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The extrapolation of social landscape values to a national level in New Zealand using landscape character classification

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ABSTRACT

The human perception and valuation of landscapes is a complex process but has been pragmatically advanced through public participation GIS (PPGIS). PPGIS methods have the capacity to generate spatial data to empirically examine relationships between human landscape values and physical landscape character. In 2011, PPGIS methods were used to identify a range of social landscape values for two regions in southern New Zealand, Otago and Southland. Seven of these landscape values were analysed to identify significant relationships with physical landscape character from the New Zealand Landscape Classification system. In this paper we examine methods to extrapolate landscape values from this regional data set to a national level using these landscape value and character relationships. In the absence of empirical value data at a national level, we examine two quantitative approaches for extrapolating landscape values: (1) landscape component weights based on the percentage of value counts found within landscape components, and (2) landscape component weights based on the ratio of landscape values to the landscape area. We prepare and present maps of seven landscape values for the entire country of New Zealand to demonstrate the method. We conclude that landscape value extrapolation can assist impact assessment for land use change but should be kept simple for decision support.

Introduction

Within the geospatial sciences, extensive resources have been invested to identify and map physical, biological, and human-developed landscapes using remote sensing and geographic information systems (GIS) technologies (Geri, Amici, & Rocchini, 2010; Shalaby & Tateishi, 2007; Tansey, Chambers, Anstee, Denniss, & Lamb, 2009). But the direct mapping of social landscape values, arguably the most elemental source of land use compatibility and conflict, has had less attention (Kaltenborn, 1998). Some exceptions include the mapping of recreation value (e.g., Joyce & Sutton, 2009), historical features (e.g., Mallinis, Emmanoloudis, Giannakopoulos, Maris, & Koutsias, 2011), studies that seek to explain landscape change (Serra, Pons, & Saurí, 2008), and public participatory landscape values mapping (Brown & Raymond, 2007). Yet landscape is a combination of the physical (what is out there) and how this is perceived (Jones, 1991). Psychophysical analysis, regarded as the most valid form of landscape assessment (Daniel & Vining, 1983), researches this combination but tends to use photos rather than maps. An exception is Kliskey and Kearsley's (1993) mapping of wilderness perceptions. Our research extends these studies by exploring techniques to extrapolate landscape values obtained through regional participatory mapping to the whole of New Zealand using nominal landscape character categories.

Social landscape values are collective perceptions about places and locations that reflect land use aspirations and potential conflict. Landscape values are perceived attributes of a landscape that are thought to result from a transactional concept of human–landscape relationships (Brown, 2005; Zube, 1987). In the transactional model, humans are active participants in a landscape—thinking, feeling, and acting—leading to the attribution of meaning and the valuing of specific landscapes and places. The mapping of social landscape values reveal human connection to place and the complexity of human/landscape relationships that may paradoxically, seek to exploit and degrade land in one location while protecting and preserving it in another.

Over the past decade, participatory GIS methods (also known as "public participation GIS or simply PPGIS") have been developed to identify and spatially map a range of social landscape values. The mix of social landscape values has ranged on a continuum from relatively tangible and objective (e.g., recreation, economic, and

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ecological values) to more intangible and subjective values (e.g., aesthetic, spiritual, and wilderness value). These participatory GIS studies have been motivated by the need to enhance practical methods for land use planning and environmental management. For example, typologies of social landscape values have been developed and implemented to inform forest management (Beverly, Uto, Wilkes, & Bothwell, 2008; Brown & Reed, 2000, 2009; Clement & Cheng, 2010), national parks and protected area management (Brown & Weber, 2011; Pfueller, Xuan, Whitelaw, & Winter, 2009), urban park planning (Brown, 2008; Tyrväinnen, Mäkinen, & Schipperijn, 2007); residential and tourism development (Brown, 2006; Raymond & Brown, 2007); coastal area management (Alessa, Kliskey, & Brown, 2008), rural development (Nielsen-Pincus, 2007; Pocewicz, Schnitzer, & Nielsen-Pincus, 2010, 16 pp.), and climate change risk (Raymond & Brown, 2011).

