Applied Geography 53 (2014) 77–89

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Assessing the value of public lands using public participation GIS (PPGIS) and social landscape metrics

Greg Brown [a,*], Delene Weber [b], Kelly de Bie [c,d]

[a] School of Geography, Planning, and Environmental Management, University of Queensland, Brisbane, QLD 4072, Australia
[b] Barbara Hardy Institute, School of NBE, University of South Australia, Mawson Lakes, SA 5085, Australia
[c] School of Botany, The University of Melbourne, Parkville, VIC 3010, Australia
[d] Parks Victoria, 535 Bourke St, Melbourne, VIC 3000, Australia

Keywords:
Public lands
Social metrics
Public participation
PPGIS
Place values

A B S T R A C T

Public lands provide a wide range of values—ecological, socio-cultural, and economic—but systematic methods to assess the social and cultural values of public lands are underdeveloped. In this study, we present a method that uses public participation GIS (PPGIS) to identify and quantify the social and cultural values associated with different types of public land, ranging from national parks and reserves, to multiple-use lands. In 2014, we conducted a PPGIS study to identify public land values in Victoria, Australia. Over 35,000 landscape value and land use preference locations were mapped by study participants ($n = 1905$). We analyzed the spatial data for association with public land type, IUCN classification, and an agency level management system. We generated social landscape metrics to quantify values by individual public land units based on value abundance, richness, diversity, and the potential for management conflict. We found statistically significant associations between values and public land type, IUCN protected area classification, and management level of protection. The social landscape metrics indicate that the most highly valued public lands (national parks) have the greatest potential for management conflict, but also reveal several less iconic public lands as having high potential for management conflict. We discuss the strengths and limitations of the PPGIS methods in the study and provide suggestions to improve the process for future assessments of social and cultural values associated with public lands.

Introduction

Public lands provide a vast array of environmental, social, and economic benefits to society. While much work has been dedicated to economic valuation, there has been little systematic research to assess the social and cultural values attributable to public lands across the range of different public land types. These less tangible values of public lands are considered to be undervalued despite suggestions they are likely more important to the general public than many material values associated with public lands (Harmon & Putney, 2003). The true value of public lands should account for multiple, interacting values including environmental services, personal values associated with learning, the psychological benefits of visiting a site, the cultural and spiritual values associated with particular landscapes, and the social value of bringing families and friends together through recreation.

Typical categories of public lands include forests, national parks, wilderness areas, historic areas, and nature reserves. The quantity, structure, regulations, and management of public lands vary by country, and often states or regions within countries. However, the size of the public land estate in many countries is significant. For example public lands comprise 23% of terrestrial land area in Australia (Geoscience Australia, 2014), and in the United States, the combined total of federal and state-owned public land encompasses 35% of total land area (NRCM, 2014). The majority of public land focused research has been directed at single units of public lands, most commonly protected areas, which comprise nearly 15% of world's land area (WDPA, 2014). Yet protected areas only account for 9.5% of federal public lands in the United States (Gorte, Hardy Vincent, Hanson, & Rosenblum, 2012) and 34.3% of public lands in Australia (Geoscience Australia, 2014). The absence of a global framework that defines types of public lands has restricted researchers' ability to compare public land values across countries

* Corresponding author.
E-mail addresses: greg.brown@uq.edu.au (G. Brown), delene.weber@unisa.edu.au (D. Weber), khun@unimelb.edu.au (K. de Bie).

http://dx.doi.org/10.1016/j.apgeog.2014.06.006
0143-6228/

and regions. Unlike the broader category of public lands, there is an internationally recognized system for classifying protected areas based on management objectives (Dudley, 2008; IUCN, 1994). This system developed by the International Union for the Conservation of Nature (IUCN) consists of six categories ranging from Class Ia (strict nature reserve) to Class VI (managed resource protected area) and is intended to assist in the establishment and management of protected areas. While the conservation of biological diversity is a desirable management outcome for all categories, the system recognizes that protected areas categories provide for different mixes of ecosystem values. For example, national parks (Category II) statutorily provide for both natural and historic preservation as well as public recreational use. Although the IUCN classification provides a useful tool to assist in some public land research, it is limited by its intended purpose, as are other tools developed by management agencies to classify and manage their holdings, such as the *Levels of Protection* system developed by Parks Victoria in Australia. How to assess and measure the value of public lands that is applicable across a range of public land units remains a challenge that we address in this paper.

One approach to measuring the value of public lands is through the ecosystem services framework. This framework expresses the importance of landscapes in three value domains—ecological, socio-cultural, and economic (De Groot et al., 2010; MA, 2003). The ecological and economic valuation domains have received considerable research attention with development of a range of evaluation criteria. For example, the ecological value of ecosystems can be assessed using such criteria as species richness, diversity, or rarity, while the contribution of an area to a larger network can be assessed on the basis of representativeness and complementarity (Bonn & Gaston, 2005; Margules, Nicholls, & Pressey, 1988; Margules & Pressey, 2000; Myers, Mittermeier, Mittermeier, Da Fonseca, & Kent, 2000; Pressey, Humphries, Margules, Vane-Wright, & Williams, 1993; Pressey, Johnson, & Wilson, 1994; Smith & Theberge, 1986). The economic value of ecosystems involves translating selected ecosystem services into monetary values through methods such as value transfer, hedonic analysis, spatial modeling, and contingent valuation (see e.g., Costanza et al., 2006; Loomis, Kent, Strange, Fausch, & Covich, 2000). Of the three value domains, the valuation of social and cultural services lags behind other categories and is common only for recreation value (Crossman et al., 2013; Egoh, Drakou, Dunbar, Maes, & Willemen, 2012; Martínez-Harms & Balvanera, 2012).

One method for assessing the social and cultural values for ecosystem services on public lands involves participatory mapping using public participation GIS (PPGIS) or participatory GIS (PGIS) (Brown and Fagerholm, 2014). PPGIS/PGIS refers to spatially explicit methods and technologies for capturing and using non-expert spatial information in participatory planning processes (Brown & Kyttä, 2014; Rambaldi, Kyem, McCall, & Weiner, 2006; Sieber, 2006;). PPGIS/PGIS has been increasingly used to identify a range of ecosystem services that originate in place-based, local knowledge and appears appropriate to identify provisioning and cultural benefits that are grounded in personal experience (Brown, Montag, & Lyon, 2012; Fagerholm, Käyhkö, Ndumbaro, & Khamis, 2012).

In the academic literature, and in planning practice, there is continuing ambiguity between PPGIS and PGIS, and the related concept of volunteered geographic information (VGI) described by Goodchild (2007). Brown and Kyttä (2014) provide some contrast between the concepts, observing that PPGIS is typically sponsored by government planning agencies to enhance public involvement in developed countries for urban and regional planning, often using random sampling methods and digital mapping technology, where spatial data quality is a primary focus. In contrast, PGIS is typically sponsored by NGOs in rural areas of developing countries to build social capital using purposive sampling and non-digital mapping technology, where spatial data quality is of secondary importance. VGI methods tend to be highly variable, with NGOs and ad hoc groups sponsoring spatial data collection using volunteers in a variety of settings, with the most notable example being the OpenStreetMap project.

Within the field of PPGIS, the terms “public” and “participation” that comprise PPGIS are also ambiguous. Schlossberg and Shuford (2005) describe how the term “public” may include decision makers, implementers, affected individuals, interested observers, or the random public, while the term “participation” can be described as either specific activities or the broader purposes that participation is supposed to achieve. If the intended meaning is the purpose of engagement, the participation spectrum can range from simply informing the public to providing citizen control. To understand what is meant by PPGIS, one must identify the objective of “participation” in the specific PPGIS project. The research reported herein is best described as PPGIS involving “affected individuals” from the public for the participation purpose of “consultation” on future public land management in Victoria.

Social and cultural values for ecosystem services have been identified using PPGIS methods for public lands such as national forests (Beverly, Uto, Wilkes, & Bothwell, 2008; Brown & Reed, 2009; Clement-Potter, 2006), national parks (Brown & Weber, 2011; van Riper, Kyle, Sutton, Barnes, & Sherrouse, 2012), wilderness areas (Brown & Alessa, 2005), regional conservation lands (Brown & Brabyn, 2012), and urban parks (Brown, 2008; Tyrväinen, Mäkinen, & Schipperjn, 2007). To date, PPGIS studies that measure ecosystem services have focused on case studies of specific public land units such as national parks, forests, and wilderness areas. There has been no research whose purpose was to comprehensively identify and compare the mix of social and cultural ecosystem values associated with the different types of public lands and protected areas within an entire state or country. This study addresses this knowledge gap.

Our research progresses from descriptive analysis, i.e., what is the geographic distribution of social and cultural values across the public land estate in the Australian state of Victoria, to more complex inquiry that examines the relationships between distributions of values by various public land classification schemes. We begin at a broad, statewide scale and then narrow to an examination of the values associated with individual public land units. Our research methods involve the use of spatial analysis of PPGIS data collected in 2014 and the application of “boundary” social landscape metrics (Brown & Reed, 2012a). Boundary landscape metrics are calculated by analyzing the distribution of mapped PPGIS attributes that fall within pre-defined management areas of interest such as national parks, state forests, and other public lands.

Social/cultural values and public land classifications

The social and cultural values for ecosystem services have been identified and operationalized in PPGIS systems using three typologies—the millennium ecosystem assessment typology (MA, 2003), a *landscape values* typology (Brown & Reed, 2000), and a *landscape services* typology (Fagerholm et al. 2012). The most frequently used typology in PPGIS has been the landscape values typology consisting of up to 13 values that are customized for the particular PPGIS study. The landscape values typology has been used in more than 15 published PPGIS studies (Brown & Kyttä, 2014) and contains cultural ecosystem values such as recreation, aesthetics, history/culture, and spiritual values, but also includes perceived values for provisioning ecosystem services (economic/

subsistence value), and supporting/regulating ecosystem services (biological and life sustaining values). The landscape values and definitions used in this study appear in Table 1.

