in a GeoTiff format are provided by the U.S. Geological Survey online at http://pubs.usgs.gov/sir/2016/5019/Social_Value_Rasters_SIR_GeoTiffs.zip.

Methods

The methods section describes the survey distribution, structure, and directions used to obtain data for analysis. Also included are the postprocessing procedures used to transpose paper survey maps with marked points to a shapefile containing the information provided by survey respondents. Methods also describe the SolVES process and outputs used in the analysis.

Survey Information

The data used by SolVES to generate the social-value maps were collected from three surveys randomly distributed by mail to households in counties within or adjacent to the national forest boundaries (1,500 surveys for each forest unit; 4,500 total). These surveys were performed by Colorado State University to assess public perception of the mountain pine beetle's impact on wildland fire management (Czaja and Cottrell, 2014). The three surveys were identical in content but focused on a national forest area as defined by the Forest Service. The national forests of Arapaho, Roosevelt, Medicine Bow, and Routt are specific zones in larger management units that include grasslands (Arapaho and Roosevelt National Forests/Pawnee National Grassland and Medicine Bow–Routt National Forests/Thunder Basin National Grassland), but the surveys and resulting analysis focused on the national forests rather than the accompanying grasslands. Most pertinent to the SolVES analysis were two additional sections included in the surveys.

The first section of the survey asked respondents to allocate a hypothetical $100 among 13 social-value types. These social-value types were presented to survey respondents by asking the question, "In what ways do you value the national forest," and providing an explanation of the 13 social-value types such as aesthetic and recreation as possible responses (table 1). The included values were based on a typology for forests originally proposed by Rolston and Coufal (1991) and has been widely used and adapted for a variety of management objectives (Brown and others, 2002, 2004; Brown, 2005; Alessa and others, 2008; Clement and Cheng, 2011). The second section of the survey asked respondents to identify areas on a map of the national forest (by hand-marking points) that they identified as representing the social values to which they had allocated value. The maps provided in the survey (1:450,000 scale) included features that assisted respondents in locating places that represented a specific social value. These features included: boating sites, campgrounds, interpretive sites, scenic overlooks, picnic sites, wildlife viewing, trailheads, ski areas, major highways, and wilderness boundaries.

Socioeconomic and demographic information was also collected for each survey respondent such as education, income, gender, age, and years living in community. No personally identifiable information was recorded through this survey or analysis. In addition to the 12-page, self-administered survey, multiple mailings included a prenotification postcard, first survey packet, thank you and reminder postcard, a replacement survey packet, and a final thank you and reminder postcard (Czaja and others, 2012).

Postsurvey Processing and Data Preparation

A total of 783 completed surveys were received for the three national forest areas with an overall response rate of 17 percent. Of the returned surveys, 319 respondents or 41 percent completed the mapping portion, and 2,256 points were collected from the 319 respondents (see the next paragraph for details on digitizing points). The total number of points received was less than optimal, but some factors may have contributed to

Table 1. Description of the social-value types included in the value and preference surveys for Arapaho, Roosevelt, Medicine Bow, Routt, and White River National Forests.

Social-value type	Social-value description
Aesthetic	I value these forests because I enjoy the scenery, sights, sounds, smells, etc.
Biodiversity	I value these forests because they provide a variety of fish, wildlife, plant life, etc.
Cultural	I value these forests because they are a place for me to continue and pass down the wisdom and knowledge, traditions, and way of life of my ancestors.
Economic	I value these forests because they provide timber, fisheries, minerals, and/or tourism opportunities such as outfitting and guiding.
Future	I value these forests because they allow future generations to know and experience the forests as they are now.
Historic	I value these forests because they have places and things of natural and human history that matter to me, others, or the Nation.
Intrinsic	I value these forests in and of themselves, whether people are present or not.
Learning	I value these forests because we can learn about the environment through scientific observation or experimentation.
Life sustaining	I value these forests because they help produce, preserve, clean, and renew air, soil, and water.
Recreation	I value these forests because they provide a place for my favorite outdoor recreation activities.
Spiritual	I value these forests because they are a sacred, religious, or spiritually special place to me or because I feel reverence and respect for nature there.
Subsistence	I value these forests because they provide necessary food and supplies to sustain life.
Therapeutic	I value these forests because they make me feel better, physically and (or) mentally.

the smaller sample. Czaja and Cottrell (2014) identified limitations that may have reduced the sample size, and these included the length of the survey (12 pages) along with the complex mapping component. These two factors contributed to pretest completion times that ranged from 16 to 30 minutes, which may have deterred some respondents from completing the full survey including the mapping portion (Czaja and Cottrell, 2014). The process of how the survey responses were digitized and attributed is detailed below.

The original ArcMap documents used to create the maps included in each survey were used to establish reliable control points for digitizing the point data marked by respondents on the paper survey maps. A minimum of four control points were selected using forest boundaries and map grid marks as spatial references. The points marked on each paper map were then digitized using the marker tool on the ArcGIS drawing toolbar to create a series of shapefiles containing the points from each survey map. The scale of the paper maps required that each forest be divided onto two pages, and in some cases, inset maps were also necessary. As a result, individual shapefiles were created for each map page or inset and uniquely identified.

Because the survey map questions were completed differently by individual survey respondents depending on their interpretation of the survey instructions, some general rules were followed to consistently guide if, when, and where a point was digitized.

- If a respondent properly followed the survey instructions, a point would be marked on the map notated with a letter near it corresponding to the value type for that point (for example, an A for aesthetic value). This point was digitized at the same location where the respondent had marked the point on the paper survey map.
- If a respondent did not provide a point on the map but notated a location on the paper map with an identifiable value type, this point was digitized at the centroid of the annotation characters.
- If a respondent drew a circle or polygon around an area and attributed a specified value to it, the centroid of the circle or polygon was used to digitize a point.
- If a respondent drew a line to represent a trail or linear feature they valued, the center point of the line was used to digitize a point.
- If a single point on the map was intended to indicate multiple values, multiple points were digitized at the same location with each point representing one of the values indicated by the respondent.
- If a respondent indicated that they valued the entire forest for all values, no point was digitized because of the lack of information regarding a specific location or value type.
- If a respondent included points on the map but did not provide any notation to distinguish which values the points represented, no points were digitized.
- If a respondent included values and location names somewhere on the survey other than the map, no points were digitized. (If a specific place name was unambiguous, could be resolved to a single point on the map, and was identified as representing a specific value, a point could be digitized).

After digitization, the add field tool was used to create SURVEY_ID (long integer), VALUE_ID (short integer), and PLACE_NAME (text) fields in each shapefile. The points were then attributed to identify the individual survey from which they were obtained (SURVEY_ID), the value type they represented (VALUE_ID), and the place name (PLACE_NAME) associated with each point (if a name was provided). After attribution, all shapefiles were merged and loaded into an ArcGIS geodatabase that served as the data source for the SolVES analysis. Amounts allocated by respondents in the value-allocation section of the survey were transcribed to identify the individual survey from which they were obtained (SURVEY_ID, long integer), the value type to which they were allocated (VALUE_ID, short integer), and the amount allocated (AMOUNT, double). These were then loaded into a VALUE_ALLOCATION table in the source geodatabase. Additional information regarding the specific data structure requirements for SolVES analysis is included in the user manual (Sherrouse and Semmens, 2015).

Finally, 6 environmental variables in the form of 30-meter resolution raster datasets were loaded into the geodatabase for inclusion in the analysis: distance to water, distance to roads, slope, landforms, land use, land cover, and elevation (table 2). These variables were selected for their potential to explain the spatial distribution of the points collected from survey respondents.

SolVES Analysis of Survey Data

The application of SolVES to the survey and environmental data collected for the national forest areas is summarized in a generalized process flow diagram of SolVES (fig. 2). This figure illustrates how user-supplied survey and environmental data are processed to generate the social-value maps and associated environmental metrics (Sherrouse and others, 2014).

Using the points associated with each value type, weighted by the total allocation amount associated with that value type, SolVES generated a kernel-density surface for each value type that was then normalized using the overall maximum density value found among all the surfaces. SolVES then standardized the normalized kernel density surfaces for each value type to the 10-point VI scale (ranging from 0 to 10) by multiplying each surface by 10 and rounding to the nearest integer. These standardized value surfaces provide an indicator of which social-value types attained higher scores on the VI scale (for example, aesthetic might attain a maximum score of 10 while biodiversity only attains a 7).

Table 2. Environmental variables used to generate social-value models. All raster variables have a 30-meter resolution (Sherrouse and others, 2014).

Layer name	Description	Source
Elevation	Digital Elevation Model (DEM) in meters	USGS National Elevation Dataset (NED) http://viewer.nationalmap.gov/launch/ [Database moved by time of publication; Web site accessed February 10, 2015, at http://seamless.usgs.gov/website/seamless/viewer.htm. Search parameters may have changed.]
Slope	Percent slope	Derived from elevation layer using ArcGIS Slope tool
Distance to roads (DTR)	Horizontal distance to nearest road in meters	USGS The Road Indicator Project (TRIP) NORM ED Datasets, http://rmgsc.cr.usgs.gov/trip/data/ [Available as of February 10, 2015.]
Distance to water (DTW)	Horizontal distance to nearest water body in meters	Derived from USGS National Hydrography Dataset (NHD), http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd, using ArcGIS Euclidian Distance tool
Land cover	16-class categorical land cover data	USGS National Land Cover Database (NLCD) 2006 Land Cover, http://www.mrlc.gov/nlcd06_data.php
Land surface forms	10-class categorical land surface form data	USGS Global Ecosystems, http://rmgsc.cr.usgs.gov/ecosystems/data.shtml

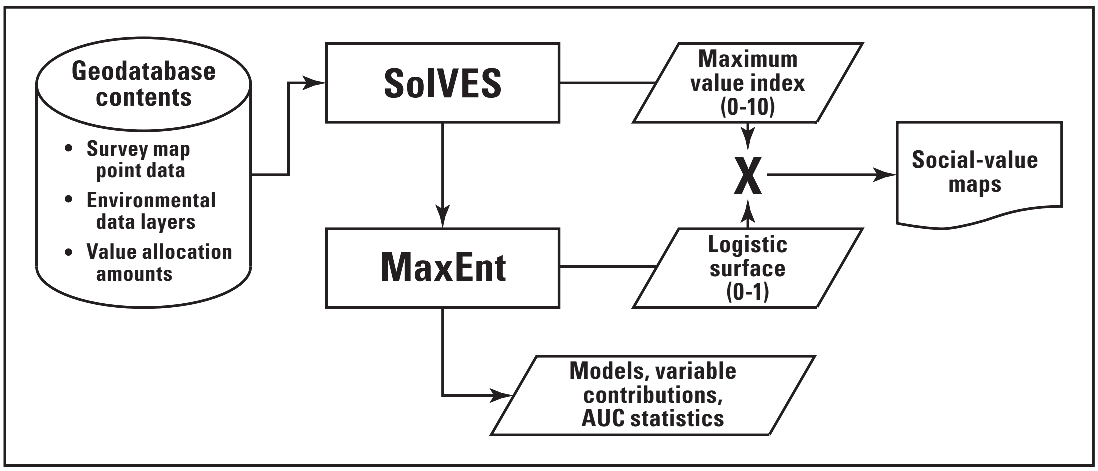

Figure 2. SolVES structure and process flow.