The majority of participatory GIS studies involving empirical data collection have been local or regional in scale. In the absence of social landscape value data covering wide areas, models have been used to extrapolate social landscape values to larger areas based on the quantitative, empirical relationships with physical landscape attributes. In this paper, we review existing methods for scaling-up social landscape values and demonstrate an alternative method for the entire country of New Zealand using a classification of landscape character rather than numerical metrics. We argue that categorical landscape classes relate closer to how people perceive landscape and therefore more accurately model landscape value. In describing and demonstrating the method, we provide maps of New Zealand showing the potential locations of selected social landscape values—aesthetic, recreation, economic, ecological, social, historical, and wilderness values.

The mapping of social landscape values for an entire country is possible due to the presence of the New Zealand Landscape Classification (NZLC) system (Brabyn, 2009) and participatory GIS studies that collected social landscape value data in the Otago and Southland regions located on the South Island in 2011. Although our operational approach is different to existing models, the basic premise is similar—use empirical landscape value/character relationships to extrapolate landscape values to other regions and in this case, the entire country of New Zealand. While the social landscape maps for the New Zealand are an interesting product of the analysis, the more important objectives of this paper are to present a transparent method for extrapolating social landscape values and to provide critical discourse of the strengths and weaknesses of the approach.

A review of approaches for spatially modelling the relationship between physical landscapes and social landscape values

An early approach to spatially modelling social landscape values using physical landscapes was the mapping of wilderness by Kliskey and Kearsley (1993) using the recreational opportunity spectrum (Clark & Stankey, 1979, 32 pp.) and a perception study. A rule based, descriptive model was used that included distances from facilities and infrastructure (remoteness) and presence/absence of natural landcover. These were proxies for wilderness attributes such as the level of risk, skill required, and noise. The recreational opportunity spectrum was subsequently developed for all of New Zealand by Joyce and Sutton (2009). This model only mapped one landscape value – wilderness, and as the model is descriptive, there is no measure of error associated with the model.

A statistical model of landscape value extrapolation has been developed through a program called SolVES (http://solves.cr.usgs.gov/) or the ***S***ocial ***V***alue ***o***f ***E***cosystem ***S***ervices developed by the U.S. Geological survey. The model was developed using landscape value data collected as part of a participatory GIS process for national forest planning in the U.S. (Sherrouse, Clement, & Semmens, 2011). The SolVES model is a raster-based GIS model that quantifies the relationship between the density of social landscape values and physical landscape numerical metrics such as elevation, slope, distance to roads, and distance to water. These value/character relationships are extrapolated or "value-transferred" to a different or larger region using a multiple regression model that applies the empirical regression coefficients to the physical character of the new geographic area of interest. Thus, the model identifies the *potential* for social landscape values in areas where no participatory GIS mapping data exists.

An important issue with the SolVES approach is that the landscape metrics used can be the same for completely different landscape types. For example elevation could be high because the location is on a high plateau (tableland) or because it is on the top of a high, steep mountain. Slope can be steep because it is on the side of a canyon or on the side of a mountain. Distance to water could be to an open ocean or to a lake. Logically and intuitively, people would value these landscapes quite differently. This paper describes an alternative method that uses a PPGIS landscape values survey that is spatially overlaid with a landscape character classification system that uses nominal classes. The resulting model is based on value frequency counts which are used to extrapolate landscape values to a larger area, as described below.

Data and method

Collection of landscape values using participatory GIS

Before any landscape values could be collected, a typology of landscape values was required. The first landscape value typology used in participatory GIS mapping was developed by Brown and Reed (2000) and consisted of 13 values (aesthetic, economic, recreation, life sustaining, learning, biological, spiritual, intrinsic, historic, future, subsistence, therapeutic, and cultural). Variations of this value typology were subsequently adapted by other researchers to different planning contexts and alternatively termed as forest values (Brown & Reed, 2000), ecosystem values (Reed & Brown, 2003), environmental values (Brown, Reed, & Harris, 2002; Brown, Smith, Alessa, & Kliskey, 2004), landscape values (Alessa et al., 2008; Beverly et al., 2008; Raymond & Brown, 2011; Zhu, Pfueller, & Whitelaw, 2010), wilderness values (Brown & Alessa, 2005), and social values (Nielsen-Pincus, 2011; Sherrouse et al., 2011). The shifting terminology for the value typology appears to reflect, in part, the particular study context.