The study was conducted in the state of Victoria, Australia, which similar to the United States, has a public land system covering 35% of the terrestrial land area. The primary types of public lands (Crown lands) in the state are parks and protected areas (50%) and forestry reserves (40%) (DEPI, 2013). Public lands in Victoria are reserved and managed within the context of State and Commonwealth legislation, international treaties, and government policies. Several of the most influential legislative acts include the National Parks Act (1975), the Crown Lands (Reserves) Act (1978), Parks Victoria Act (1998), and the Forests Act (1958). These acts describe the broad purposes for the public lands with reference to the values that these lands are intended to provide. For example, the National Parks Act preamble supports the permanent reservation of areas for the "enjoyment, recreation, and education of the public." Further, the act justifies the reservation of areas not otherwise suitable for national parks that contain features of scenic, historical, archaeological, biological, geological, or scientific interest, urban areas that contain natural beauty or that are suitable for recreation, and natural areas that serve as reference sites for scientific study. State forests in Victoria have the additional purposes of conserving flora and fauna, protecting water catchments and water supply, and providing timber through sustainable forestry.

The public land estate in Victoria is presumed to collectively contain the full range of values described in the landscape values typology in Table 1. However, the legislative intent of the public land reservation, in combination with regulatory policies and management guidelines, suggest that certain categories of public lands may exhibit stronger association with certain types of landscape values expressed by the public. In Table 1, we provide some presuppositions about expected value associations with public land types based on our reading of the enabling legislation and contemporary regulatory and management policies. The purpose here is not to examine the legislative rationality behind the original reservation of the public land, but to determine the extent to which the public perceives public land values to be consistent with the purposes of the reservation. One would not expect landscape values to be distributed proportionately across highly variable biophysical landscapes associated with public lands, but rather exhibit differentially important associations based on the features and qualities of the area and the characteristics of the people that express values for the different types of public land.

A primary purpose of this research is to improve our understanding of the contribution of different public land units to system-wide ecosystem values. To achieve this purpose, we propose a series of research questions applied at various scales. We begin with a statewide focus on all public lands, then narrow to national parks and reserves as a subset of all public lands, and conclude with specific public land units using boundary landscape metrics.

Table 1
Landscape values typology, operational definitions, and expected associations of values with public lands in Victoria.

Values	Operational definition	Expected association by public land type
Scenic/aesthetic	These areas are valuable because they contain attractive scenery including sights, smells, and sounds.	National parks, state forests, coastal reserves
Recreation	These areas are valuable because they are where I enjoy spending my leisure time — with family, friends or by myself, participating in outdoor recreation activities (e.g., camping, walking, or fishing).	National parks, state forests, state parks, and community/metro/regional parks
Economic	These areas are valuable because they provide natural resources or tourism opportunities.	State forests, national parks
Life Sustaining	These areas are valuable because they help produce, preserve, clean, and renew air, soil, and water.	State forests, reservoirs
Learning/education/research	These areas are valuable because they provide places where we can learn about the environment through observation or study.	National parks, state forests
Biological/conservation	These areas are valuable because they provide a variety of plants, wildlife, and habitat.	National parks, state forests, marine sanctuaries, nature conservation reserves
Heritage/cultural	These areas are valuable because they represent natural and human history or because they allow me or others to continue and pass down the wisdom and knowledge, traditions, and way of life of ancestors.	National parks, heritage/cultural reserves
Therapeutic/health	These places are valuable because they make me feel better, physically and/or mentally.	Community/metro parks, state forests
Spiritual	These areas are valuable because they are sacred, religious, or spiritually special places or because I feel reverence and respect for nature here.	National parks
Intrinsic/existence	These areas are valuable in their own right, no matter what I or others think about them.	National parks, natural features reserves
Wilderness/pristine	These areas are valuable because they are wild, uninhabited, or relatively untouched by European activity.	National parks, wilderness areas

Preferences	Operational definition
Increase conservation/protection	Increase conservation and protection here (e.g., due to encroaching development, feral animals/weeds, illegal use).
Add recreation facilities	Add more recreation facilities (e.g., walking trails, playgrounds, picnic ground) here.
Add tourism services/development	Add new tourism services (e.g., guided tours, signs, brochures, apps) or development (e.g., trail head, toilet block, visitor center) here (Please specify).
Improve access	Improve vehicular access (i.e., from no access to 4WD access or from 4WD road to 2WD road). Note: please map increased walking trail access under the recreation facilities icon.
Improve bushfire protection	Improve bushfire protection here.
Resource extraction	Engage in resource extraction such as logging or mining here.
Resource use	Engage in resource use such as grazing, hyroelectric energy, or wind energy here.
Decrease or limit access	Decrease or limit access here (e.g., close to vehicles or 4WD).
No development or change	No development or change to land use here.

For all public lands we address the following research questions:

- Which values are mapped most frequently across public lands statewide?
- What is the geographic distribution of mapped values?
- Are there significant associations between the distribution of values and the general classification of public lands?
- Do certain types of public lands exhibit stronger association with certain types of values? For example, Brown and Alessa (2005) found that wilderness areas in Alaska contain disproportionately more values associated with indirect and intangible uses of the landscape such as life-sustaining, spiritual, and intrinsic values—whereas landscape values outside wilderness areas on multiple-use lands reflect more direct and tangible values such as recreation, economic, and subsistence values. On multiple-use national forests, recreation and esthetic values have been consistently the most frequently mapped values (Beverly et al., 2008; Brown & Reed, 2009; Clement & Cheng, 2011).

With respect to parks and reserves we address the following questions:

- Are there any significant associations between the distribution of values and the IUCN classification system for protected areas? For example, a logical presupposition is that Class Ib lands should have disproportionately more wilderness values given the presumed higher level of regulatory and management protection of these lands.
- Are there any significant associations between mapped values and the internal management classification operationalized by Parks Victoria, the agency responsible for the management of parks and reserves in Victoria? The agency uses a Level of Protection (LoP) classification scheme to guide the management of parks and reserves under its jurisdiction. Is there consistency between the management schemes and the distribution of mapped values?

For individual parks and reserves we ask the following question:

- How are values distributed by park or reserve unit as determined by social landscape metrics including abundance, diversity, intensity, and the potential for conflict?

We focus particular attention on the conflict metric, operationalized and adapted from Brown and Raymond (2014) that combines PPGIS mapped values and land use preferences into a conflict index. Given the historic controversy over the grazing practices in Alpine National Park, (Fraser & Chisholm, 2000), one might expect the mapped landscape values and preferences in this particular national park to reflect a high degree of potential conflict.

As the first comparative study of ecosystem values across different types of public lands classifications using PPGIS, our empirical results are fundamentally linked to the strengths and limitations of the research methods. In the Discussion, we reflect on both the practical implications of the results for public land management agencies as well as the PPGIS methods for conducting this type of value assessment.

Methods

Study location and context

The study location was the state of Victoria, the sixth largest state or territory in Australia with an area of 237,629 km^2 and an estimated population of 5,768,600 (ABS, 2013). Most of the state's population is concentrated in the area near the capital city of Melbourne, Australia's second-largest city. The state's economy is highly diversified with the most significant contributing industries including financial and insurance services, manufacturing, professional, scientific and technical services, and construction (ABS, 2013).

The public land estate in Victoria comprises approximately 35% of the terrestrial land area (DEPI, 2013) with the largest contiguous areas located in the mountainous eastern third of the state, and the northwest sector. Public lands in Victoria, also known as “Crown” lands, comprise a wide variety of classifications including state managed national parks, state forests, federally managed commonwealth lands, metropolitan and regional parks, and specialized reserves for the protection of historic and cultural resources. Parks and conservation reserves make up 3.98 million hectares (approximately 50% of all Crown land), state forests comprise 3.14 million hectares (approximately 40%), and other Crown lands cover 796,000 ha (10%) including Commonwealth Government land, metropolitan parks, and land held under lease from the Crown (DEPI, 2013). Approximately 90% of Victorian parks and conservation reserves by area have been assigned protected area status category I or II, under the International Union for Conservation of Nature (IUCN) system, which is arguably quite typical for park systems established in the pre-1900s.

Data collection process

The research team designed, pre-tested, and implemented an internet-based PPGIS website for data collection. See Fig. 1. The study website consisted of an opening screen for participants to either enter or request an access code, followed by an informed consent screen for participation, and then a Google® maps interface where participants drag and drop digital markers onto a map of Victoria. The interface consisted of two different panels with the first panel containing markers representing 11 landscape values and the second panel consisting of nine management preferences (see definitions in Table 1). The instructions requested the participant to “drag small icons onto a map of Victoria to identify places you value and your public land preferences … although you can place markers anywhere, the focus of this study is on public lands”. The different types of markers placed and their spatial locations were recorded for each participant on the web server in a database, along with other information including a timestamp of when the marker was placed, the Google® map view at time of marker placement, and the Google® map zoom level (scale) at which the marker was placed. Participants could place as few or as many markers as they deemed necessary to express their values and management preferences. Following completion of the mapping activity (placing markers), participants were directed to a new screen and provided with a set of text-based survey questions to assess general, non-spatial public land management preferences and to measure respondent socio-demographic characteristics. PPGIS data collection ended with completion of the survey questions. Study participants had the option to return to the PPGIS website later to use their access code to add new markers or to adjust previously-placed markers.