SolVES interfaces with the MaxEnt maximum entropy modeling software (Phillips and others, 2004, 2006; Phillips and Dudík, 2008; Elith and others, 2010) to generate logistic surfaces (ranging from 0 to 1) and associated models describing the relation between the point data and the selected explanatory environmental variables. MaxEnt was originally developed to model the geographic distribution of species, with the logistic surfaces providing a relative indicator of each location's habitat suitability for a selected species, given environmental conditions and the known presence of the species. In a social-values context, the logistic surfaces provide a relative indicator of where survey respondents would assign value for a particular value type given the underlying environmental characteristics and the distribution of points representing that value type (Sherrouse and others, 2014). Combined by multiplication with the maximum VI scores calculated by SolVES for each corresponding value type, the resulting surfaces are again standardized to the 10-point VI scale to produce final social-value maps for each social-value type. The goodness-of-fit of these maps to the forests can be evaluated according to the training area under the curve (AUC) statistics generated by MaxEnt for each model. The AUC statistic ranges from 0 to 1. Training AUC statistics of 0.70 and above indicated potentially useful models (Swets, 1988; Hosmer and Lemeshow, 2000). To acquire the best AUC statistics for the forests in this study, we replicated similar model variations proposed by Sherrouse and Semmens (2014) which examined 13 combinations of the 6 environmental variables used in SolVES. Through this examination of multiple model runs, we determined that the best combination of environmental variables to explain survey responses is a model that included all six variables. MaxEnt output also provided information regarding the relative contribution of each environmental variable to each model.

The national forests examined in this study were analyzed by SolVES as a single, contiguous area with 13 social-value maps produced. In addition to the 13 value maps, a combined social-value map is included to illustrate the distribution of overall social-value intensity across these forests. This combined map was created by summing the 13 social-value surfaces and dividing the resulting surface by its maximum value (52). Using the same calculations as the individual maps, the combined map was standardized to the 10-point VI scale. To remain consistent with the survey map scale of 1:450,000, all social-value maps were generated at an output cell size of 450 meters.

In addition to the national forests examined in this study, Rocky Mountain National Park and Colorado State Forest State Park were also included in the final maps because of their proximity to the adjacent national forests and the inclusion of points that respondents placed inside the parks' boundaries. Respondents of the Arapaho and Roosevelt survey placed approximately 152 points in Rocky Mountain National Park. The focus of the surveys was not Rocky Mountain National Park, and the paper survey maps provided to respondents showed less detail in terms of reference information inside the park and used a different background color than the surrounding national forests which may have deterred respondents from placing more points inside the park. Likewise, Colorado State Forest State Park is adjacent to Arapaho, Roosevelt, Medicine Bow, and Routt National Forests. Although the points marked by survey respondents within Colorado State Forest State Park were fewer than those in Rocky Mountain National Park, we thought the inclusion of Colorado State Forest State Park was warranted due to the contiguous relation the park has with the surrounding national forests. Including areas like Rocky Mountain National Park and Colorado State Forest State Park illustrates how values extend beyond formal, administrative forest boundaries into similar surrounding areas.

Results

The results section focuses on individual social-value types and examines the mean and maximum value indexes, point counts, AUC values, and environmental variable contributions to the SolVES models. A discussion of the combined social-value map is also included in this section to identify high-values areas produced when combining the 13 social-value types.

Results by Social-Value Type

The social-value maps (see appendix, figs. 3–16) produced with SolVES represent the modeled spatial distribution and relative intensity of social values within the Arapaho, Roosevelt, Medicine Bow, Routt, and White River National Forests. The maps were rendered in ArcMap using a cool to hot (blue to red) color gradient with higher value intensity indicated by increasingly warmer colors. Table 3 includes the maximum VI, point counts, allocation amounts, and training AUC associated with each social-value type. Table 4 includes the proportional contribution of each environmental variable to each social-value model.

An analysis of the mean VI for the most highly rated social values among survey respondents is shown in table 5 and illustrates the difference in mean VI for the general forest area, the wilderness areas, and the general forest area with wilderness areas removed. The mean VI for aesthetic, biodiversity, and life sustaining values was higher inside wilderness areas compared to the general forest areas. The economic value-type map, however, exhibits a lower mean VI within wilderness boundaries compared to the rest of the forest area. Recreation's mean VI is slightly lower inside wilderness areas compared to the forest area, although not to the extent as seen for the economic value type.

Respondents provided the greatest number of points for aesthetic (413) and recreation (443) values (table 3). These two values also attained the highest maximum VI (9 and 10, respectively), which is an indication that they were the highest rated values among survey respondents.

Table 3. Maximum value index, point counts, allocation amount (dollars), and training areas under the curve for social-value types of the national forests.

[VI, value index; AUC, area under the curve]

		Arapaho, Roosevelt, Medicine Bow, Routt, and White River National Forests			
		Maximum VI	**Point count**	**Allocation amount (dollars)**	**Training AUC**
Social Values	Aesthetic	9	413	8,231	0.70
	Biodiversity	7	219	9,645	0.69
	Cultural	4	67	2,797	0.74
	Economic	6	148	6,091	0.73
	Future	6	142	6,791	0.73
	Historic	4	100	3,168	0.72
	Intrinsic	5	127	5,971	0.72
	Learning	3	55	3,000	0.79
	Life sustaining	7	187	11,585	0.71
	Recreation	10	443	7,984	0.67
	Spiritual	4	83	3,417	0.72
	Subsistence	4	39	2,080	0.81
	Therapeutic	4	151	4,810	0.71

Table 4. Environmental variable contribution to each social-value model.

[DTR, distance to road; DTW, distance to water; LULC, land use land coverage; %, percent]

		Environmental variables					
		DTR (%)	DTW (%)	Elevation (%)	Landform (%)	LULC (%)	Slope (%)
Social Values	Aesthetic	8.94	0.54	39.58	27.99	11.58	11.37
	Biodiversity	60.51	2.10	12.35	2.79	21.10	1.14
	Cultural	17.12	12.12	0.56	36.55	24.24	9.42
	Economic	26.36	20.22	31.40	13.83	5.52	2.68
	Future	12.25	5.63	27.31	12.70	40.03	2.08
	Historic	20.43	7.41	2.44	30.02	32.34	7.35
	Intrinsic	14.39	11.91	61.27	3.36	7.79	1.28
	Learning	12.98	9.43	33.42	8.73	31.71	3.72
	Life sustaining	25.95	3.72	40.38	9.23	18.19	2.53
	Recreational	26.79	1.84	28.16	13.47	25.29	4.45
	Spiritual	14.17	0.01	25.35	24.83	34.76	0.89
	Subsistence	7.99	19.95	18.34	16.69	15.46	21.57
	Therapeutic	5.52	6.45	17.38	39.19	13.43	18.02

The training AUC values listed in table 3 are indicators of the goodness-of-fit of the maps generated by SolVES to the national forest unit areas, with higher numbers indicating a better fit. To present a regional representation of social values that was afforded by the simultaneous collection of data from three national forest areas using the same methodology and for the same purpose, the forests were modeled as a single, contiguous area. The training AUC represents how well each social value fit that area. The biodiversity and recreation values were the only social values that had training AUCs below the 0.70 threshold (0.69 and 0.67 respectively). This is indicated on the social-value maps included in the appendix and warns users of the data to interpret these social values with caution because of the AUC values not meeting the threshold. Reasons why biodiversity and recreation may have performed below the threshold for AUC values are explained later in the discussion. The other social values all demonstrated training AUCs at or above the 0.70 threshold. The cultural, learning, spiritual, and subsistence social-value types exhibited low point counts and low maximum VI (table 3). These social values have generally registered lower in previous studies that analyze cultural ecosystem services (Sherrouse and others, 2014). The social-value maps (figs. 5 [cultural], 10 [learning], 13 [spiritual], and 14 [subsistence]) illustrate that with a lower maximum VI, the map values remain homogeneous throughout the entire study area because of the restricted range of the VI scale and provide few comparisons between low- and high-valued areas. Biodiversity and recreation have some of the highest point counts, value allocations, and maximum VI, and yet they fail the goodness-of-fit test for the forests.

The maps produced by SolVES reveal relations between social value indicated by survey respondents and the underlying environmental variables (table 4). Aesthetic value (fig. 3) is influenced by elevation (40 percent) and landforms (28 percent), as can be seen in the higher valued areas concentrated around mountains and ridgelines. In contrast, the value of biodiversity (fig. 4) is influenced by the distance to roads environmental variable (60 percent). The life sustaining social-value type (fig. 11) is associated with higher elevations (40 percent), areas farther from roads (26 percent), and the type of land cover present (18 percent). The value map for recreation (fig. 12) has mostly even contributions from distance to roads (27 percent), elevation (28 percent), and land use and land cover (25 percent).

Table 5. Mean value index for entire general forest areas of Arapaho, Roosevelt, Medicine Bow, Routt and White River; all wilderness areas; and the general forest areas excluding wilderness areas.

Value type	Mean value index		
	Entire general forest areas	All wilderness areas	General forest areas excluding wilderness areas
Aesthetic	3.65	4.68	3.35
Biodiversity	2.53	3.21	2.33
Economic	2.41	2.03	2.53
Life sustaining	2.43	3.23	2.19
Recreation	4.36	4.18	4.41
Combined	4.88	5.62	4.65

Combined Social-Value Results

The combined map (fig. 16) was created to highlight areas of high intensity that are valued by survey respondents across all 13 social values. It uses the same value-index scale and color gradient as the individual social-value maps. The combined social-value map displays multiple social values to be considered for management decisions that are a representation of where social values are perceived by the public. It is important to note that the combined map is representative of all 13 social values but is influenced by the social values that have the greatest maximum VI (aesthetic, biodiversity, life sustaining, and recreation).

Discussion

The discussion section outlines the general findings of the SolVES analysis with a focus on the most highly rated social values from survey respondents. The findings from the SolVES analysis allow for a discussion of management implications along with the potential of future work to further incorporate social values into management and planning practices for the Forest Service.

General Findings

By using SolVES, this study illustrates where and how intensely social values are perceived by survey respondents throughout five national forests in the southern Rocky Mountains. Spatially representing the intensity of social values can help support management decisions by identifying where values perceived by the public are concentrated in the national forests. Combining public input on social values with environmental variables using SolVES, resource managers can more readily identify environmental factors that have strong relations with particular social value types.