Seven landscape values were chosen for demonstration purposes—aesthetic, recreation, economic, ecological, social, historical, and wilderness. This choice was based on the mix that best assists the New Zealand Department of Conservation (DOC), who is responsible for managing 30% of New Zealand's land area. The set of landscape values reflect a spectrum of values that can influence decisions for regional conservation and development. Under the Conservation Act (1987), DOC is required to develop 10 year strategic plans called Conservation Management Strategies (CMS). The purpose of a conservation management strategy is to implement general policies and establish objectives for the integrated management of natural and historic resources, recreation, and tourism.

Two neighbouring DOC regions (known locally as Conservancies) were used as the initial study area to collect in situ data on landscape values. The Otago and Southland regions are located in the southern part of the South Island of New Zealand. The Southland region covers more than 3.1 million hectares, has over 3400 km of coastline, and includes New Zealand's largest national park, Fiordland National Park. Southland is one of New Zealand's most sparely populated regions (approximately 94,200 in 2010) with an economy based in tourism, agriculture, fishing, forestry, and energy resources.

The Otago region covers approximately 3.2 million hectares with an estimated population of 207,400 in 2010. Major centres of population include Dunedin, Oamaru, and the tourist centres of Queenstown and Wanaka. In the west of the region, high alpine mountains and glacial lakes dominate the landscape including Mt. Aspiring National Park. Tussock grasslands dominate the dry lands of the central region, while the hill country of the Catlins is located in the region's southeast. Key economic sectors include tourism, education, agriculture, and manufacturing.

Separate participatory GIS websites for each of the regions were developed after consultation and pilot testing with DOC staff. Data collection consisted of two parts; (a) spatial attribute mapping using a custom Google® maps application, and (b) general survey questions assessing participants' familiarity with conservation areas in the region and selected socio-demographic information. Participants were recruited through a random mail sample of households in the Southland and Otago regions, by visitor contact at conservation areas, and by advertising in media outlets such as local newspapers.

The spatial attributes included 30 landscape values, experiences, and development preference markers located in three panels on the left of the screen. Participants were instructed to drag and drop markers onto the appropriate Google® map locations representing the attribute. The same list of markers and associated definitions were used for the two regions. Of relevance to this paper are the 11 landscape values applicable to regional conservation and development issues in New Zealand (see Table 1).

PPGIS mapping precision by participants was enforced by only allowing the placement of markers if the participant had zoomed-in to a predetermined zoom level (Level 12) in Google® Maps (approximately 1:100,000 scale). Respondents could optionally view the region in different Google® map views including "Map", "Terrain", "Satellite", "Hybrid" and 3-D "Earth". The default Google® map view, and the one in which the majority of markers were placed, was "Terrain".

Landscape description and classification

The purpose of landscape classification is to provide a frame of reference for communicating landscape research, just as a plant classification improves communication for botanists. The landscape classification system used in this paper is the New Zealand Landscape Classification (NZLC) system which provides a GIS data set of landscape character. This classification of character was developed using GIS and a range of topographic and landcover data sets. One advantage of a GIS-based landscape classification is that statistics on the total area and relative abundance landscape components at a regional or national can be easily calculated. The NZLC has a spatial resolution of 100 m. The first version of the system was released in 1996 (Brabyn, 1996) and a second version in 2009 (Brabyn, 2009). The website (Brabyn, 2012) provides details and graphical displays of this classification system. The NZLC has been used to automatically tag photos (Brabyn & Mark, 2011) and describe the landscape experience of walking tracks.

The fundamental premise of the NZLC is that landscape consists of many layers (landform, landcover, etc.) and it is the composition and perception of these layers that form the landscape. For practical reasons of description and communication, it is useful to deconstruct landscape into layers; however, the individual layers are not a landscape. The viewer's perception, which can involve place attachment, understanding, and preferences, are also layers of the landscape. Thus, both physical and perceptual layers comprise landscape. We label the physical landscape layers as landscape components and the perceiver's layers as landscape values. We use the term "landscape class" to describe the unique combination of landscape components. A landscape component will have multiple classification categories (e.g., component = landform, category = high mountain, hill, or plateau).

The NZLC is built from the unique combination (spatially overlaying) of six landscape components—landform, landcover, infrastructure, water, dominant landcover, and water views. The latter two components provide the classification with a wider experiential context of a place. This database describes landscape components and classes with common language that is recognized and used by the general public. The categories associated with each landscape component are listed in the result tables (Tables 2 and 3). The six landscape components have the potential to produce many thousand landscape classes which can be impractical for some applications. Consequently, a hierarchical structure is imposed on the classification system so users can select a level of generalisation to meet their needs. This study uses the most detailed level of NZLC Version 2 (Level 3a), which has 7209 classes and 426,734 discrete polygons for the whole of New Zealand.