From December 2013 to February 15, 2014, study participants were recruited using both purposive and convenience sampling methods: (1) visitors to 16 national parks, 5 state parks and 9 metropolitan parks were contacted on site as part of the Parks Victoria's annual visitor satisfaction survey and provided with an invitation card describing the study, along with the study URL and an access code; (2) Parks Victoria prepared and distributed a press release about the study, placed a link to the study URL on the

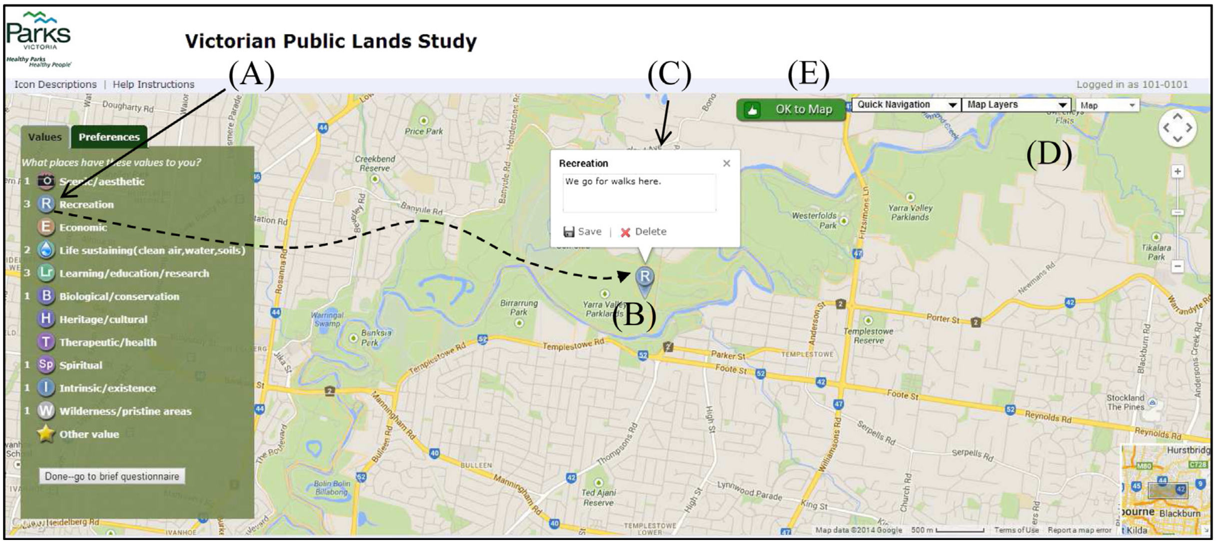

Fig. 1. The PPGIS mapping interface for public land values. The Google® maps application allows participants to drag and drop value and preference markers from "tab panels" on left (A) onto map location (B) and optionally annotate each marker with a pop-up window (C). There are map controls on right (D) providing quick navigation to different locations in the state, for map pan/zoom, and to select alternative base map views such at satellite or terrain. There is an indicator (E) that informs the participant when map is sufficiently zoomed to place a marker.

agency's website, and an agency spokesperson promoted the study in an Australian Broadcasting Corporation radio interview; and (3) a recruitment letter was distributed to members of the Victoria National Parks Association (VNPA), a non-governmental organization (NGO) that promotes nature conservation in Victoria. Participants in the study were also encouraged to refer friends, relatives, and acquaintances to the study website. Any member of the public could request an instant access code to participate in the study. To encourage participation, three incentive options were provided the to the first 1500 study participants: (1) a $10 electronic voucher redeemable at Amazon.com, (2) a free movie pass, or (3) the donation of $10 in the participant's name to one of three preselected charities. The decision to include the option of a charitable donation was an innovation to increase study participation rates. Previous experience by the research team showed that a small, cash-equivalent incentive provided a relatively small increase in participation rates over no incentive. The idea was that perhaps a $10 benefit to charity provides greater participant satisfaction than receiving the incentive personally.

Analyses

Participant characteristics

We assessed the representativeness of study participants with census data on the variables of age, gender, education, income, and family structure. We also asked participants to self-identify their level of knowledge about public lands in Victoria, their frequency of use of public lands, and the number of times they had visited national or state parks in the past 12 months. We also examined the geographic distribution of participants within Victoria based on postcode to assess the participant distribution relative to population distribution.

Association of mapped values with public lands

Summary statistics were generated to describe the frequency distribution and general location of the PPGIS mapped values. The mapped point data was then intersected (with 100 m tolerance) with the public land classification (PLMGEN) geodatabase (polygons) maintained by the Victorian Department of Environment and Primary Industries (DEPI) (http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803004213&publicId=guest&extractionProviderId=1). We selected 11 major categories of public lands (coastal reserves, community/metro/regional parks, state forests, marine parks and sanctuaries, national parks, natural features reserves, nature conservation reserves, wilderness parks, state parks, and water production and reservoir areas) that accounted for over 90% of Victorian public lands, and cross tabulated point counts with the categories. We generated chi-squared statistics and standardized residuals to determine whether the number of mapped value points differed significantly from the number of points that would be expected in each public land category.

We also conducted correspondence analysis of the two categorical variables to visualize the value and public land type relationships. Correspondence analysis computes row and column scores and produces normalized plots based on the scores. In the plot, the distances between category points reflect the relationships between the categories with similar categories plotted close to each other. Interpretation of the plot is done by rows (public land types) and columns (values). If two public land types have very similar profiles, their points in the plot will be close together. Similarly, if two values have similar profiles, their points will be proximate. The distance between a row point and a column point has no direct interpretation but the directions of columns and rows from the plot origin are meaningful.

Association of mapped values with public lands by IUCN category

To determine the association between landscape values and protected areas classification, we identified all public lands in Victoria that had been classified according to the IUCN scheme. We intersected these polygons with the mapped PPGIS data. We cross-tabulated the point counts with the categories and generated chi-squared statistics and standardized residuals to determine whether particular types of values are associated with different IUCN protected area categories. We also ran correspondence analysis to visually display the associations of values by IUCN categories in a normalized plot.

Association of mapped values with Parks Victoria Level of Protection (LoP)

The mapped values were intersected with national parks and reserves classified by Parks Victoria using a management classification system. Levels of Protection (LoP) is a framework utilized by Parks Victoria to aid planning and resource allocation by placing individual parks in a statewide context. LoP groups parks according to biodiversity criteria and allocates broad conservation objectives to each group. Parks are classified into terrestrial (A1, A2, B, C, D and E1 and E2) and marine (A, B and C) groups. Parks and reserves in the A group are generally large, intact, and protect the most species and habitats. These parks are assigned a "high priority for active management". At the other end of the spectrum, level E parks are generally small with few natural assets where the management objective is to maintain assets and give priority only to emerging threats. The PPGIS point data was cross tabulated with the LoP categories to generate chi-squared statistics and standardized residuals to determine whether values have significant association with the Parks Victoria management scheme.

Quantifying park/reserve qualities with social landscape metrics

We examined the distribution of park/reserve values using multiple social landscape metrics described by Brown and Reed (2012a). The purpose of social landscape metrics is to better understand the structure and distribution of common and unique values across the park/reserve system. In addition, metrics provide the foundation for value compatibility analysis (Brown & Reed, 2012b) that assesses the consistency of potential management actions with values located within a park/reserve. To provide sufficient data to assess the park/reserve, we selected parks and reserves with a minimum of 30 mapped values to calculate the metrics. The *value count* (**P0**) metric counts the number of value point locations within the park/reserve unit while the *value percent* **(P1)** metric calculates the percent of mapped points in the unit relative to the total number of mapped points across all units. The *dominant value* (**D**) metric is simply the landscape value with largest count of points within the park/reserve unit. The *value dominance index* (**D1**) metric quantifies the dominance relationship between the dominant value within the park/reserve unit and the next most common landscape value on a scale that ranges from 0 (i.e., there is no difference in dominance among values) to 1.0 (there is only one landscape value in the park/reserve unit). The *value density* (**D2**) metric calculates the density of landscape values per park/reserve area while the *value diversity index* (**D3**) metric is the standard Shannon diversity index commonly used in ecological studies calculated within a park/reserve unit. The *value richness* metric (**R**) is the number of different value types mapped in the park/reserve unit and can range from 0 to 11 in this study. The *conflict potential index* (**C**) metric can be calculated many ways, but here we follow one of the methods suggested by Brown and Raymond (2014) where the conflict index is derived from a mathematical combination of mapped preferences and values where differences in preferred land use, in this case conservation versus development, are amplified by the intensity of values located in the park/reserve unit. Specifically, we operationalized the conflict index as follows:

$$C = \frac{\mathrm{MAX}(\mathrm{MIN}(P_s, P_o), 0.1)}{\mathrm{MAX}(P_s P_o)} * V_c$$

where C is conflict index (higher values indicate greater conflict potential, P_s is the number of mapped preferences supporting greater conservation and protection in the park unit, P_o is the number of mapped preferences supporting additional development in the park unit (extraction, resource use, tourism, or recreation facilities), and V_c is the total count of all values in the park unit.

Results

Response and participant characteristics

A total of 1905 participants accessed the study website and placed one or more markers from December 2013 to February 15, 2014. See Table 2. Of these participants, 1624 (85%) fully or partially completed the survey questions that followed the mapping activity. A total of 35,347 markers were mapped during data collection, with 30,194 (85%) of these attributable to public lands in Victoria. The number of markers placed per participant ranged from 1 to 426 with the average number of numbers placed being 18.8. Approximately 85% of the markers placed were *value* markers with the remaining 15% being *preference* markers.

The participants learned of the study through multiple information channels. About 26% learned of the study through referral from a relative, friend, or acquaintance. Other non-referral sources of recruitment were the Parks Victoria website (23%), on-site recruitment at parks (9%), and other groups with interests in Victoria public land issues. Key contributing groups were the Victoria National Parks Association ($n = 306$), various bushwalking clubs

Table 2
Participation statistics and respondent characteristics with comparison to Victoria census data (ABS, 2013).

Participation statistics				
Number of participants (one or more locations mapped)		1905		
Number completing post-mapping survey		1624		
Number of locations mapped		35,347		
Number of locations attributable to public lands		30,194		
Range of locations mapped (min, max points)		1 to 426		
Mean, median of all locations mapped		18.8, 14		
Mean, median of values mapped		16.8, 10.5		
Mean, median of preferences mapped		6.3, 3		
How participants learned of study				
Parks Victoria website		423 (23%)		
From relative, friend, acquaintance		477 (26%)		
On-site recruitment at parks		179 (9%)		
Other (major identifiable sources)		826 (43%)		
Bushwalking clubs		127		
Victoria National Parks Association (VNPA)		306		
4WD clubs		79		
Conservation group		49		
Outdoor recreation group		45		
ABC Radio interview by Parks Victoria		35		
Non-disclosed or indeterminate		184		
	Study participants		ABS Census 2011	
Age (median)		36		37
Gender	Male	57%	Male	49%
	Female	43%	Female	51%
Education (highest level completed)				
Bachelors degree		39%		16%
Postgraduate education		16%		11%
Household income (annual)				
Median		$110,000		$63,200
Less than $20,000		2.6%		3.1%
$140,000–$160,000		15.1%		7.3%
$160,000–$180,000		9.4%		4.2%
$180,000–$200,000		5.0%		1.9%
$200,000+		2.9%		3.1%
Families with children		41%		46%

Note: ABS income percentages are estimates to match survey income categories.