We have identified through the quantitative analysis of maximum VI, value allocation, point count, training AUC, and mean VI that the social-value maps illustrate varying value intensities across individual value types and forests. Similar to previous social-value studies (Sherrouse and others 2011, 2014), aesthetic and recreation are among the most highly rated social-value types, whereas cultural, learning, spiritual, and subsistence value types are ascribed less often by survey respondents. The biodiversity social-value type has been analyzed in previous studies (Brown and others 2004; Christie and others 2006; Garcia and others 2007), and the results revealed that the public has a low awareness and general lack of understanding of biodiversity and from where its value is derived. Accompanied by a relatively low sample size, these factors may also help explain our inability to generate a social-value map of biodiversity that exceeds the minimum training AUC threshold for a useful model (0.70). Because of the disconnect between perceived and actual biodiversity value, other studies (Alessa and others, 2008; Bagstad and others, 2015) have focused on identifying areas of high biological diversity using biophysical models, which can then be used in conjunction with value and preference information to locate areas where public values may synergize or conflict with current management objectives. These studies identified that biodiversity as a social-value type can be a good indicator where the public perceives there to be biodiversity in the ecosystem contrary to where it actually exists. In the study conducted by Bagstad and others (2015), a 2×2 matrix was used to illustrate potential management implications through the combination of biophysical ecosystem services and social values. Areas where low values exist for biophysical and cultural ecosystem services may indicate potential development or resource extraction sites, assuming other natural or cultural resources are absent. An area of high value for biophysical and cultural ecosystem services would indicate a high support for ecosystem service-based management, a period when social and biophysical values align, or a potential zone of conflict where traditional uses and biophysical based management are not complementary (Bagstad and others, 2015).

Through an analysis of the environmental variable contributions to each social-value model within SolVES, we can start to identify why survey respondents assigned value to an area in a particular national forest. The distribution of life-sustaining value in Arapaho, Roosevelt, Medicine Bow, Routt, and White River National Forests shows the highest intensity within wilderness areas, which by design lack roads. This value aligns with a study done in the Chugach National Forest in Alaska where Brown and others (2002) noticed a unique distribution where only 30 percent of the life-sustaining points gathered were within 7,500 meters of the Chugach road network. The high intensity of life-sustaining value present throughout wilderness areas in our study illustrates the same pattern of greater distance from roads as seen in the Chugach National Forest study.

Many of the common social values that respondents indicated (for example, aesthetic, biodiversity, and life sustaining) have high-value intensity within wilderness areas. Table 5 provides a quantitative analysis of mean VI for some of the highly rated social values (aesthetic, biodiversity, economic, life sustaining, and recreation) and outlines differences in mean VI between wilderness areas and the general forest area. The economic social-value type is one of the social values that does not follow the pattern of high-value intensity within wilderness. This is an expected outcome because of the restrictions inside wilderness areas that preclude resource extraction, development, and mechanized recreation. There are nonmechanized recreational opportunities inside wilderness areas, which are shown in the recreation value type, yet value is still slightly lower inside wilderness areas, but the difference is less pronounced than it is for economic social value. This result can likely be attributed to the diverse recreational opportunities inside the national forests and wilderness areas, which lead to greater variability in where respondents placed values throughout the forests. A similar study analyzing social values identified how differing forms of recreation, including sport-hunting and off-highway recreation, may indicate why recreation has significantly higher values outside wilderness areas (Sherrouse and others, 2014).

The analysis of different uses remains a difficult aspect of forest management with recreational uses being diverse and often conflicting with one another. Along with identification of high-valued areas within different regions of the forests, SolVES provides additional information on the contribution of environmental variables to particular social-value types. Different national forests are distinguished by various recreational activities that can influence the social values that the public assigns to specific areas in a particular forest. White River National Forest, for example, benefits from 11 major ski areas, compared to 3 in Arapaho and 1 in Routt. We created environmental variables that described a certain aspect of the five national forests in a distance-to-ski-area variable. This helped describe White River National Forest because of the numerous ski areas located within its boundaries, but it was left out of the regional analysis because of this variable's lack of relevance to the other forests examined.

In addition to skiing, the diversity of recreational activities throughout these national forests may have contributed to the inconsistent relation between recreational value assigned by survey respondents and the environmental variables analyzed. Consider the streams valued by fishermen versus the forests roads valued by motorized recreationists versus the mountain peaks valued by hikers. These three examples of recreation activities would be identified through SolVES by a different dominant environmental variable associated to each point placed by respondents (distance to water for fisherman, distance to roads for motorized recreationists, and elevation or land cover for hikers of mountain peaks). Recreation was not categorized into these different activities in the original survey design, and this may have had a negative effect on how the SolVES models reacted to a wide variety of points being explained by a consistent set of environmental variables. Because of the differences in value assigned by respondents, no one environmental explanatory variable stood out (table 4). As a result, the recreation social-value model ranks lowest overall in terms of training AUC (table 3) in the SolVES analysis. However, this particular analysis still provides a general look at recreation as a whole inside of the selected national forests and can generate further interest in exploring the recreation social value in future studies.

Management Implications

The growing population adjacent to some of the already most visited national forests in the Nation will create the need for additional management to mitigate negative effects and user conflicts associated with increased use. Johnson and Stewart (2007), for example, found that recreational areas in close proximity to large urban centers are prone to rapid growth in use and that these landscapes are the most prone to effects related to that growth. Stein and others (2007) have identified a number of impacts from development pressures that will be important to residents adjacent to national forests similar to those analyzed in our study. These include native fish and wildlife habitats and populations, invasive plant species, recreation access and management, fire management, water quality and hydrology, boundary management, social and economic considerations, and Federal use planning and administration (Stein and others, 2007). Social-value information, particularly when paired with information on the production of other ecosystem goods and services (for example, Bagstad and others, 2013), can inform complex spatial planning and tradeoff analyses and would be useful in addressing many of the issues rapid population growth and development pose for national forests. The ability for managers to consider public value preferences in their forest plan decisions will help the public understand why certain decisions were made and help to better communicate any potential tradeoffs and contradictions between managerial decisions and values assigned by the public (Clement and Cheng, 2011). This type of information gives forest managers a better understanding of the complex relations that exist through the public's valuation of particular areas for certain social values and of the uses currently being managed in those areas.

The analysis presented in this report focused mainly on the spatial dimensions of social values, but the original survey also acquired information about the public's perception of fire management associated with the outbreak of mountain pine beetle. SolVES can pair this information with spatial responses to analyze how management actions will impact different user groups. For example, Sherrouse and others (2014) focused on differing attitudes from survey respondents for motorized recreation, oil and gas drilling, logging for wood products, and wilderness areas. By identifying subgroups of survey respondents with different attitudes and value orientations towards the environment, information can be obtained to support management strategies that reflect the needs of a diverse population using the forests for different reasons. Socioeconomic and demographic information collected through the survey is another way to categorize distinct user subgroups to identify why certain social values are being allocated to a particular area of the forest.

SolVES can also assist in addressing the five components of the 2012 Forest Service Planning Rule: desired conditions, objectives, standards, guidelines, and suitability of lands. These plan components are used to provide the vision, strategy, guidance, and constraints throughout the management process. When developing or revising plans, forest managers are encouraged to make the process as transparent and efficient as possible to reflect principles of adaptive management and engage the public through meaningful opportunities for participation early and throughout the process (USDA, 2015). The results generated from SolVES can assist in identifying where public values have been identified throughout the forests. The desired conditions of a management area would depend on the type of area being managed, but generally visitors should be able to participate in various recreational uses of the forests, including mechanized uses where applicable, while still providing visitors opportunities to engage in other activities corresponding to social values identified through the outputs generated by SolVES. To remain consistent with a multiuse stance, forests can also be managed to provide future economic opportunities from resource extraction and development. Understanding the spatial distribution of public value for a variety of different value types can assist managers in meeting satisfaction rating goals from visitors by incorporating additional public information into the planning process. Ecological standards could still be maintained throughout the planning process to protect places such as riparian areas, and adding SolVES output on social-value perceptions could expand the standards to include areas highly valued for their aesthetic, spiritual or other social-value properties and thereby expand opportunities for public involvement in the planning process. Guidelines for management can then be established that meet current ecological standards, but also include considerations for multiple social values provided by the public. This approach would permit a more rigorous and consistent process for managing conflicting uses of the forest.

Future Studies

Future studies involving spatially explicit social-value data may explore the incorporation of scenario design to help anticipate future management problems before they become an issue. Scenarios are defined as “plausible descriptions of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces” (International Panel on Climate Change, 2012, p. 2). Exploring scenario development for cultural landscapes corresponding to social values like aesthetic, recreation, and biodiversity, Plieninger and others (2013) identify the uses of scenarios that enable managers to better understand the forces driving landscape change and work with landscape stakeholders in the Swabian Alb biosphere in Germany. This study focused on identifying the driving forces influencing local communities, building contrasting narratives about potential alternative futures, refining the narratives, discussing scenario impacts on local communities, and developing management strategies (Plieninger and others, 2013). They found that participatory scenarios focused at the local scale have strength in terms of credibility, transferability, and confirmability of the insights gained, but are often weak in ensuring the dependability of modeled scenarios (Plieninger and others, 2013). An analysis conducted for national forest management would rely on the same type of participatory information seen in the Plieninger study, acquired from surveys used for the National Visitor Use Monitoring (NVUM) program. Using existing visitor surveys, we could explore the use of scenarios to anticipate future population growth and how these scenarios relate to crowding and social-value impacts inside national forests adjacent to large population centers.

The numerous recreational uses of the forests are another concern that prompts further investigation. The recreation social value can be difficult to interpret because of how a survey respondent identifies with that value type. For example, a fishermen, a skier, and a hunter would assign recreation value to different parts of the forests and could indicate changes in management practices to encourage these various uses throughout the forests. Future efforts to model recreation value may include categorizing the various use types, either by asking respondents specifically what recreational activities they pursue or by incorporating the different use types into the value typology used by the survey. Splitting the recreation social value into categories that reflect a specific use type can assist managers in identifying areas that are used more heavily by different recreation user groups.

Conclusions

The influence that social-value mapping will have on management decisions for public lands in the southern Rocky Mountain region will depend on how this type of information can be incorporated with current management procedures. Public participation early and throughout the planning and decision-making process is a key point outlined in the 2012 Forest Service Planning Rule—36 CFR Part 219. The outputs generated from SolVES help to identify where the public values cultural ecosystem services and can provide the bridge between forest managers and public opinion. SolVES provides a way to use social-value information collected through public surveys to model and map the spatial distribution of social values on a landscape. Certain social values, aesthetic and recreation, were observed to be the highest rated social values gathered from the survey respondents indicating increased forest use at various locations throughout the forests. Recreation, though highly rated by respondents, has known issues with accuracy because of the different recreation use types that survey respondents may have identified with, but the overall recreation value observed still indicates increased forest uses at specific locations throughout the forests. The other 11 social values were not as highly rated as aesthetic and recreation but provide valuable information on locations in the forest that the public has assigned value for the different social values. Understanding the value of the forests biophysically is a strength that the managers of these national forests demonstrate in current management practices. Social-value information found in this report can help incorporate public values in the planning process to become more transparent and encourage public outreach to assist in keeping our national forests healthy and productive for future generations.