To prepare the spatial data for analysis, we intersected the landscape values point data from the PPGIS survey with the six NZLC landscape components (landform, landcover, dominant landcover, water, water view, and infrastructure). The number and type of landscape values falling within each landscape component

Table 1
Landscape value definitions used in public participation GIS (PPGIS) process in New Zealand. Asterisks denote the landscape values selected for analysis and extrapolation in this study.

Landscape values
***Scenic/aesthetic** – these areas are valuable because they contain attractive scenery including sights, smells, and sounds.
***Recreation (non-facility based)** – these areas are valuable because they provide dispersed recreation opportunities where users are relatively self-reliant, i.e. tramping (trekking/backpacking), climbing, hunting/fishing or adventure activities.
Recreation (facility based) – these areas are valuable because they provide recreation activities through the provision of managed tracks, huts, campsites, and other facilities.
***Economic** – these areas are valuable provide because they provide income and employment opportunities through industries like tourism, natural resources, or other commercial activity.
***Ecological/life sustaining** – these areas are valuable because they help produce, preserve, and renew air, soil, and water.
Native wildlife – these are valuable because they provide areas for indigenous (native) wildlife to live and/or opportunities for humans to observe.
Native vegetation – these areas are valuable because they sustain areas of indigenous (native) plants.
Marine – these areas are valuable because they support marine life.
***Social** – these areas are valuable because they provide opportunities for social interaction.
***Historical/cultural** – these areas are valuable because they represent history, NZ identity, or provide places where people can continue to pass down memories, wisdom, traditions, OR a way of life.
***Wilderness** – these areas are valuable because they are wild, uninhabited, or relatively untouched by human activity.

Table 2
Percentage of aesthetic values by landcover, landform, and dominant landcover in Otago and Southland regions. (Notes: "Pct" is an abbreviation for percent. The numbers in brackets show ranking of magnitude and the Spearman rank correlation shows the degree of similarity of these ranking between Otago and Southland.)

Landcover	Otago	Southland	Combined Pct	Pct count/Pct area
Alpine Rock	3.1(9)	1.3(9)	2.7	1.3
Coastal Sand	0.2(16)	0.0(14)	0.2	5.3
Exotic Forest	3.3(8)	0.7(11)	2.6	0.9
Exotic Scrub	2.1(10)	0.0(15)	1.6	2.4
Freshwater wetland	0.2(17)	1.3(10)	0.5	0.9
High Producing Grassland	14.9(3)	12.7(3)	14.3	0.5
Horticulture	0.2(18)	0.0(16)	0.1	1.5
Indigenous Forest	10.2(4)	43.4(1)	18.7	0.9
Indigenous Scrub	9.4(5)	4.9(6)	8.3	2.3
Lake	3.7(7)	8.7(4)	5.0	2.0
Low Producing Grassland	18.9(2)	5.8(5)	15.6	1.3
Mine or Dump	0.3(15)	0.0(17)	0.2	8.5
Permanent Snow and Ice	0.5(14)	0.0(18)	0.4	1.8
River	1.4(11)	1.8(8)	1.5	3.2
Saltwater wetland	1.0(12)	0.7(12)	0.9	14.0
Sub Alpine Scrub	1.0(13)	0.7(13)	0.9	0.5
Tussock	25.7(1)	14.9(2)	23.0	1.1
Urban	3.9(6)	3.1(7)	3.7	10.7
Spearman Rank Correlation = 0.84				

Landform	Otago	Southland	Combined Pct	Pct count/Pct area
High Hill	21.4(1)	10.5(5)	18.6	0.9
High Mountain	12.8(3)	7.1(7)	11.4	1.2
High Plateau	4.7(7)	0.4(13)	3.6	2.0
Hill	6.0(6)	4.9(8)	5.7	2.3
Large Open Lake	0.0(14)	2.4(11)	0.6	2.0
Low Hill	4.3(8)	11.6(3)	6.2	0.5
Low Plateau	0.1(13)	1.6(12)	0.5	1.3
Mostly Flat	2.4(10)	8.5(6)	3.9	0.5
Mountain	12.5(4)	22.9(1)	15.2	0.7
Open Valley with Hill	2.0(11)	2.7(10)	2.1	0.7
Open Valley with Mountain	9.5(5)	10.7(4)	9.8	2.9
Plateau	3.6(9)	2.7(9)	3.3	0.7
Very High Mountain	20.1(2)	13.8(2)	18.5	1.5
Very High Plateau	0.8(12)	0.2(14)	0.6	1.6
Spearman Rank Correlation = 0.70				