($n = 127$), four-wheel drive clubs ($n = 79$), conservation groups ($n = 49$), and outdoor recreation groups ($n = 35$).

Table 2 also provides a socio-demographic profile of study participants with comparative census data (ABS, 2011). The median age of participants was 36 (similar to census), but participants were more proportionately male, with higher levels of formal education, and higher self-reported household income than census data. The PPGIS sampling bias toward more highly educated and higher income males is consistent with other reported PPGIS studies in developed countries (Brown & Kyttä, 2014).

About 78% of respondents rated their self-identified knowledge of public lands as “good” or “excellent”, 20% “average”, and only 2% reporting “below average” or “poor”. About 43% of respondents indicated they use public lands either daily or at least once per week. About 87% percent of respondents use public lands at least once per month or more frequently. The median number of visits to national or state parks in Victoria in the past 12 months was 10 visits. In summary, the study participants appear knowledgeable about the public lands they mapped.

We assessed the geographic distribution of participants in Victoria by comparing the expected counts of participants per postcode based on census data with the actual number of study participants from each postcode. An important question, given the dominant volunteer sampling method used in the study, was whether regional Victoria was under-represented in study participation compared to the capital city, Melbourne. One might presuppose a potential digital divide between urban and regional Victoria but we did not find strong evidence. The central Melbourne postcode (3000) was significantly over-represented in response compared to census data, but there were multiple other Melbourne suburbs that were significantly under-represented. The over-representation of central Melbourne was offset by multiple regional postcodes that were over-represented compared to census data. On the whole, the geographic distribution of participants was roughly proportional to the general population distribution in Victoria.

Frequency of mapped values and management preferences on public lands

We generated frequency counts of the PPGIS mapped values and preferences on public lands. The most frequently mapped values were recreation ($n = 5939$/20% of all markers), scenic/esthetic (4904/16%), biological (3397/11%), life sustaining (2051/7%), and wilderness (2030/7%). The least frequently mapped values were economic (644/2%), spiritual (845/3%), and therapeutic (1197/4%). Falling in the middle of the distribution were heritage (1596/5%), learning/education (1491/5%), and intrinsic/existence values (1391/5%). The spatial distribution of the three most frequently mapped values—recreation, scenic/aesthetic, and biological value—and for comparison, intrinsic/existence value, are provided in Fig. 2. The images do not reveal significant contrast between recreation and scenic/esthetic values, with the same public lands having larger value counts. There is greater contrast in the maps of biological and intrinsic values with relatively higher frequencies of these values in the western mallee lands, the Murray River lands, and the eastern coast of Victoria.

The mapping of management preferences, in aggregate, totaled 4446 markers or about 15% of all markers mapped. The most frequently mapped preferences were to prohibit future development and/or land use change (1439/32%), to increase conservation and protection (1277/29%), and to improve vehicle access (415/9%). The least frequently mapped preferences were to increase extractive activities (e.g., mining, logging) (57/1%), to increase resource use (e.g., grazing) 105 (2%), and to increase tourism development (118/3%). Other management preferences mapped were to improve bushfire protection (390/9%), add recreation facilities (308/7%), and decrease or limit vehicle access (234/5%).

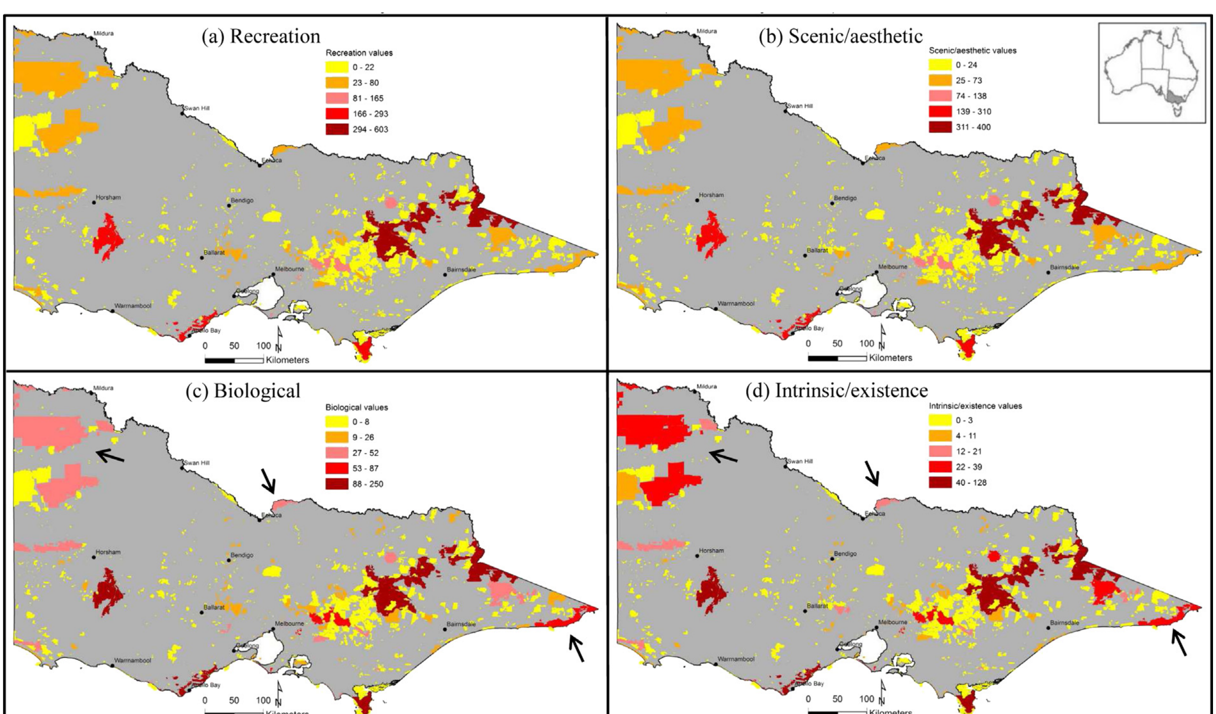

Fig. 2. Frequency distribution of mapped values in public land units: (a) Recreation, (b) scenic/aesthetic, (c) Biological, and (d) intrinsic/existence values. Recreation and scenic values indicate similar spatial distribution while biological and intrinsic/extrinsic values deviate in western mallee lands, River Murray lands, and the eastern coastline (indicated by arrows).

Association of mapped values with public land categories

There was a statistically significant association between public land type and landscape value ($X^2 = 1160.4$, $df = 100$, $p < .001$) with cross-tabulated frequencies appearing in Table 3. Adjusted standardized residuals more than 2.0 or less than −2.0 indicate the number of cases in the cell is significantly larger or smaller than would be expected. The larger the absolute value of the standardized residual, the greater the deviation from expected counts. Especially large standardized residuals command particular attention. For example, larger, disproportionate associations were found between scenic/esthetic values and coastal reserves (residual = 6.5); recreation values and metro/community/regional parks (9.9), state forests (7.0), and water reservoirs (5.9); life sustaining values and water production/reservoirs (5.5); biological values and nature conservation reserves (11.8); heritage values and historic/cultural reserves (8.3); intrinsic/existence values and national parks (5.9); and wilderness values in national parks (18.0) and wilderness parks (5.0). Larger, under-representative associations were found between recreation values and national parks (−12.3); biological values and metro/community/regional parks (−5.9); and wilderness values with natural features reserves (−6.1) and historic/cultural reserves (−4.5). The majority of these findings appear logically consistent with what would be expected based on legislative and management purposes.

The normalized plot of the two variables from correspondence analysis appears as Fig. 3a. From the plot, metro/community/regional parks have a similar profile to heritage and cultural reserves, nature conservation reserves and marine parks/sanctuaries are similar, and wilderness parks are the least similar to other public land types. The public land types of state parks, state forests, coastal reserves, and natural feature reserves appear clustered in the plot and thus are more similar than different. National parks lie in-between this cluster and wilderness parks. Plots of the values indicate that biological and wilderness values are most distinct from the other values types. Recreation, heritage, and economic values appear most similar, as do therapeutic, life sustaining, and spiritual values. Biological values align with marine parks/sanctuaries and nature conservation reserves while wilderness values are in the same region as wilderness parks.

Association of mapped values with IUCN categories

There was a statistically significant association between public land type and IUCN protected area classification ($X^2 = 651.2$, $df = 50$, $p < .001$). The cross-tabulated frequencies appear in Table 4 and the normalized plot from correspondence analysis appears in Fig. 3b. Larger, disproportionate associations were found between scenic/esthetic values and national monuments (IUCN III) (residual = 4.7); biological values and strict nature preserves/wilderness areas (IUCN Ia and Ib) (10.6), sustainable use areas (IUCN VI) 4.9, habitat/species areas (IUCN IV) (3.9); and wilderness values and national parks (IUCN II) (15.4). Larger, under-representative associations were found between recreation values and national parks (IUCN II) (−9.6); and wilderness values and national monuments (IUCN III) (−3.7). Thus, the aggregation of public land types into broader IUCN classifications produced relatively weaker associations with values. In the normalized plot (Fig. 3b), IUCN categories I, IV, and VI were most similar to each other while categories II and III were similar.

Association of mapped values with Parks Victoria Level of Protection (LoP)

There was a statistically significant association between public land type and LoP classification ($X^2 = 467.4$, $df = 50$, $p < .001$). The cross-tabulated frequencies appear in Table 5. Larger, disproportionate associations were found between recreation values and LoP class B (residual = 8.8) and class C (5.0); economic values and LoP class E1/E2 (4.0); heritage values and LoP class D (4.1); and wilderness values and LoP class A1/A2 (15.1). Larger, under-representative associations were found between recreation values

Table 3
Association of mapped values with public land type. Overall association is significant ($X^2 = 1160.4$, $df = 100$, $p < .001$) with residuals less than −2.0 (pink) or greater than 2.0 (green) highlighted.