We present results that fill the gap of spatially explicit social-value information reflecting the public’s perceptions of where a variety of cultural ecosystem services exist throughout the selected national forests. These results help to define the previously unconsidered social aspects of forest management as indicated by the Millennium Ecosystem Assessment and implemented in the U.S. Department of Agriculture’s 2012 Forest Service Planning Rule (36 CFR Part 219). This type of analysis can assist managers in identifying areas of high social value and allow for existing and future management plans to be integrated with social-value information to assist in managing our public lands.

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Appendix

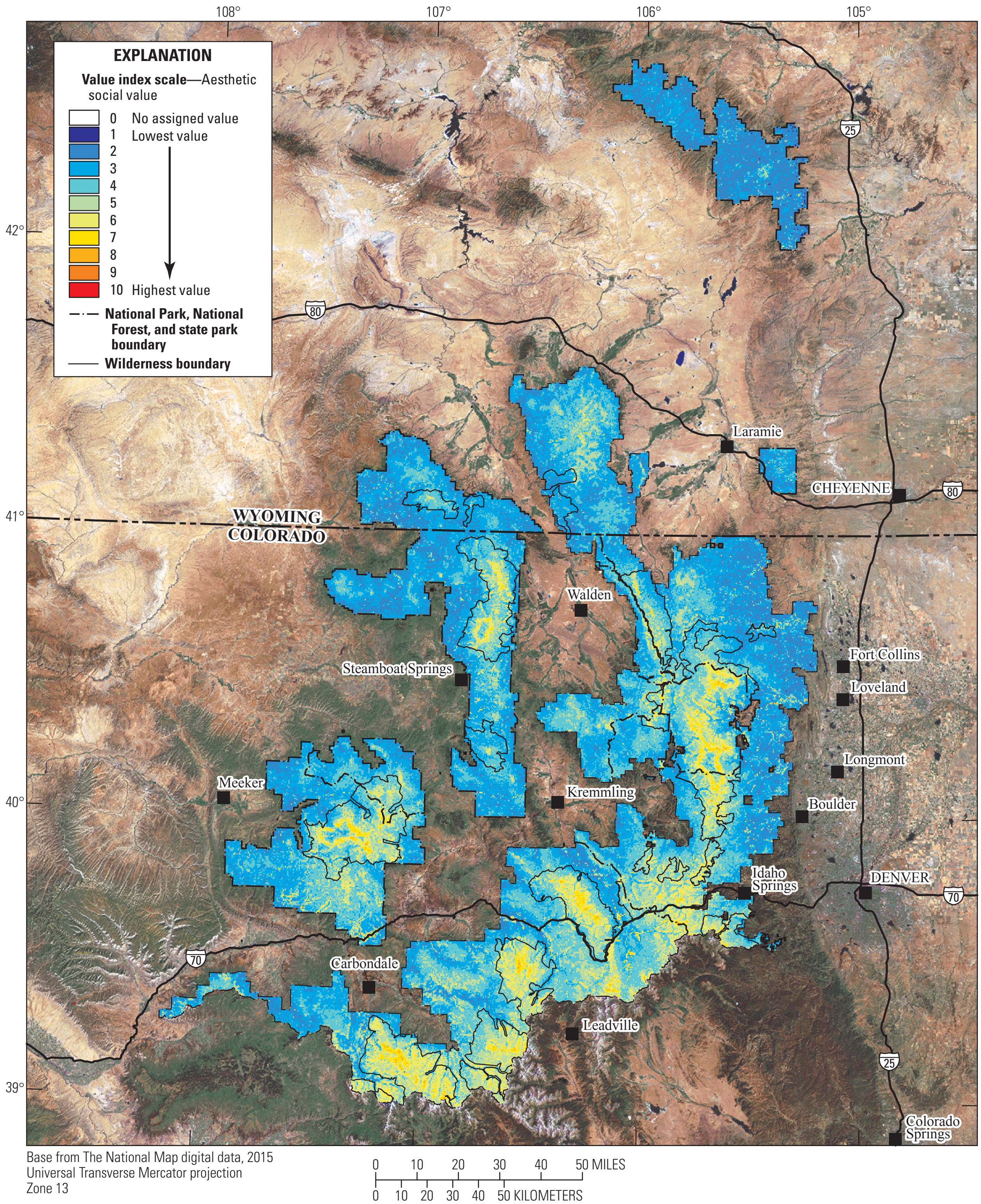

Figure 3. Aesthetic value map illustrating spatial distribution of the 10-point value index.

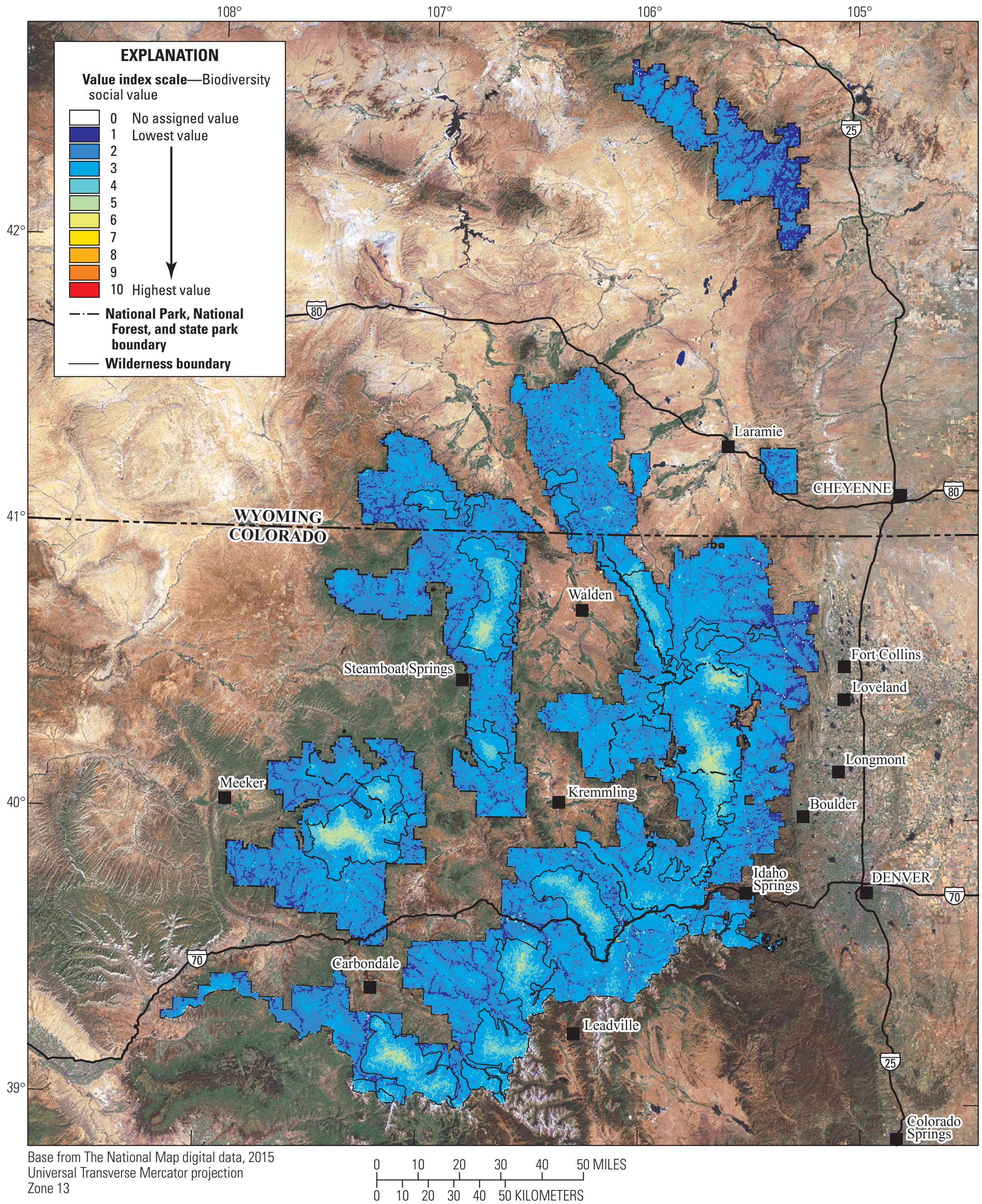

Figure 4. Biodiversity value map illustrating spatial distribution of the 10-point value index.

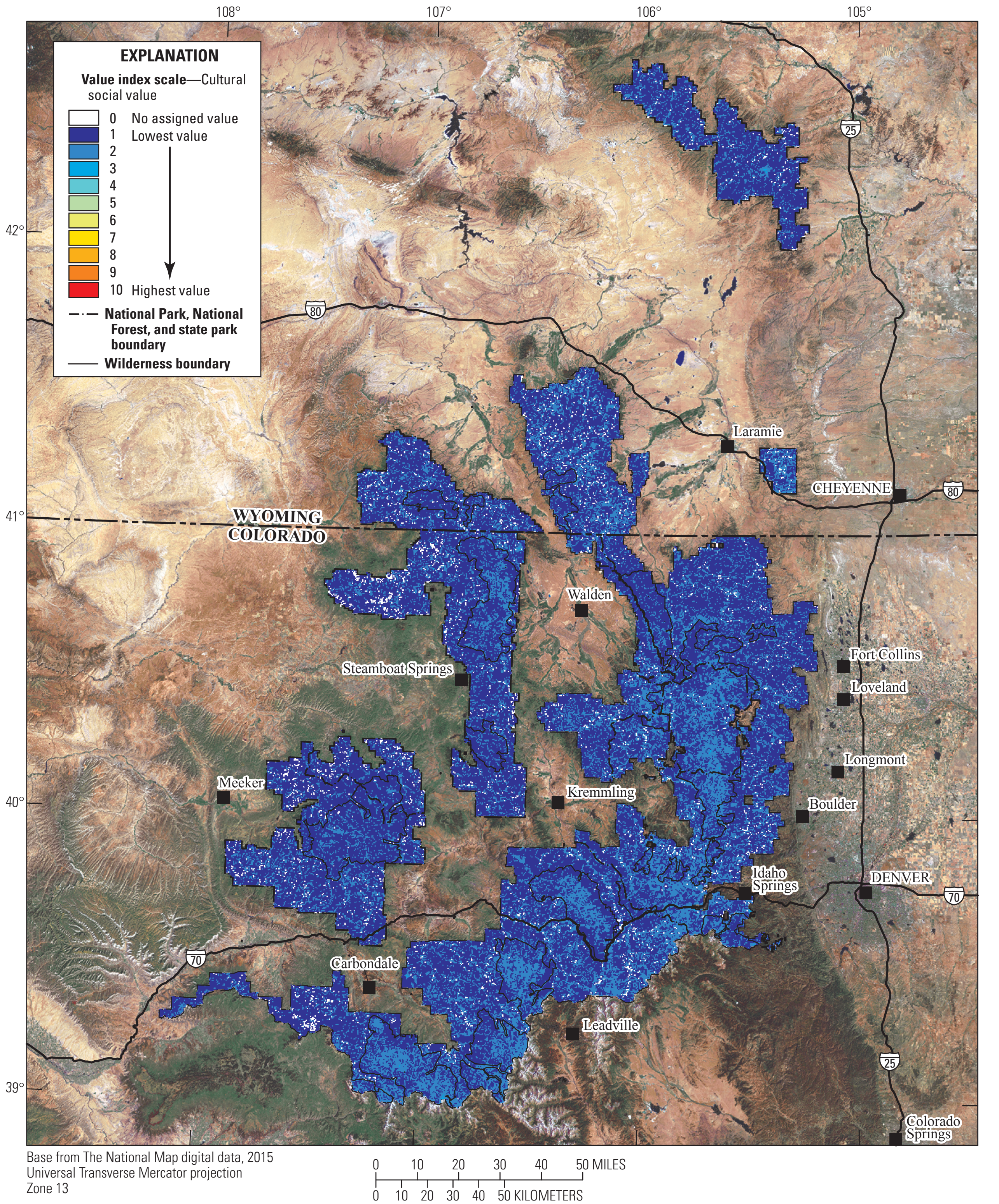

Figure 5. Cultural value map illustrating spatial distribution of the 10-point value index.