Dominant landcover	Otago	Southland	Combined Pct	Pct count/Pct area
Developed Agriculture	19.0(2)	24.5(2)	20.4	0.5
Exotic Forest and Scrub	1.1(6)	0.0(6)	0.8	0.6
Indigenous Landcover	58.0(1)	67.7(1)	60.5	1.0
Large Lake	3.3(4)	6.7(3)	4.1	1.6
Semi Developed Agriculture	16.8(3)	0.7(4)	12.7	1.0
Urban	1.9(5)	0.4(5)	1.5	9.6
Spearman Rank Correlation = 0.94				

Table 3
Percentage of aesthetic values by water, water view, and infrastructure in Otago and Southland regions. (Notes: "Pct" is an abbreviation for percent. The numbers in brackets show ranking of magnitude and the Spearman rank correlation shows the degree of similarity of these ranking between Otago and Southland).

Water	Otago	Southland	Combined Pct	Pct count/Pct area
Island in Lake	0.9(4)	0.0(7)	0.7	26.5
Land	93.6(1)	88.9(1)	92.4	0.8
Large Coastal Island	0.0(7)	0.4(5)	0.1	0.2
Large Lake	3.3(2)	6.7(2)	4.1	1.6
Medium Size Lake	0.4(5)	1.3(4)	0.6	3.3
River	1.4(3)	1.8(3)	1.5	2.8
Small Coastal Island	0.3(6)	0.2(6)	0.3	2.4
Spearman Rank Correlation = 0.75				

Water view	Otago	Southland	Combined Pct	Pct count/Pct area
Lake	3.7(4)	8.7(4)	5.0	1.8
No close View of Lake or Sea	67.0(1)	52.8(1)	63.4	0.7
View of Enclosed Sea	1.7(6)	4.7(5)	2.4	0.7
View of Estuarine	1.6(7)	2.7(7)	1.9	6.8
View of Large Lake	11.7(2)	11.6(3)	11.7	2.7
View of Medium Size Lake	3.6(5)	4.5(6)	3.8	2.6
View of Open Ocean	9.6(3)	13.1(2)	10.5	3.9
View of Small Lake	1.1(8)	2.0(8)	1.4	1.0
Spearman Rank Correlation = 0.95				

Infrastructure	Otago	Southland	Combined Pct	Pct count/Pct area
Highway	1.1(4)	1.1(4)	1.1	2.0
Land	92.1(1)	95.1(1)	92.9	18.7
Natural with Mast	0.2(8)	0.4(6)	0.3	1.7
Natural with Overhead Cable	0.1(9)	0.(9)	0.1	14.1
Natural with Sealed Road	0.5(7)	0.4(5)	0.5	16.3
Natural with Ski Lift	0.1(10)	0.0(10)	0.1	3.4
Natural with Unsealed Road	1.7(3)	1.6(2)	1.6	1.6
Natural with Vehicle Track	2.4(2)	1.1(3)	2.1	0.9
Railway	0.7(6)	0.2(7)	0.6	1.1
Transmission Line	1.1(5)	0.0(8)	0.8	0.6
Spearman Rank Correlation = 0.88				

and category (e.g., component = landform, category = high mountain) were tabulated along with the size of the landscape component category as a percentage of the study area. The number of landscape categories varies by landscape component and ranges from 18 categories in *landcover* to six categories in *dominant landcover*. See Tables 2 and 3 for a list of categories within each landscape component.