Public land type		Scenic	Recreation	Economic	Life	Learning	Biological	Heritage	Therapeutic	Spiritual	Intrinsic	Wilderness	Totals
Coastal reserve	Count	257	223	21	72	45	121	43	41	34	38	43	938
	%	27.4%	23.8%	2.2%	7.7%	4.8%	12.9%	4.6%	4.4%	3.6%	4.1%	4.6%	100.0%
	Residual	6.5	.2	-.1	-.4	-1.3	-.5	-2.1	-.3	.7	-2.0	-4.2	
Metro/community/regional park	Count	622	987	105	235	191	331	262	188	122	137	76	3256
	%	19.1%	30.3%	3.2%	7.2%	5.9%	10.2%	8.0%	5.8%	3.7%	4.2%	2.3%	100.0%
	Residual	-.2	9.9	3.9	-1.8	.3	-5.9	4.8	3.4	1.7	-3.6	-13.2	
State forest	Count	253	469	40	144	58	239	80	48	34	54	100	1519
	%	16.7%	30.9%	2.6%	9.5%	3.8%	15.7%	5.3%	3.2%	2.2%	3.6%	6.6%	100.0%
	Residual	-2.6	7.0	1.0	2.2	-3.4	2.7	-1.5	-2.8	-2.3	-3.5	-2.4	
Historic/cultural reserve	Count	74	109	15	20	20	43	63	18	4	13	8	387
	%	19.1%	28.2%	3.9%	5.2%	5.2%	11.1%	16.3%	4.7%	1.0%	3.4%	2.1%	100.0%
	Residual	-.1	2.2	2.1	-2.1	-.5	-1.4	8.3	.0	-2.5	-1.9	-4.5	
Marine park/sanctuary	Count	76	48	9	22	21	63	25	9	12	24	33	342
	%	22.2%	14.0%	2.6%	6.4%	6.1%	18.4%	7.3%	2.6%	3.5%	7.0%	9.6%	100.0%
	Residual	1.4	-4.1	.4	-1.1	.3	2.7	.9	-1.8	.3	1.2	1.0	
National park	Count	2650	2896	286	1159	816	1838	830	671	480	881	1536	14043
	%	18.9%	20.6%	2.0%	8.3%	5.8%	13.1%	5.9%	4.8%	3.4%	6.3%	10.9%	100.0%
	Residual	-1.7	-12.3	-2.9	1.7	.4	-1.9	-2.0	1.5	1.7	5.9	18.0	
Natural features reserve	Count	155	247	28	60	73	156	62	40	39	47	27	934
	%	16.6%	26.4%	3.0%	6.4%	7.8%	16.7%	6.6%	4.3%	4.2%	5.0%	2.9%	100.0%
	Residual	-2.1	2.2	1.5	-1.8	2.7	3.0	.6	-.5	1.6	-.7	-6.1	
Nature conservation reserve	Count	114	127	11	36	61	196	29	21	14	37	39	685
	%	16.6%	18.5%	1.6%	5.3%	8.9%	28.6%	4.2%	3.1%	2.0%	5.4%	5.7%	100.0%
	Residual	-1.8	-3.1	-1.2	-2.7	3.6	11.8	-2.1	-1.9	-1.8	-.2	-2.5	
Wilderness park	Count	21	27	1	12	1	18	2	5	2	13	26	128
	%	16.4%	21.1%	0.8%	9.4%	0.8%	14.1%	1.6%	3.9%	1.6%	10.2%	20.3%	100.0%
	Residual	-.8	-.6	-1.1	.6	-2.4	.2	-2.2	-.4	-1.1	2.3	5.0	
Water production/reservoir	Count	69	129	9	56	17	22	15	8	8	10	9	352
	%	19.6%	36.6%	2.6%	15.9%	4.8%	6.2%	4.3%	2.3%	2.3%	2.8%	2.6%	100.0%
	Residual	.2	5.9	.4	5.5	-.8	-4.0	-1.5	-2.1	-1.0	-2.2	-3.9	
State park	Count	367	422	25	120	92	229	85	65	38	85	97	1625
	%	22.6%	26.0%	1.5%	7.4%	5.7%	14.1%	5.2%	4.0%	2.3%	5.2%	6.0%	100.0%
	Residual	3.5	2.5	-2.1	-.9	-.2	.8	-1.6	-1.2	-2.1	-.5	-3.4	
Total	Count	4658	5684	550	1936	1395	3256	1496	1114	787	1339	1994	24209
	%	19.2%	23.5%	2.3%	8.0%	5.8%	13.4%	6.2%	4.6%	3.3%	5.5%	8.2%	100.0%

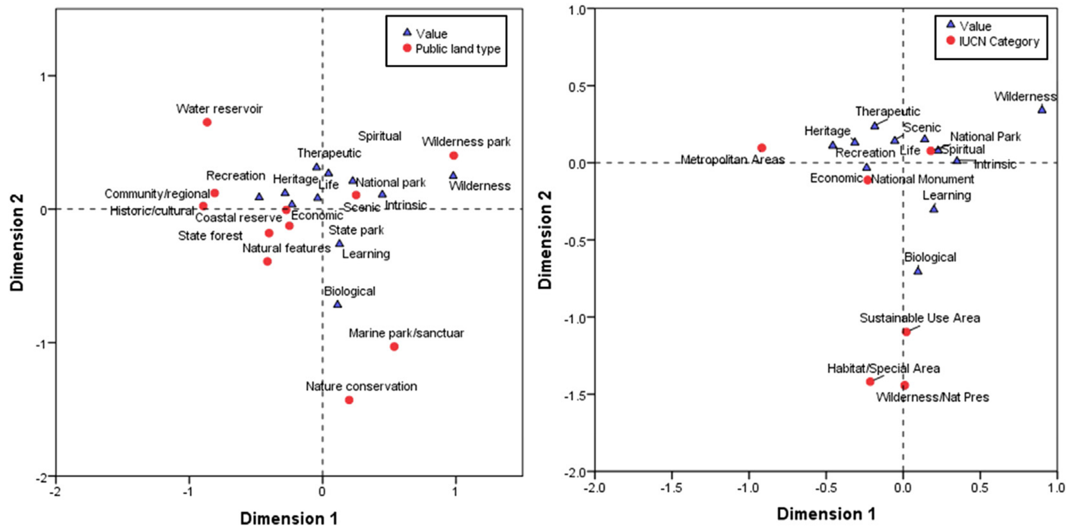

Fig. 3. Symmetrical normalized plots from correspondence analysis of values by (a) public land type and (b) IUCN classification.

and LoP class A1/A2 (−10.4) and Marine A/B (−4.0); and wilderness values and class B (−7.8), C (−8.0), D (−5.6) and E (−6.0).

These results are generally consistent with the IUCN results. The A1/A2 LoP classes contain predominantly national parks (82%) with high levels of species diversity and numbers of threatened species. The B to E classes contain conservation reserves, regional parks and metro parks that are smaller in size (<140,000 ha) and are thus more fragmented with fewer wilderness values. The D and E classes

Table 4
Association of mapped values with IUCN protected area categories. Metropolitan parks are not classified within the IUCN system, but were included in the analysis for contrast. The overall association is significant ($X^2 = 651.2$, $df = 50$, $p < .001$) with standardized residuals less than −2.0 (pink) or greater than 2.0 (green) highlighted.

IUCN Category		Scenic	Recreation	Economic	Life	Learning	Biological	Heritage	Therapeutic	Spiritual	Intrinsic	Wilderness	Total
Strict Nature Preserve or Wilderness (Ia and Ib)	Count	90	114	11	37	45	171	28	20	14	33	31	594
	%	2.3%	2.6%	2.9%	2.3%	3.9%	6.2%	2.3%	2.1%	2.2%	2.8%	1.7%	3.0%
	Residual	-2.6	-1.8	-.1	-1.6	1.9	10.6	-1.4	-1.6	-1.2	-.3	-3.3	
National Park (II)	Count	2927	3150	285	1257	886	2049	890	707	506	953	1637	15247
	%	75.9%	71.2%	74.4%	79.6%	77.0%	73.8%	73.6%	75.6%	79.2%	81.8%	91.2%	76.5%
	Residual	-1.1	-9.6	-1.0	3.0	.4	-3.7	-2.5	-.7	1.6	4.4	15.4	
National Monument (III)	Count	232	205	9	63	60	132	45	43	39	36	51	915
	%	6.0%	4.6%	2.3%	4.0%	5.2%	4.8%	3.7%	4.6%	6.1%	3.1%	2.8%	4.6%
	Residual	4.7	.1	-2.1	-1.2	1.0	.4	-1.5	.0	1.9	-2.5	-3.7	
Habitat//Species Area (IV)	Count	8	16	3	7	5	23	4	5	3	2	3	79
	%	0.2%	0.4%	0.8%	0.4%	0.4%	0.8%	0.3%	0.5%	0.5%	0.2%	0.2%	0.4%
	Residual	-2.1	-.4	1.2	.3	.2	3.9	-.4	.7	.3	-1.3	-1.6	
Sustainable Use Areas (VI)	Count	55	66	8	21	33	80	22	7	11	27	17	347
	%	1.4%	1.5%	2.1%	1.3%	2.9%	2.9%	1.8%	0.7%	1.7%	2.3%	0.9%	1.7%
	Residual	-1.7	-1.4	.5	-1.3	3.0	4.9	.2	-2.4	.0	1.5	-2.7	
*Metropolitan parks	Count	545	876	67	194	122	323	221	153	66	114	55	2736
	%	14.1%	19.8%	17.5%	12.3%	10.6%	11.6%	18.3%	16.4%	10.3%	9.8%	3.1%	13.7%
	Residual	.8	13.3	2.2	-1.7	-3.2	-3.5	4.7	2.4	-2.5	-4.0	-13.8	
Totals	Count	3857	4427	383	1579	1151	2778	1210	935	639	1165	1794	19918
	%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 5
Association of mapped values with Parks Victoria designated *Level of Protection* (LoP) classifications. The overall association is significant ($X^2 = 467.4$, $df = 50$, $p < .001$) with standardized residuals less than −2.0 (pink) or greater than 2.0 (green) highlighted.