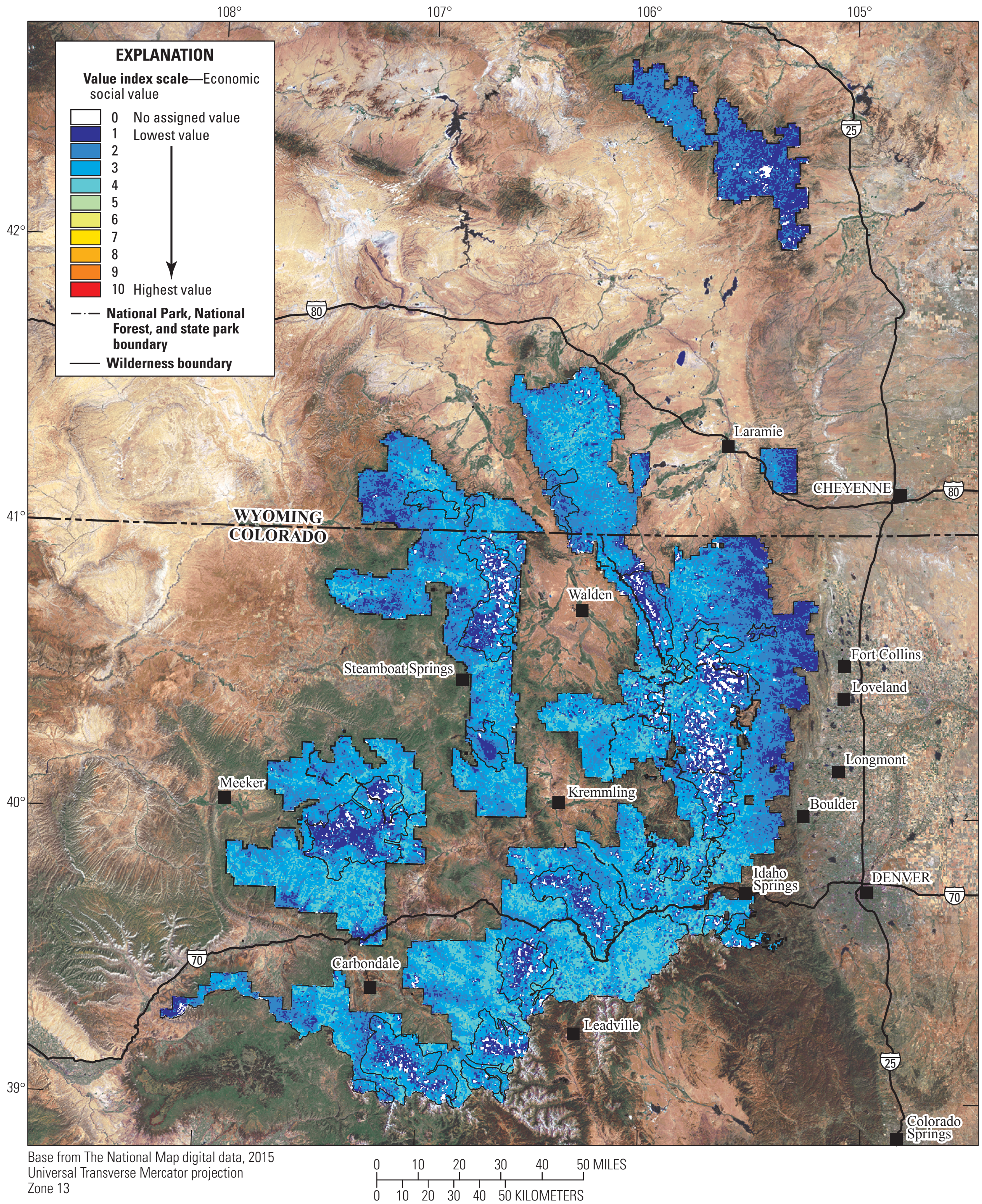

Figure 6. Economic value map illustrating spatial distribution of the 10-point value index.

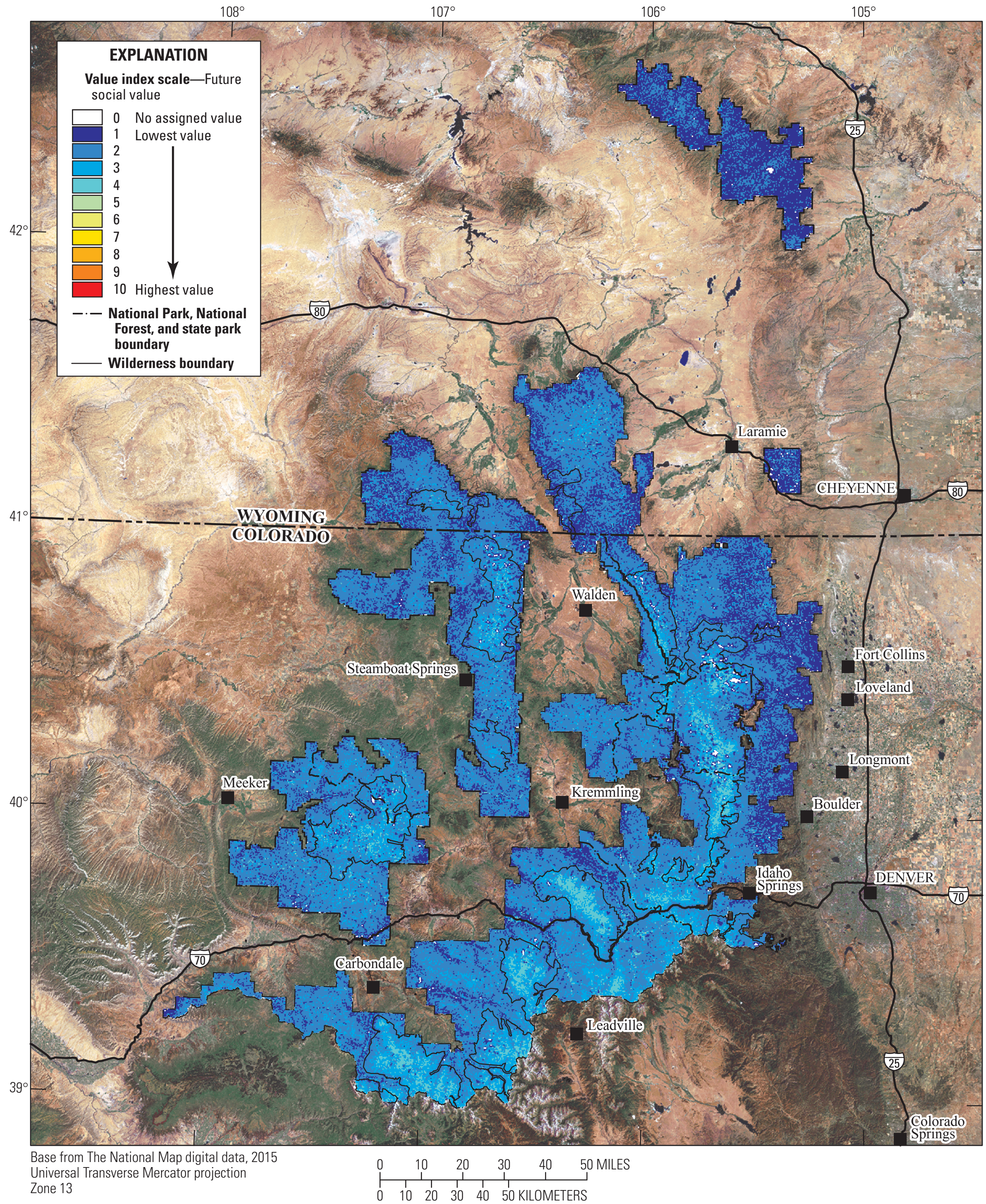

Figure 7. Future value map illustrating spatial distribution of the 10-point value index.