Data analysis

Details of our analysis are described below but we first provide a summary of the process. Fig. 1 displays an overview of our process for generating social landscape value maps for New Zealand. First, the two data sets (consisting of landscape values and character) from the Southland and Otago regions were combined. Using this data, two separate indices were calculated for each landscape component category. The first uses percent count and the other considers the ratio of the percent count to the area of landscape component category. The former index we call "count percent" and the latter we call "spatial proportion". These indices were then applied to all landscape components across New Zealand using the GIS polygons in the NZLC. Both indices were then separately aggregated for a landscape class that consist of six landscape components using the additive sum. These aggregated scores were then separately mapped. The process was repeated for each

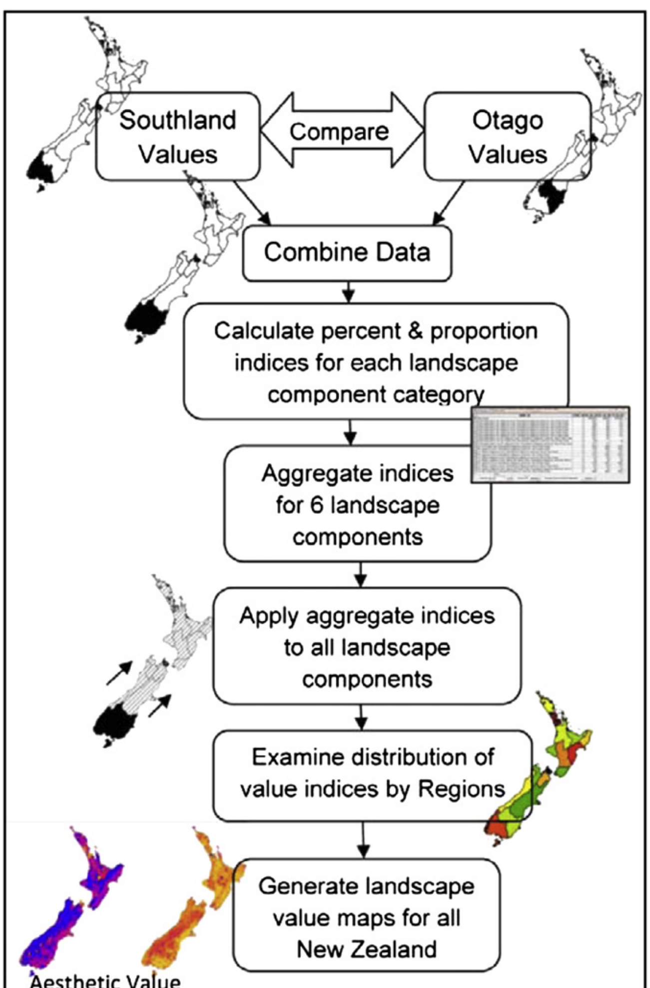

Fig. 1. Overview of process to extrapolate landscape values to all of New Zealand.

landscape value. The final outcome is a set of maps that display the distribution of landscapes values in New Zealand derived from the empirical relationships found in the Otago and Southland region.

Combining of Southland and Otago data sets

To have the largest possible number of empirical observations to extrapolate landscape values across New Zealand, it is desirable to combine (spatially join) the two data sets. Because the landscape values collected in the two regions were drawn from different study populations, we first needed to determine the potential effect of combining the spatial data for analysis before proceeding with value extrapolation. It is important that the two data sets are similar in their associations of landscape values with landscape character. If the data sets are not similar, then there would be increased variability resulting from combining the data sets and therefore there would be no advantage in combining the data sets. We checked for similarity by examining *aesthetic* value as a test case to compare the similarity of results between the two regions. Aesthetic value was chosen because it is a common value associated with landscape which was verified by our PPGIS survey results. Using GIS, we generated the percentage of total aesthetic points falling within each category of the six landscape components. We calculated Spearman's rank correlation to compare aesthetic value rankings within each of the six landscape components. Spearman's rank correlation converts the percentages associated with each landscape component category to ranks, then calculates a coefficient (r) that provides a quantitative indicator of the similarity of aesthetic/landscape character relationships (rankings) between the two regions.

Following a conclusion of reasonable concurrence in results, we combined the social landscape value data sets for the two regions. The combined data provides a significantly larger number of observations from which to generate the landscape component indices or weightings. The resulting indices thus reflect a blending of the quantitative relationships across the two regions.

Calculating landscape component indices

As described above, we used two approaches to quantify the relationship between values and landscape components. The first approach measures the frequency count of landscape values that fall within various landscape components regardless of the areal proportions of landscape value components. This count is calculated as a percentage of the total count for a given value that falls within the different landscape component classes. This approach rewards the presence of values and can generate a ranked list of landscape components with the most abundant values.