Level of Protection		Scenic	Recreation	Economic	Life	Learning	Biological	Heritage	Therapeutic	Spiritual	Intrinsic	Wilderness	Total
A1 or A2	Count	2503	2644	248	1080	756	1756	798	613	460	826	1468	13152
	%	19.0%	20.1%	1.9%	8.2%	5.7%	13.4%	6.1%	4.7%	3.5%	6.3%	11.2%	100.0%
	Residual	-1.8	-10.4	-.1	1.8	.1	-2.6	-.4	-.5	3.2	3.4	15.1	
B	Count	706	1031	56	307	194	541	182	191	89	204	209	3710
	%	19.0%	27.8%	1.5%	8.3%	5.2%	14.6%	4.9%	5.1%	2.4%	5.5%	5.6%	100.0%
	Residual	-.6	8.8	-1.9	.8	-1.5	1.5	-3.4	1.4	-3.1	-1.1	-7.8	
C	Count	384	502	36	135	109	265	130	90	55	85	73	1864
	%	20.6%	26.9%	1.9%	7.2%	5.8%	14.2%	7.0%	4.8%	3.0%	4.6%	3.9%	100.0%
	Residual	1.4	5.0	.1	-1.2	.2	.5	1.6	.2	-.7	-2.5	-8.0	
D	Count	118	145	13	40	51	91	61	26	18	30	16	609
	%	19.4%	23.8%	2.1%	6.6%	8.4%	14.9%	10.0%	4.3%	3.0%	4.9%	2.6%	100.0%
	Residual	.0	.9	.4	-1.3	2.8	.8	4.1	-.5	-.4	-1.0	-5.6	
E1 or E2	Count	136	145	23	31	29	78	42	24	15	20	10	553
	%	24.6%	26.2%	4.2%	5.6%	5.2%	14.1%	7.6%	4.3%	2.7%	3.6%	1.8%	100.0%
	Residual	3.1	2.2	4.0	-2.1	-.5	.2	1.5	-.4	-.7	-2.3	-6.0	
Marine A or Marine B	Count	62	33	5	13	18	53	20	7	10	19	28	268
	%	23.1%	12.3%	1.9%	4.9%	6.7%	19.8%	7.5%	2.6%	3.7%	7.1%	10.4%	100.0%
	Residual	1.6	-4.0	.0	-1.9	.7	2.8	.9	-1.6	.5	.9	.9	
Total		3909	4500	381	1606	1157	2784	1233	951	647	1184	1804	20156
		19.4%	22.3%	1.9%	8.0%	5.7%	13.8%	6.1%	4.7%	3.2%	5.9%	9.0%	100.0%

include historic and natural features reserves so their stronger association with heritage values would be expected.

Social landscape metrics by park/reserve

Social landscape metrics were calculated for all parks and reserves containing 30 or more mapped values ($n = 93$). Results for the 50 most frequently mapped parks appear in Table 6. Landscape metrics identify distinctive or unusual value distributions that can provide a focal point for managerial attention. The two metrics that measure the frequency of mapped values (P0, P1) indicate that four national parks in particular—Alpine, Wilsons Promontory, Grampians, and Great Otway—are most important to residents of Victoria. These four national parks were mapped more than twice as often as any other park/reserve in Victoria. In terms of visitor numbers, these parks are among the most popular of Victoria's National Parks and appear deserving of the title of the "People's Choice Award" for Victoria's most valuable national parks.

Scenic/esthetic and recreation values were the most frequently mapped in all but two of the park/reserves and thus were the

Table 6
Social landscape metrics for most frequently mapped values in park/reserve units in Victoria. Highlighted cell (green) indicate park/reserve metrics that merit special attention.

Name	Area (Hectares)	Dominant Value (D)[a]	Count (P0)[b]	Percent (P1)[c]	Richness (R)[d]	Dominance (D1)[e]	Density (D2)[f]	Diversity (D3)[g]	Conflict index (C)[h]
Alpine NP	661934.5	Recreation	2411	0.11	11	0.34	3.64	2.13	383.4
Wilsons Promontory NP	48244.2	Scenic	1722	0.09	11	0.07	35.69	2.21	220.1
Grampians NP	168112.6	Scenic	1398	0.08	11	0.08	8.32	2.25	145.8
Great Otway NP	104084.8	Scenic	1218	0.08	11	0.06	11.71	2.17	139.0
Dandenong Ranges NP	3542.1	Recreation	675	0.05	11	0.13	190.58	2.12	143.2
Yarra Ranges NP	77218	Scenic	666	0.05	11	0.11	8.62	2.19	191.6
Mount Buffalo NP	27471.8	Scenic	587	0.04	11	0.10	21.37	2.25	232.6
Croajingolong NP	88470.7	Wilderness	502	0.04	11	0.15	5.67	2.12	20.5
Mornington Peninsula NP	2685.4	Scenic	474	0.04	11	0.11	176.52	2.08	41.8
Port Campbell NP	2407.1	Scenic	342	0.03	11	0.44	142.17	2.21	16.3
Snowy River NP	114674	Scenic	311	0.03	11	0.04	2.71	2.16	55.5
Baw Baw NP	12796.7	Recreation	306	0.03	11	0.13	23.91	2.09	91.8
Wyperfeld NP	360365.6	Recreation	293	0.03	11	0.17	0.81	2.15	19.1
Little Desert NP	131583.4	Recreation	282	0.03	11	0.19	2.14	2.15	56.4
Murray - Sunset NP	666615.1	Recreation	277	0.03	11	0.07	0.42	2.14	63.9
Lerderderg SP	20560.2	Recreation	255	0.03	11	0.29	12.40	2.01	110.9
Point Nepean NP	533.3	Scenic	243	0.03	11	0.18	455.65	2.19	77.3
Yarra Bend Park	247.7	Recreation	232	0.03	11	0.36	936.62	2.04	61.9
Yarra Valley Parklands	922.3	Recreation	231	0.03	11	0.59	250.46	1.80	46.2
Lower Glenelg NP	26448.5	Recreation	231	0.03	11	0.06	8.73	2.17	12.2
Hattah - Kulkyne NP	50059.8	Recreation	222	0.03	11	0.20	4.43	2.21	38.3
Brisbane Ranges NP	8855.1	Recreation	217	0.03	11	0.18	24.51	2.03	37.7
Bunyip SP	16646.4	Recreation	211	0.03	11	0.38	12.68	1.99	58.2
Cathedral Range SP	3598.4	Recreation	210	0.03	11	0.11	58.36	2.02	11.7
Tarra-Bulga NP	2017.9	Scenic	195	0.03	11	0.22	96.64	2.22	0.8
Barmah NP	28502.4	Recreation	189	0.03	11	0.16	6.63	2.23	40.1
Lysterfield Park	1434.6	Recreation	186	0.03	11	0.50	129.65	1.82	65.6
Kinglake NP	23173.1	Recreation	168	0.02	10	0.32	7.25	1.87	93.3
Discovery Bay Coastal Park	10642.4	Scenic	161	0.02	10	0.42	15.13	1.96	8.1
Cape Liptrap Coastal Park	4323	Scenic	155	0.02	10	0.17	35.85	1.99	8.9
Errinundra NP	40090.3	Scenic	151	0.02	10	0.14	3.77	2.15	7.6
Warrandyte SP	682	Scenic	148	0.02	11	0.26	217.01	2.05	49.3
Mount Arapiles-Tooan SP	7455.1	Recreation	139	0.02	11	0.26	18.64	2.15	11.6
Mitchell River NP	14346.5	Recreation	138	0.02	11	0.10	9.62	2.11	63.7
Lake Eildon NP	27853.5	Recreation	137	0.02	11	0.33	4.92	2.02	137.0
Castlemaine Diggings NHP	7585.2	Recreation	124	0.02	9	0.30	16.35	1.95	56.4
Yarra Valley Parklands	140.7	Recreation	115	0.02	10	0.68	817.34	1.60	38.3
Dandenong Valley Parklands	810.7	Recreation	114	0.02	10	0.73	140.57	1.67	76.0
Chiltern-Mt Pilot NP	21598.2	Scenic	101	0.02	11	0.00	4.68	2.04	13.5
Howqua Hills H.A	1093.5	Recreation	100	0.02	11	0.26	91.45	2.06	50.0
Port Phillip Heads Marine NP	3474	Scenic	100	0.02	11	0.09	28.79	2.10	16.7
Wilsons Promontory MP	5566	Scenic	97	0.02	10	0.39	17.43	1.93	0.9
Albert Park	314.5	Recreation	94	0.02	11	0.53	438.84	1.91	25.6
Arthurs Seat SP	558.7	Scenic	90	0.02	11	0.23	161.09	1.85	90.0
Mount Worth SP	1032.1	Biological	90	0.02	11	0.06	87.20	2.11	12.9
Werribee Gorge SP	564.9	Recreation	88	0.02	9	0.04	155.78	1.83	1.1
Mount Eccles NP	8378.3	Scenic	84	0.02	10	0.24	10.03	2.16	28.0
You Yangs RP	1966.8	Recreation	83	0.02	10	0.63	42.20	1.78	51.9
Cape Conran Coastal Park	11576	Scenic	83	0.02	11	0.15	7.17	2.04	1.0
Greater Bendigo NP	17325.6	Recreation	81	0.02	11	0.26	4.68	2.04	6.8
Avon Wilderness Park	39558.4	Wilderness	80	0.02	10	0.35	2.02	2.01	53.3

[a] $D = \max\left(\sum v_i\right)$ where: v_i = number of mapped landscape value points for a given value v in a given landscape unit *i*.

[b] $P0 = \sum p_i$ where: p_i = number of landscape value points mapped within landscape unit *i*.

[c] $P1 = \dfrac{\sum p_i}{P}$ where: p_i = number of landscape value points mapped within landscape unit *i* and P = total number of mapped landscape value points.

[d] R = number of landscape value types mapped within the landscape unit. Range is from 0 to 11 values.