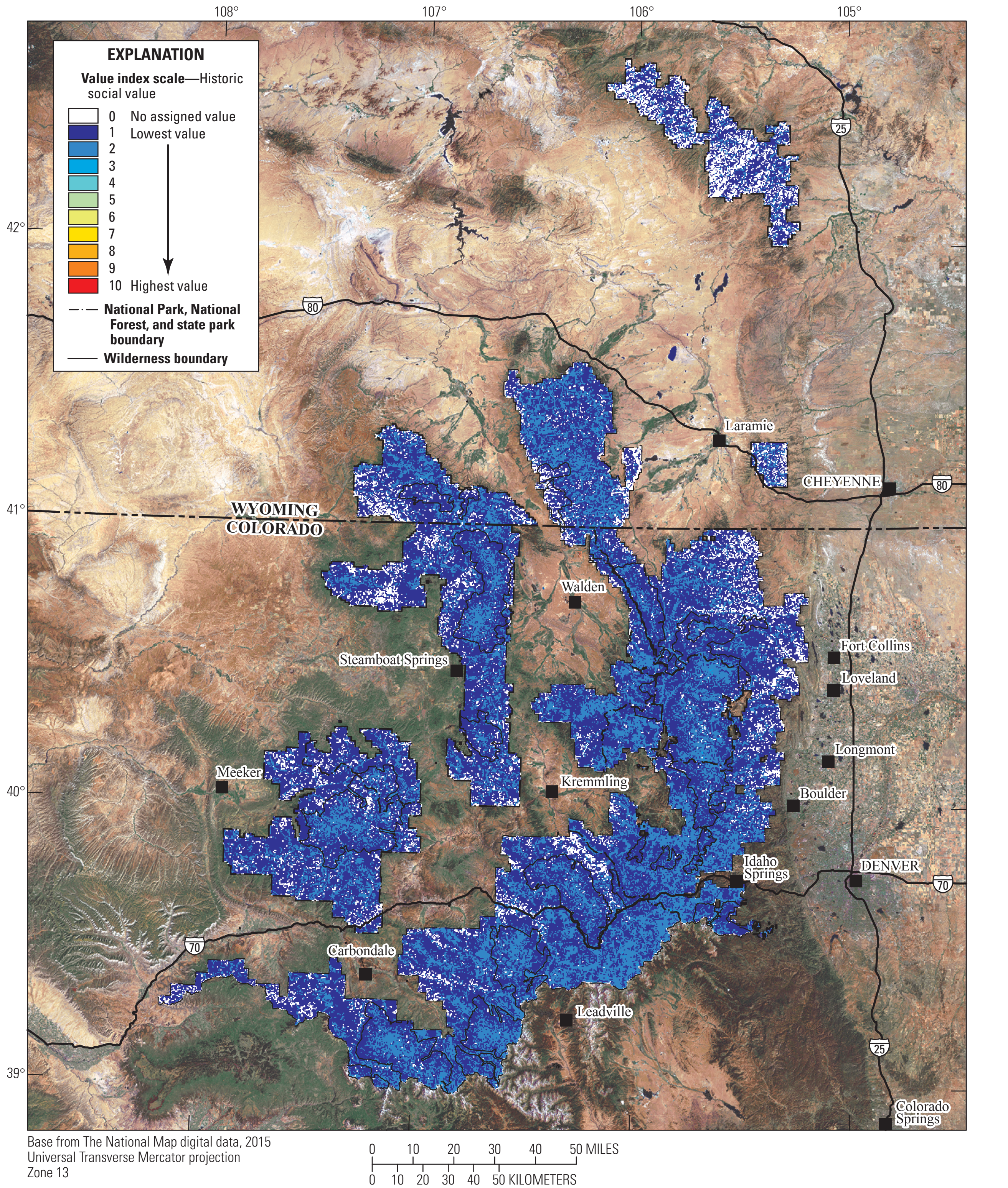

Figure 8. Historic value map illustrating spatial distribution of the 10-point value index.

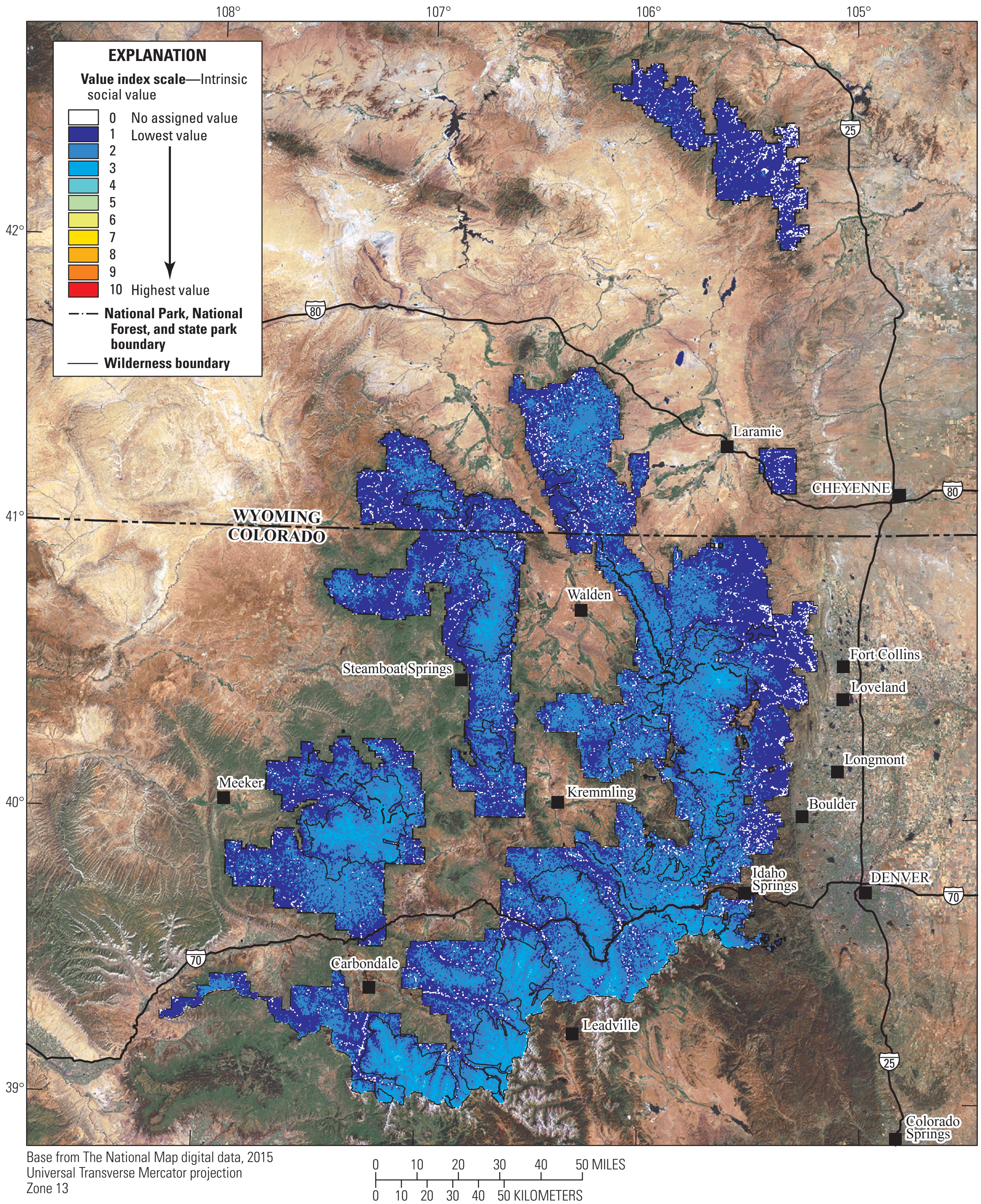

Figure 9. Intrinsic value map illustrating spatial distribution of the 10-point value index.

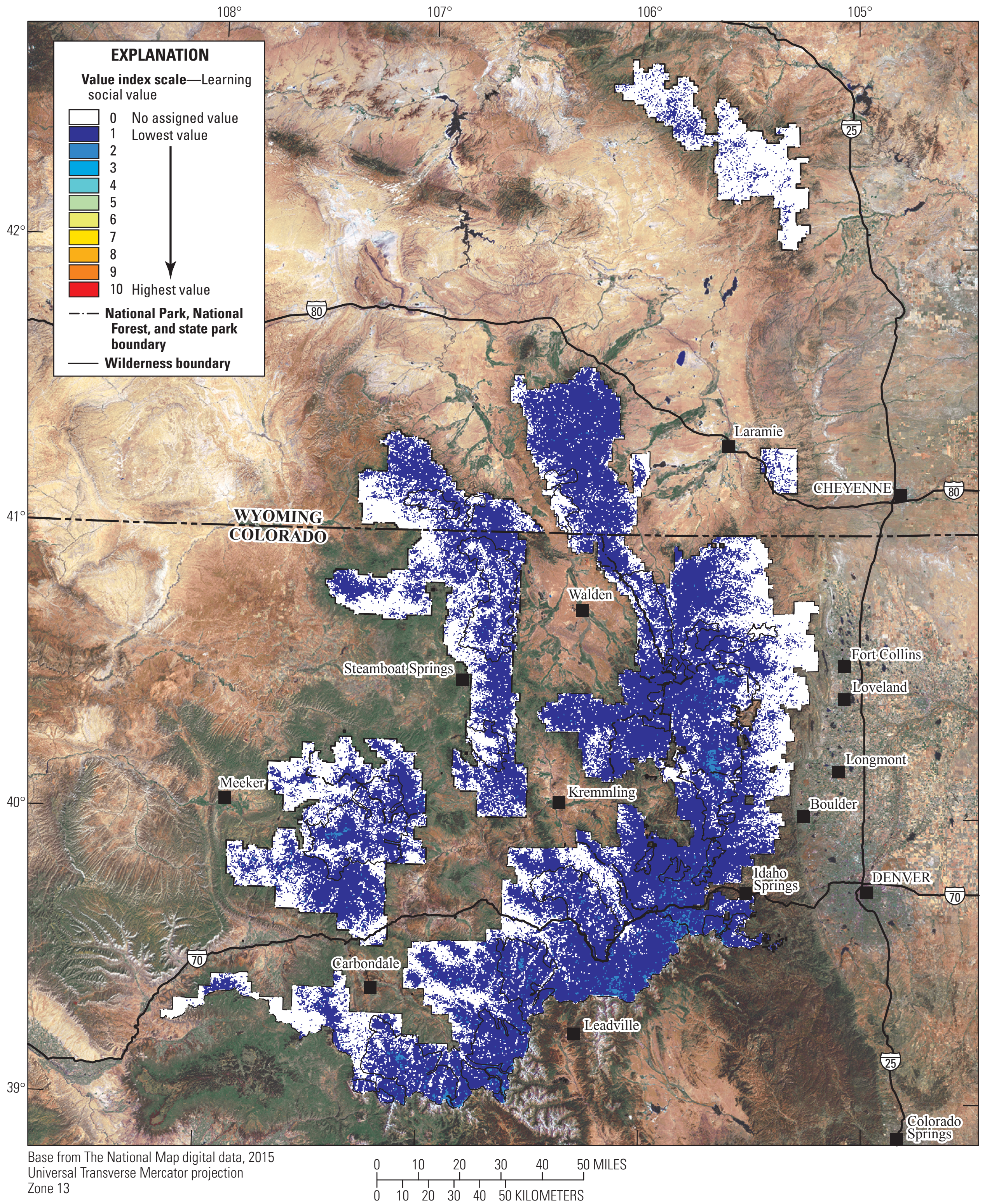

Figure 10. Learning value map illustrating spatial distribution of the 10-point value index.