The second approach accounts for the fact that some landscape component categories (e.g., mountains or grassland) constitute a larger proportion of the study region and therefore have a higher or increased probability of the participant identifying a given value in these components. This approach assumes that participant mapping of values will be influenced by the proportion of area that a particular landscape component occupies. For example, if the "Very High Mountain" landscape component comprised 20 percent of the study area, one would expect this proportion to influence the number of landscape values placed in this component.

Which approach is better? Our preference for purposes of extrapolation is value abundance as measured by the percentage of value points that fall within the different landscape components. We call this the "count percent" method. PPGIS participants have a finite amount of time to spatially locate their landscape values. Participants in the process explicitly choose to map the most important geographic areas representing those values. We don't believe that participants are making explicit cognitive choices to reject the non-mapped areas as lacking a given value. A decision to place a value marker in one location does mean the marker is not placed in another location, but the location decision is an affirmation of the value of the mapped location, not a rejection of all other non-mapped areas as lacking value.

There is some merit in considering the relative proportion of mapped landscapes within a region by landscape component. A ratio of the percent of mapped landscape values to the percent of area covered by a given landscape component indicates whether a given landscape value is (dis)proportional to the area covered by the landscape component. A ratio of 1.0 would indicate proportionately between the value count percentage and the percent of the study area covered by the landscape component. The potential benefit of this proportional ratio is that it will identify and highlight landscape components that comprise a smaller area of the study landscape but which appear significant for a given landscape value. These smaller area landscape components might be overlooked if just the count percent of these points were considered.

Aggregation of component indices to landscape class indices

A landscape class is the combination of landscape components. Therefore to extrapolate the values to landscape classes across all of New Zealand, we generated two aggregate indices based on the additive sum of count percents, and the additive sum of the proportion ratios.

The percent count index was calculated as the additive sum of the percentages associated with each of the six landscape components where each of the six components was given equal weight. For example, if 23 percent of aesthetic values fell in the “tussock” category of *landcover*, 11 percent in the “high mountain” category of *landform*, 54 percent in the “indigenous” category of *dominant landcover*, 82 percent in the “land/no water” category of *water*, 9 percent in the “view of open ocean” of *water view* component, and 85 percent in the “no infrastructure” category of *infrastructure*, the index value for this combination of categories would be $23 + 11 + 54 + 82 + 9 + 85$ or 264. The hypothetical maximum of the index would be 600 if all values fell within a single category within each of the six landscape value components.

The proportional index was calculated as the additive sum of proportion ratios associated with each landscape component category. For example, if 23 percent of aesthetic values fell within the “tussock” category and “tussock” comprised 20 percent of the region, the proportional index would be 23/20 or 1.15 which would indicate slight over-representation of aesthetic values within the tussock category. The proportion ratios for each of the six components were summed to create an aggregate proportion index. If aesthetic value counts were exactly proportional to the area in each of six landscape component categories, the aggregate proportion index would total six. Values above and below six indicate disproportionate representation (higher or lower) based on the area occupied by the combination of landscape component categories within the region.

The landscape component percentages and proportion ratios effectively function as landscape component weightings in the aggregate landscape class indices. These aggregate landscape class indices were then spatially joined to each landscape class polygon in the NZLC database and classified into seven equal quantiles calculated independently for each landscape value and mapped using contrasting colours to show the potentiality of landscape values across New Zealand.

The NZLC also identifies administration regions (Regional Councils) and these were used to calculate summary statistics of the landscape polygons by region. We examined the distribution of aggregate indices by region to ensure that the landscape components found in the Southland and Otago were reasonably distributed across the entire country. Variability bars with one standard deviation around mean indices for the seven landscape values were calculated for each Regional Council.

Results

Participation rate and number of landscape values

A total of 14,370 landscape attributes were identified by 608 PPGIS participants in the Otago and Southland regions. This spatial data was prepared for analysis by eliminating markers placed outside the two study regions and by filtering markers unrelated to the landscape values in study, leaving a total of 8824 landscape value points available for analysis.