[e] $D1 = \dfrac{\max\left(\sum v_i\right) - \max\left(\sum v_i\right)^{(2)}}{\max\left(\sum v_i\right)}$ where: v_i = number of mapped landscape value points for a given value v in a given landscape unit *i*.

[f] $D2 = \dfrac{\sum p_i}{h_i}$ where: p_i = number of landscape value points mapped within landscape unit *I* and h_i = number of hectares within landscape unit *i*.

[g] $D3 = -\sum_{i=1}^{v} p_i \ln p_i$ where: p_i = the proportional abundance of the *i*th landscape value = (n_i/N); n_i = the number of mapped landscape values in the *i*th landscape value category;
N= the total number of all mapped landscape values; ln = natural logarithm; v = the number of landscape value categories.

[h] see formula in body of article.

dominant (D) values. In contrast, Croajingolong NP and Mount Worth State Park appear distinctive because wilderness and biological values were dominant respectively. Croajingolong NP is a remote park that follows the eastern coastline of Victoria for 100 km and contains eucalypt forest, rainforest, and heathland with several secluded, coastal camping sports. The biological values of Mount Worth State Park appear dominant. The park includes an ancient Mountain Ash (*Eucalyptus regnans*) forest, including the Standing Giant, a tree seven meters in circumference and more than 300 years old.

The dominance index (D1) indicates whether the dominant value is truly dominant or only slightly more common than other values in the park/reserve. A key finding in Table 6 is that the smaller metropolitan and regional parks such as Yarra Valley (D1=.68) and Dandenong Valley Parklands (D1 = .73) are heavily dominated by recreation values, even though the parks contain most of the other value types as indicated by the richness (R) index. Although these smaller parks contain multiple values, recreational use values were much more frequently mapped than the other values.

The density metric (D2) controls for the size of the park/reserve under the assumption that larger landscape parks/reserves should have more mapped values. But some parks/reserves are highly valued despite their relatively small size. For example, Yarra Bend Park, Yarra Valley Parklands, Albert Park, and Point Nepean NP contain the highest densities of mapped values, exceeding other parks/reserves on a per hectare basis.

The diversity metric (D3) measures the number of different value types mapped in the park/reserve and also accounts for the evenness of the mapped values. One would expect larger parks to contain a higher diversity of mapped values as found previously by Brown (2008) and the results support this supposition. However, the diversity metric also reveals a few surprises. For example, two smaller national parks (Tarra-Bulga and Barmah) also have a high diversity of values. Tarra-Bulga, where scenic value is dominant, is known for its giant Mountain Ash trees, fern gullies, and ancient myrtle beeches. There is a suspension bridge through the forest canopy that provides visitors with spectacular views to the forest floor. Thus, this park provides a diversity of values across the spectrum from scenery and recreation to biological and spiritual values. Barmah, where recreation value is dominant, also provides a diversity of biological and life sustaining values. The riverine forest in the park is part of the largest River Red Gum (*Eucalytpus camaldulensis*) forest in the world where seasonal flooding of the Murray River creates a diverse natural habitat for wildlife. The park receives significant recreation use from camping, fishing, horse riding, bushwalking, swimming, and canoeing. Prior to 2010, Barmah was a state park with a long history of recreational use under a less regulated regime.

The conflict index metric (C) measures the potential for conflict under the assumption that some public land uses and values are competitive rather than complementary. The greatest potential for land use conflict is found in parks/reserves where there is conservation or development disagreement and where the park/reserve has high value. In this study, conflict potential is operationalized by the spatial concurrence of preferences for more conservation or protection and preferences for additional development activity (extraction, resource use, tourism development, vehicular access, or additional recreation facilities) that are amplified by the number of mapped values. The parks/reserves with the highest potential for conflict were several of the more popular national parks such as Mount Buffalo and Wilsons Promontory National Parks. The park with the largest conflict index was Alpine National Park. This is Victoria's largest national park and has a history of conflict over grazing (Fraser & Chisholm, 2000) and recreational use (Mckercher, 1996). Several less iconic parks such as Lerderderg State Park, Lake Eildon National Park, and Kinglake National Park were also identified as having relatively high potential for conflict. The potential conflict at Lerderberg was the result of contrasting preferences on whether to provide greater vehicular access to this park which offers a primitive recreation experience, while the higher potential conflict at Lake Eildon and Kinglake Natonal Parks derive from preferences for increased vehicle access and the provision of more recreational facilities. The conflict potential for parks and reserves in Victoria is graphically illustrated in Fig. 4 where the conflict index was grouped using natural breaks into high, medium, and low categories.

Discussion

Understanding social and cultural values of public land is an important and underdeveloped component of ecosystem services valuation. Identifying social and cultural values is also increasingly important for public land planning and management (Ives & Kendal, 2013). Our assessment of public land values—the first comprehensive assessment across an entire public land estate—used two analytical focal lengths, a wide-angle, state-wide lens that examined broad associations between values and public land types, and a zoom lens that used social landscape metrics to examine the distribution of values in individual park/reserve units. The two analyses provide alternative, but complementary assessments of public lands.

As a system, public lands in Victoria provide the full spectrum of social and cultural ecosystem values with recreation, scenic/aesthetic, and biological values being most recognized by study participants. The larger, most highly visited national parks appear disproportionately important in providing these values, but the social landscape metrics also reveal that on a per hectare basis, metro and regional parks provide higher intensities of values centered on recreation. Despite the uneven spatial distribution of public lands within Victoria, these lands comprise a complementary and representative system of social and cultural values that are abundant, rich, and diverse. National and wilderness parks provide relatively pristine natural settings that are differentially important for wilderness and intrinsic/extrinsic values, state forests provide biological and life sustaining values combined with nature-based recreation, and metropolitan and regional parks provide important recreation opportunities proximate to urban and suburban populations. The Victorian coast further augments the system by providing exceptional scenic values in combination with abundant marine life.

The analysis of specific park/reserve units using social landscape metrics reveals special and unique places. For example, Port Campbell National Park on the southern coast of Victoria contains the scenic "Twelve Apostles", an iconic coastline that features golden cliffs and crumbling pillars where scenic values dominate other mapped values. The metrics also reveal that Wilsons Promontory, another coastal national park, is similarly dominated by scenic values. The conflict metric indicates some of the larger national parks such as Alpine National Park will continue to be challenged to find the right balance between conservation and development preferences in future management.

The validity and reliability of PPGIS to assess the values associated with public lands depend on the data collection methods and representativeness of the sampling. The value and preference typologies, as operationalized in PPGIS, have a relatively high degree of construct validity given their replication across multiple studies involving public lands. For example, the relative frequency of mapped values in this study was consistent with the values found in a recent PPGIS study of Hinchinbrook Island National Park in Australia (van Riper et al., 2012). We are more ambivalent about the

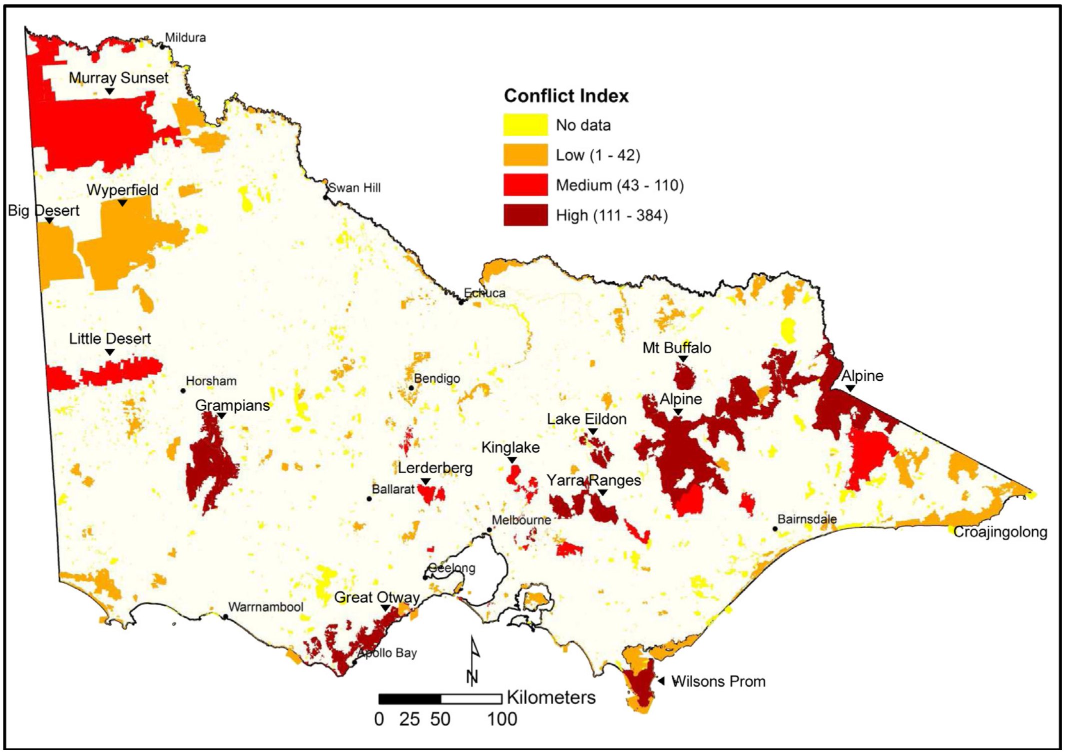

Fig. 4. Map of potential conflict in parks/reserves based on conflict index grouped into high/medium/low categories.

sampling design and implementation that necessarily relied on purposive and to a greater extent, convenience sampling, the latter being termed *volunteered geographic information* or VGI. The sampling method, especially probability vs. non-probability sampling, represents a potential, but not definitive point of distinction between PPGIS and VGI systems (Brown & Kyttä, 2014).

By the standards of science, the lack of random sampling of households in Victoria due to budget constraints must be considered a study limitation. The participant profile is biased toward individuals that are familiar and use public lands on a fairly regular basis. Further, we estimate that about half of the participants likely have memberships or other affiliations with organizations that span a variety of public land advocacy interests ranging from greater conservation to increased access. As a cautionary tale, Brown, Kelly, and Whitall (2012) observed that PPGIS participants that were mobilized by advocacy groups can influence the types of markers that are mapped in the PPGIS process, with the potential ideological bias more apparent when mapping land use preferences.