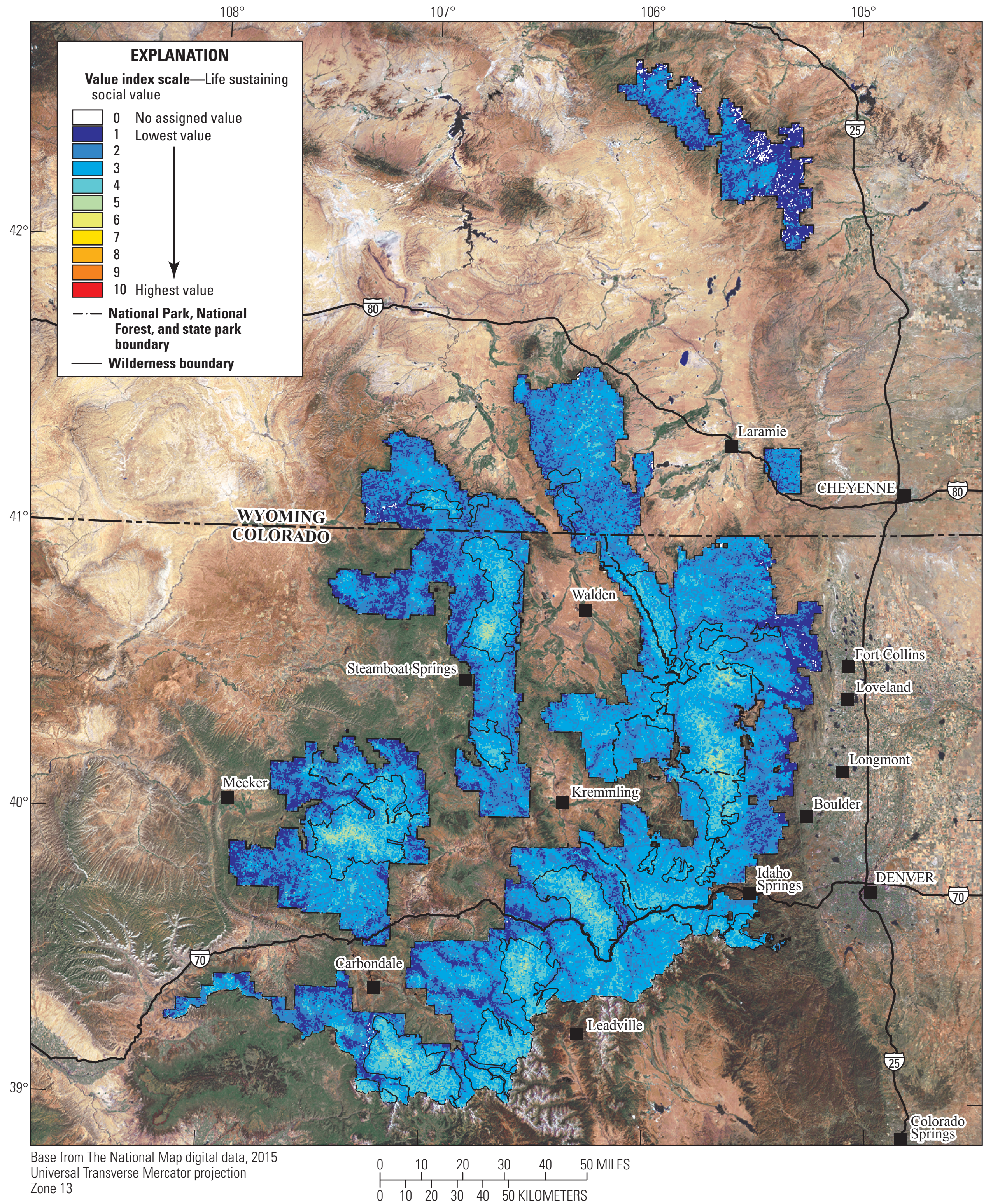

Figure 11. Life sustaining value map illustrating spatial distribution of the 10-point value index.

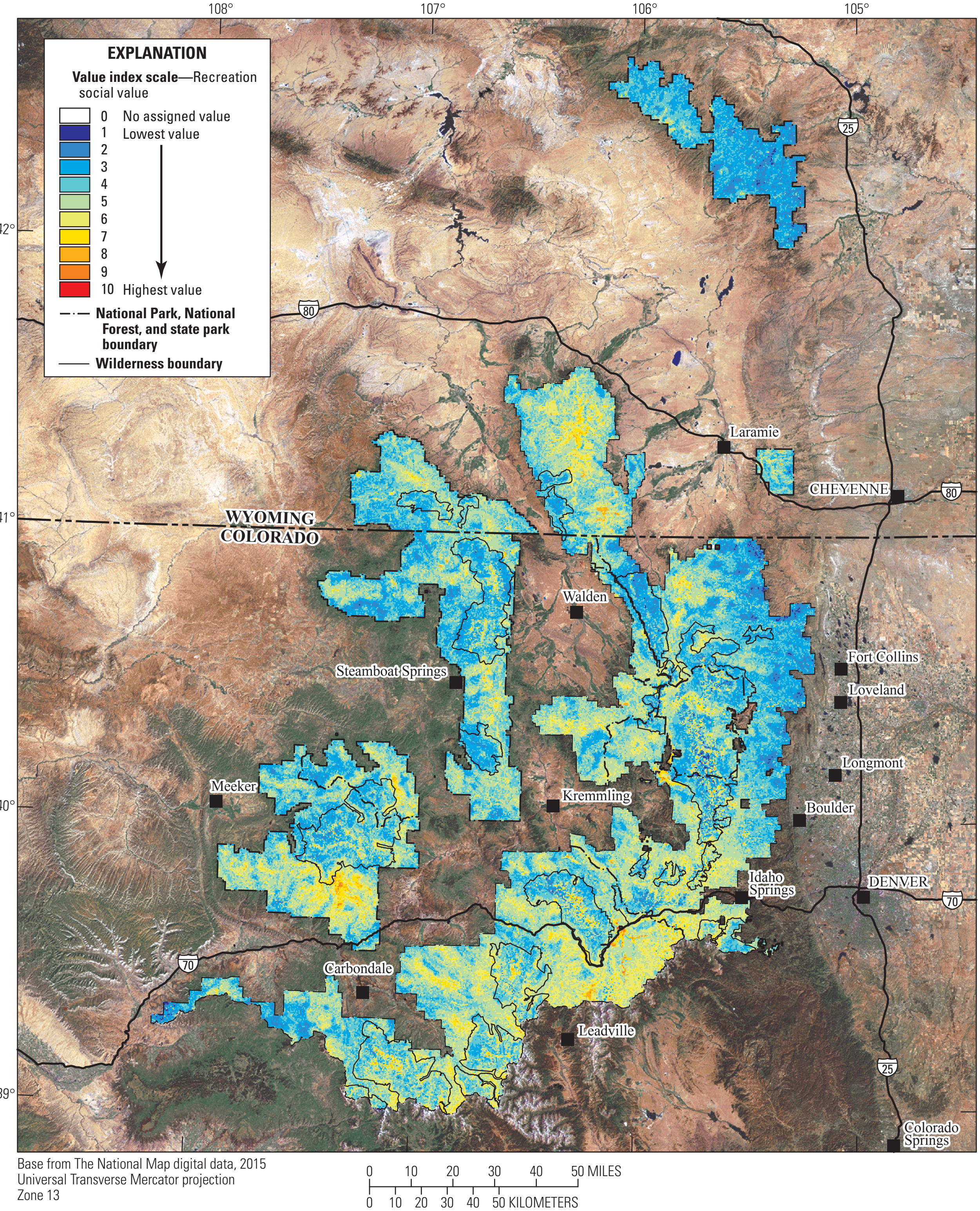

Figure 12. Recreation value map illustrating spatial distribution of the 10-point value index.

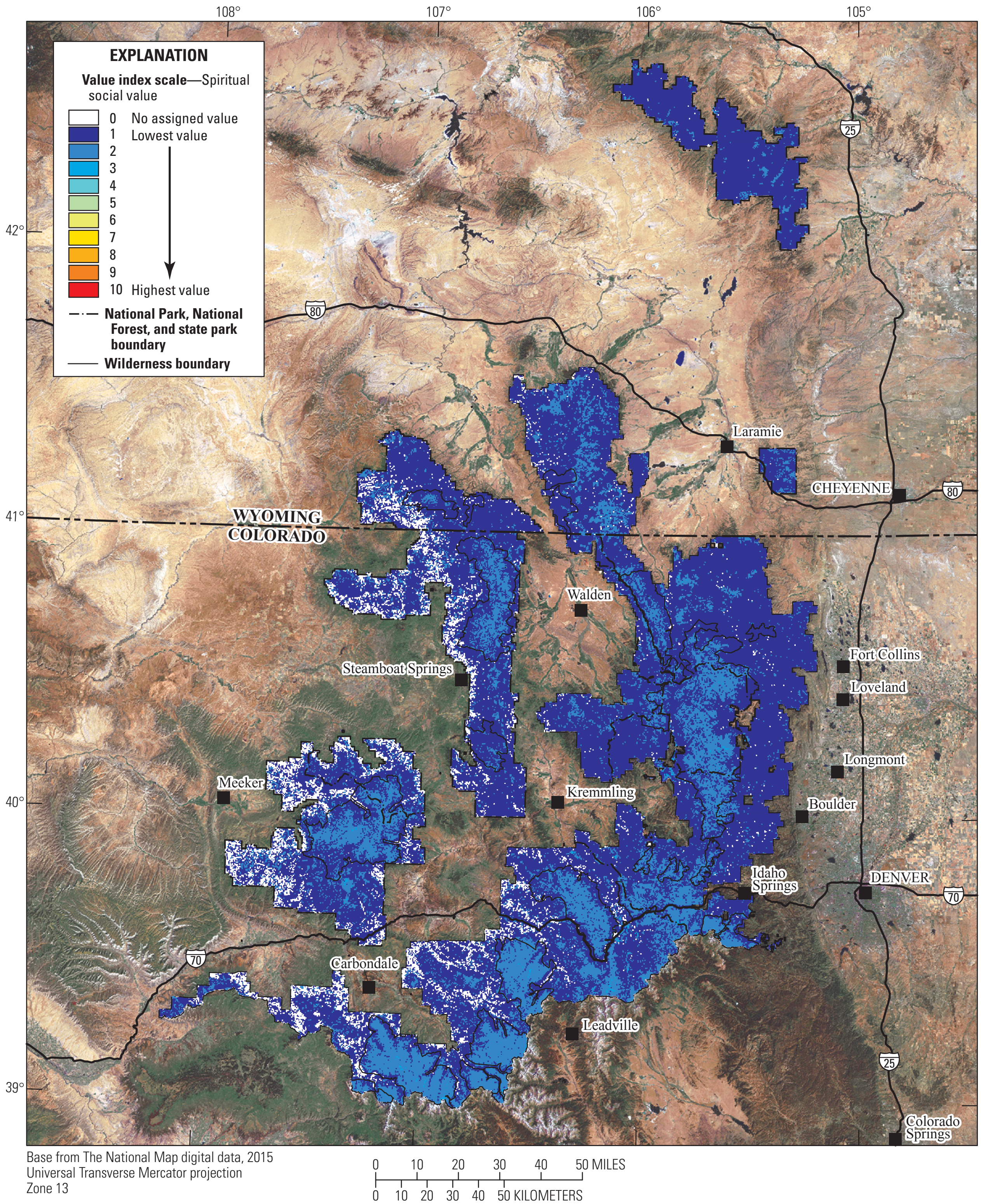

Figure 13. Spiritual value map illustrating spatial distribution of the 10-point value index.

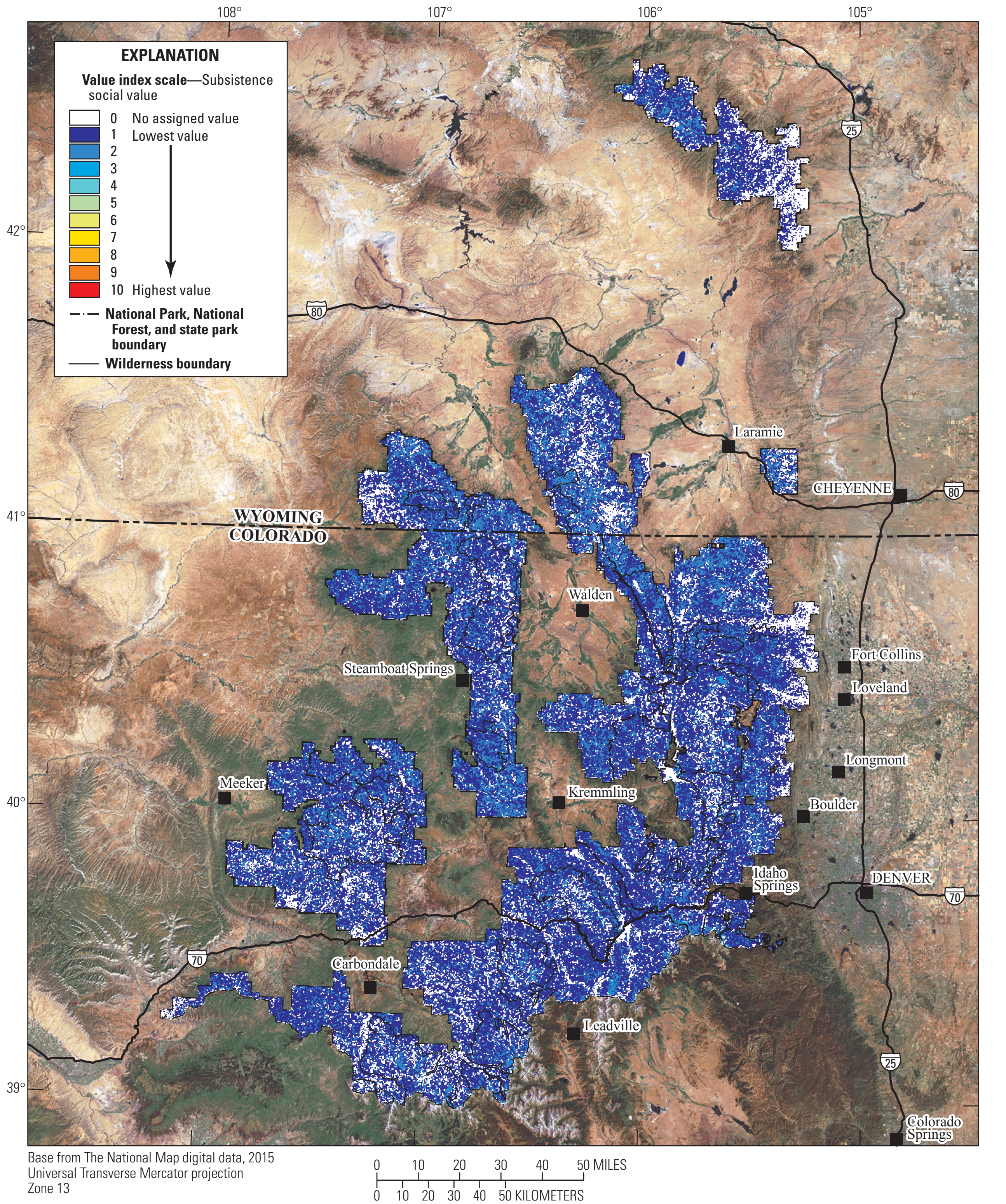

Figure 14. Subsistence value map illustrating spatial distribution of the 10-point value index.

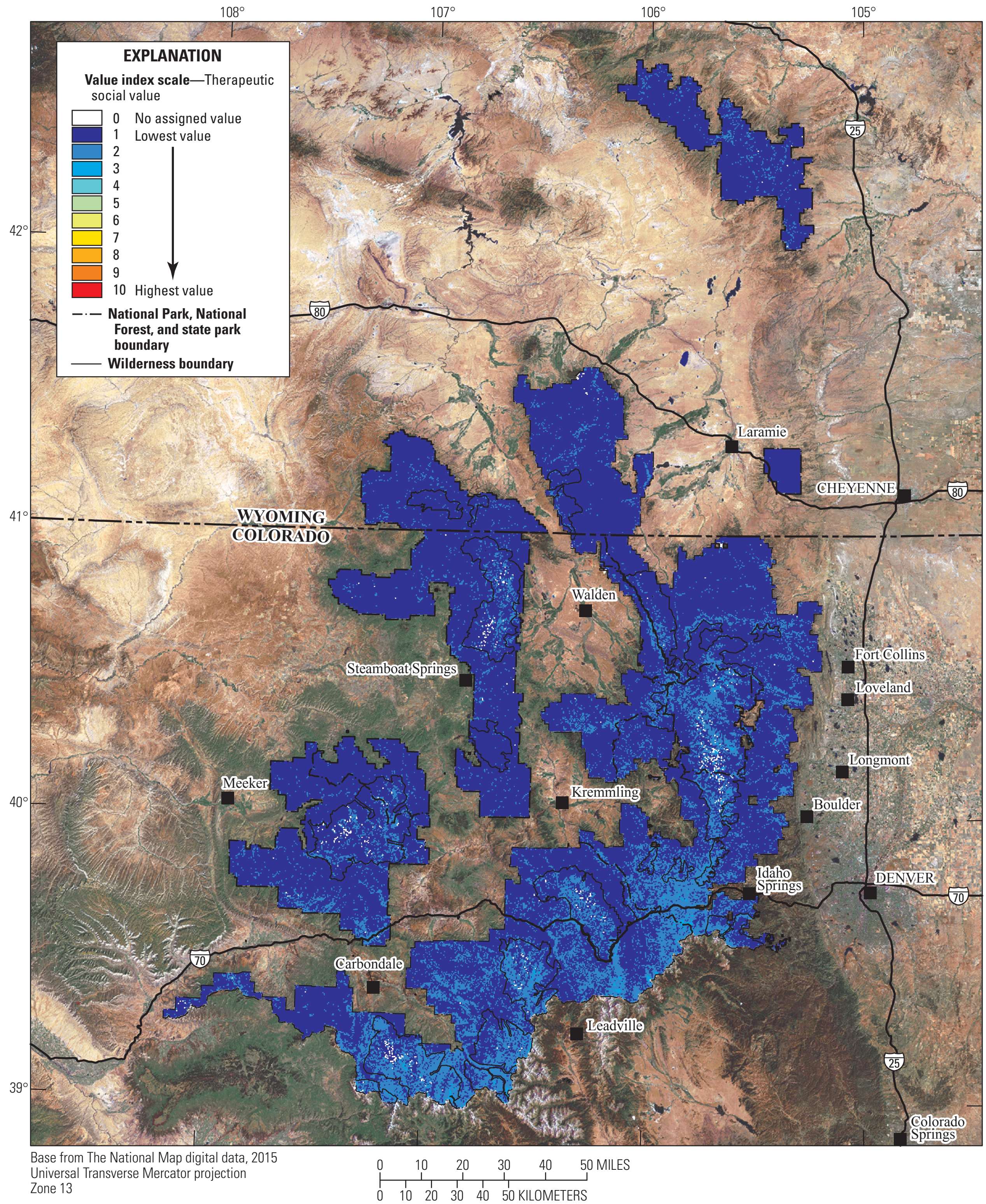

Figure 15. Therapeutic value map illustrating spatial distribution of the 10-point value index.

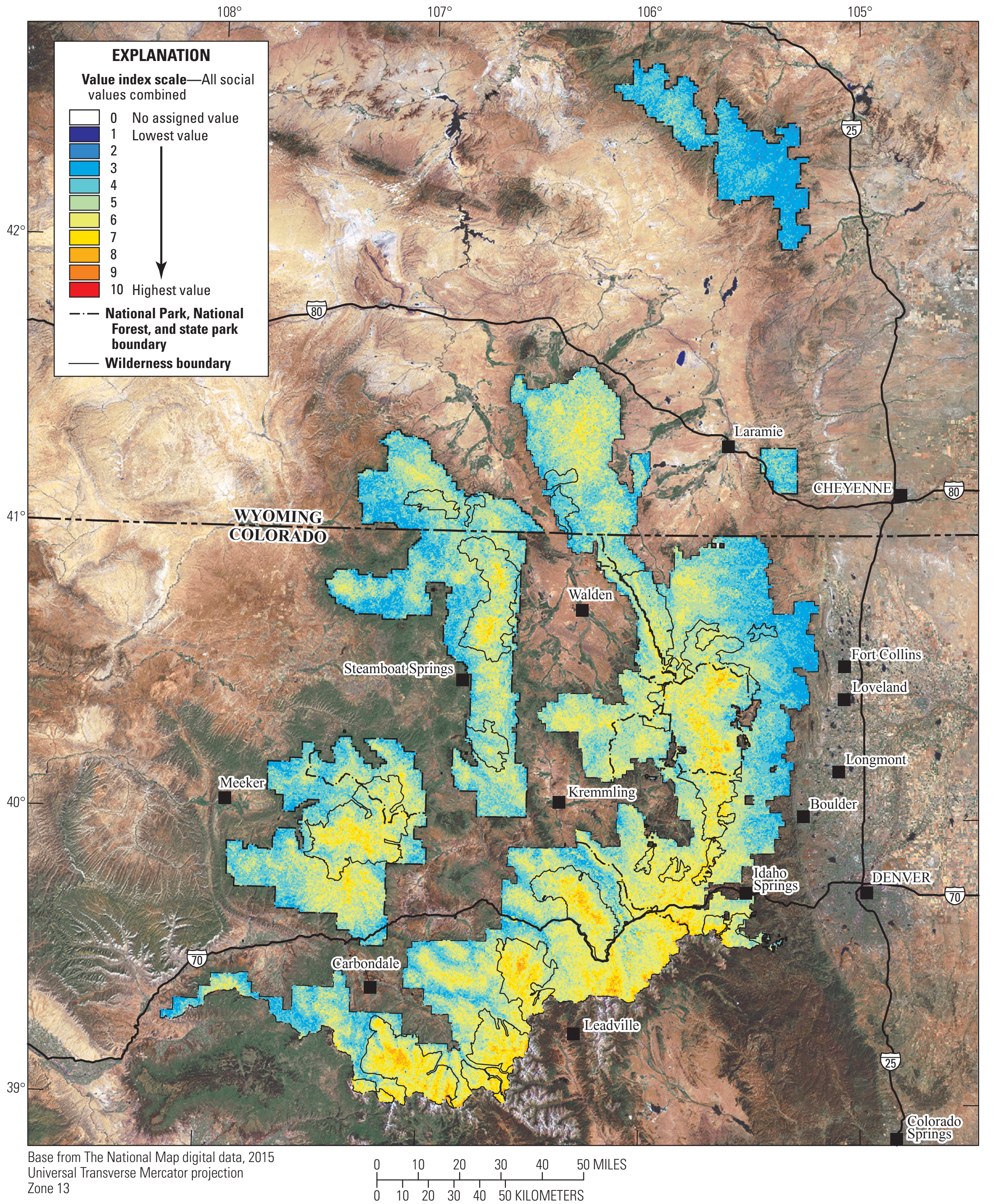

Figure 16. Combined value map illustrating spatial distribution of the 10-point value index.

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