Despite limitations in the sampling design, there were encouraging aspects of the sampling response that merit further consideration for future public land assessments using PPGIS and VGI methods. With over 1900 study participants, this study achieved nearly double the response of the largest previous study to map cultural ecosystem values (Brown & Fagerholm, 2014). Prior research by this research team that used social media and volunteer networks to recruit PPGIS participants were far less effective. We speculate that the affinity of the study topic with participants—parks and public lands—in combination with an innovation in monetary incentives that offered participants the option to donate money to selected charities on their behalf, resulted in participation rates that exceeded our expectations. The high participation rate should be considered in light of previous PPGIS studies that used random household sampling, but consistently reported very low response rates as well as sampling bias (Brown & Kyttä, 2014). Ideally, a comprehensive public lands assessment would follow the approach of Brown and Reed (2009) who advocate a PPGIS sampling design that combines regional random household sampling, volunteer opportunities for non-regional residents to participate, and the targeting of public land stakeholder groups.

In a recent review of empirical mapping of ecosystem values using PPGIS, Brown and Fagerholm (2014) found little evidence that mapped data had actually been used for decision support in land use planning and that best practice had yet to emerge from research dominated by methodological pluralism and case study research. This particular study adds yet another case study, albeit the first to map social and cultural ecosystem values across a system of public lands. Whether this assessment will influence resource allocations and management decisions from Parks Victoria and DEPI, the agencies responsible for over 90 percent of the public lands in Victoria, remains to be seen. The most important outcomes for this study were to establish the methodological viability of system-wide assessment of public lands using PPGIS/VGI methods and to establish a baseline inventory of public land values in Victoria that can be used to compare with future biological and social assessments. The system developed was both cost and time efficient and the results allow small-scale data interrogation to occur. The challenge that remains is to evaluate the use of this data by Parks Victoria and further refine the method accordingly.

References

Australian Bureau of Statistics. (2013). *QuickStats*. Available from http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/2?opendocument&navpos=220 Accessed 27.04.14.

Beverly, J., Uto, K., Wilkes, J., & Bothwell, P. (2008). Assessing spatial attributes of forest landscape values: an internet-based participatory mapping approach. *Canadian Journal of Forest Research, 38*, 289–303.

Bonn, A., & Gaston, K. (2005). Capturing biodiversity: selecting priority areas for conservation using different criteria. *Biodiversity & Conservation, 14*(5), 1083–1100.
Brown, G. (2008). A theory of urban park geography. *Journal of Leisure Research, 40*(4), 589–607.
Brown, G., & Alessa, L. (2005). A GIS-based inductive study of wilderness values. *International Journal of Wilderness, 11*(1), 14–18.
Brown, G., & Brabyn, L. (2012). The extrapolation of social landscape values to a national level in New Zealand using landscape character classification. *Applied Geography, 35*(1–2), 84–94.
Brown, G., & Fagerholm, N. (2014). Empirical PPGIS/PGIS mapping of ecosystem services: a review and evaluation. *Ecosystem Services* (Unpublished manuscript).
Brown, G., & Kyttä, M. (2014). Key issues and research priorities for public participation GIS (PPGIS): a synthesis based on empirical research. *Applied Geography, 46*, 122–136.
Brown, G., Montag, J. M., & Lyon, K. (2012). Public participation GIS: a method for identifying ecosystem services. *Society & Natural Resources, 25*, 633–651.
Brown, G., & Raymond, C. (2014). Methods for identifying land use conflict potential using participatory mapping. *Landscape and Urban Planning, 122*, 196–208.
Brown, G., & Reed, P. (2000). Validation of a forest values typology for use in national forest planning. *Forest Science, 46*(2), 240–247.
Brown, G., & Reed, P. (2009). Public participation GIS: a new method for use in national forest planning. *Forest Science, 55*, 166–182.
Brown, G., & Reed, P. (2012a). Social landscape metrics: measures for understanding place values from public participation geographic information systems (PPGIS). *Landscape Research, 37*, 73–90.
Brown, G., & Reed, P. (2012b). Values compatibility analysis: Integrating public values in a forest planning decision support system. *Applied Spatial Analysis and Policy, 5*(4), 317–332.
Brown, G., & Weber, D. (2011). Public participation GIS: a new method for use in national park planning. *Landscape and Urban Planning, 102*(1), 1–15.
Clement, J., & Cheng, A. (2011). Using analyses of public value orientations, attitudes and preferences to inform national forest planning in Colorado and Wyoming. *Applied Geography, 31*(2), 393–400.
Clement-Potter, J. (2006). *Spatially explicit values on the Pike and San Isabel national forests in Colorado*. Fort Collins, CO: Colorado State University (Ph.D. thesis).
Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S., & D'Agostino, J. (2006). *The value of New Jersey's ecosystem services and natural capital* (Vol. 13). Trenton, New Jersey: Gund Institute for Ecological Economics, University of Vermont and New Jersey Department of Environmental Protection.
Crossman, N. D., Burkhard, B., Nedkov, S., Willemen, L., Petz, K., Palomo, I., et al. (2013). A blueprint for mapping and modelling ecosystem services. *Ecosystem Services, 4*, 4–14.
DEPI—Department of Environmental and Primary Industries. (2013). *Victorian Crown land area statement*. Available from http://www.depi.vic.gov.au/__data/assets/pdf_file/0006/199068/FactSheet_CrownLandVictoria_20130821FINAL.pdf Accessed 22.04.14.
De Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity, 7*(3), 260–272.
Dudley, N. (2008). In *Guidelines for applying protected area management categories*. IUCN.
Egoh, B., Drakou, E. G., Dunbar, M. B., Maes, J., & Willemen, L. (2012). *Indicators for mapping ecosystem services: A review*. EUR 25456 EN. Luxembourg: Publications Office of the European Union.
Fagerholm, N., Käyhkö, N., Ndumbaro, F., & Khamis, M. (2012). Community stakeholders' knowledge in landscape assessments – mapping indicators for landscape services. *Ecological Indicators, 18*, 421–433.
Fraser, I., & Chisholm, T. (2000). Conservation or cultural heritage? Cattle grazing in the Victoria Alpine National Park. *Ecological Economics, 33*(1), 63–75.
Geoscience Australia. (2014). *Land tenure*. Available from http://www.ga.gov.au/education/geoscience-basics/land-tenure.html Accessed 28.04.14.
Goodchild, M. F. (2007). Citizens as sensors: the world of volunteered geography. *GeoJournal, 69*(4), 211–221.
Gorte, R., Hardy Vincent, C., Hanson, A., & Rosenblum, M. (2012). *Federal land ownership: Overview and data*. Congressional Research Service Report for Congress 7-5700. Washington DC, USA.
Harmon, D., & Putney, A. (Eds.). (2003). *The full value of parks: from Economics to the intangible*. Lanham, MD: Rowman & Littlefield.
Ives, C., & Kendal, D. (2013). Values and attitudes of the urban public towards peri-urban agricultural land. *Land Use Policy, 34*, 80–90.
IUCN – International Union for the Conservation of Nature. (1994). *Guidelines for protected area management categories*. Gland, Switzerland: IUCN Commission on Parks and Protected Areas.
Loomis, J., Kent, P., Strange, L., Fausch, K., & Covich, A. (2000). Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey. *Ecological Economics, 33*(1), 103–117.
Margules, C. R., Nicholls, A. O., & Pressey, R. L. (1988). Selecting networks of reserves to maximise biological diversity. *Biological Conservation, 43*(1), 63–76.
Margules, C. R., & Pressey, R. L. (2000). Systematic conservation planning. *Nature, 405*(6783), 243–253.
Martínez-Harms, M. J., & Balvanera, P. (2012). Methods for mapping ecosystem service supply: a review. *International Journal of Biodiversity Science, Ecosystem Services & Management, 8*(1–2), 17–25.
MA (Millennium Assessment). (2003). *Ecosystems and human well-being: A framework for assessment*. Washington D.C: Island Press.
Mckercher, B. (1996). Differences between tourism and recreation in parks. *Annals of Tourism Research, 23*(3), 563–575.
Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature, 403*(6772), 853–858.
NRCM – Natural Resource Council of Maine. (2014). *Public land ownership by state*. Available at http://www.nrcm.org/documents/publiclandownership.pdf Accessed 28.04.14.
Pressey, R. L., Johnson, I. R., & Wilson, P. D. (1994). Shades of irreplaceability: towards a measure of the contribution of sites to a reservation goal. *Biodiversity & Conservation, 3*(3), 242–262.
Pressey, R. L., Humphries, C. J., Margules, C. R., Vane-Wright, R. I., & Williams, P. H. (1993). Beyond opportunism: key principles for systematic reserve selection. *Trends in Ecology & Evolution, 8*(4), 124–128.
Rambaldi, G., Kyem, P., McCall, M., & Weiner, D. (2006). Participatory spatial information management and communication in developing countries. *EJISDC, 25*, 1–9.
Schlossberg, M., & Shuford, E. (2005). Delineating 'public' and 'participation' in PPGIS. *URISA Journal, 16*(1), 15–26.
Sieber, R. (2006). Public participation geographic information systems: a literature review and framework. *Annals of the Association of American Geographers, 96*, 491–507.
Smith, P. G., & Theberge, J. B. (1986). A review of criteria for evaluating natural areas. *Environmental Management, 10*(6), 715–734.
Tyrväinen, L., Mäkinen, K., & Schipperjn, J. (2007). Tools for mapping social values of urban woodlands and other green areas. *Landscape and Urban Planning, 79*(1), 5–19.
van Riper, C. J., Kyle, G. T., Sutton, S. G., Barnes, M., & Sherrouse, B. C. (2012). Mapping outdoor recreationists' perceived social values for ecosystem services at Hinchinbrook Island National Park, Australia. *Applied Geography, 35*, 164–173.
WDPA. (2014). *World database on protected areas*. Available from http://www.wdpa.org/resources/statistics/2013_MDG_Regional_and_global_stats_Indicator_7_6.xlsx. Last Accessed 19.04.14.