Of the 354 participants that responded to socio-demographic questions following the PPGIS mapping activity, 94% were New Zealand residents and 6% were international visitors. The New Zealand participants were 62% male (New Zealand census 49%), had a median age of 48 years (New Zealand census 36 years), with 41% reporting a bachelor’s degree or higher in formal education (New Zealand census 13%) (Statistics New Zealand, 2012). Thus, PPGIS participants were more frequently male, older, and more formally educated than the general New Zealand population. These results are consistent with other internet PPGIS studies reporting higher participation by older males with more formal education (Brown, Montag, & Lyon, 2012; Pocewicz, Nielsen-Pincus, Brown, & Schnitzer, 2012).

PPGIS participants were also disproportionately represented by individuals with a self-reported “good” or “excellent” knowledge of places in the region (68%), compared to “average” (26%) or “below average” knowledge (5%). Thus, PPGIS participants report a relatively high level of familiarity with the regional landscape, a finding consistent with other PPGIS studies (see e.g., Brown, 2005; Brown & Weber, 2012).

The number of observations available and used in the analysis varied by landscape value: aesthetic ($n = 1931$); recreation ($n = 2536$); economic ($n = 204$); ecological ($n = 526$); social ($n = 274$); historical/cultural ($n = 501$); and wilderness ($n = 535$).

Interregional comparison of the distribution of aesthetic value

To examine the potential effect of combining the spatial data for analysis before proceeding with value extrapolation, we examined the distribution of *aesthetic* value between the two regions of Southland and Otago. The percent of aesthetic values falling within each landscape category were tallied and converted to ranks within each landscape component. Spearman’s rank correlation was calculated for each of the six landscape components. The results appear in Tables 2 and 3. As expected, there was some interregional variation in the association of aesthetic values with specific landscape categories. More aesthetic values were associated with the *landcover* categories of tussock, grassland, and indigenous forest, the *landform* categories of high mountains and hills, the *dominant landcover* of indigenous cover, the *water* category of large lakes (excluding land), the *water view* categories of views of open ocean and large lakes, and *infrastructure* categories located within natural areas. The greatest similarity in the location of aesthetic values between regions was found in the *water view* and *dominant landcover* components ($r = 0.95$ and $r = 0.94$ respectively) and the least similarity in the landform component ($r = 0.70$).

Although regional distinctions are lost by combining landscape value observations across the regions, greater inferential power is gained by increasing the number of observations available to generate landscape value indices for the entire country. In our judgement, the rank correlations were sufficiently large to indicate spatial accordance in the location of aesthetic values by landscape component. In other words, the association of landscape values with the different landscape components was generally consistent across the two regions. We therefore combined the two regional data sets to generate the extrapolative indices.

Variability of aggregate indices by regions

Each landscape value is located within a combination of six landscape component categories. The count percent and proportion indices associated with each landscape component category were summed to generate aggregate indices. These aggregate indices were applied across all landscapes in New Zealand. We examined the distribution of aggregate indices for each landscape polygon by region to ensure that the landscape components found in the Southland and Otago were reasonably distributed across the entire country. Variability bars with one standard deviation around mean indices for the seven landscape values appear in Fig. 2.

Fig. 2 shows that the two quantitative indices of landscape values are reasonably distributed across New Zealand, confirming that landscape categories found in the Otago and Southland region are not unique to these regions. An exception includes the somewhat lower count percent indices in the Auckland region compared to other regions, suggesting the presence of less valued landscapes overall. The results also reveal greater wilderness values in the West Coast and Southland regions, which are expected given the mountainous composition of these regional landscapes.

The distribution of proportion indices reveal that the two regions largely associated with urban areas on the North Island (Auckland and Wellington) contain landscapes that are more variable in values, particularly with respect to economic and social values. In general, aesthetic, recreation, ecological, and wilderness values show less variation across the regions while economic, social, and historic values are more variable.

The extrapolated landscape value maps for New Zealand

The extrapolated maps for aesthetic, recreation, and economic values appear in Fig. 3, while the maps for ecological, social, historic/cultural, and wilderness appear in Fig. 4. These maps were generated by applying the percent count and proportion indices to the approximately 430,000 landscape classes across New Zealand. For visual comparison, the index values were divided into seven quantiles. The landscape value maps for *aesthetic*, *recreation*, and *economic* values appear very similar. *Aesthetic* and *recreation* values are spatially associated with high mountains, hills, and plateaus. These same areas also contain significant indigenous landcover. On the map, these values appear in dark colours that cover the western, mountainous spine of the South Island. The maps showing spatial proportion indicate that these values are over-represented in areas with large lakes and urban areas, and under-represented in agricultural areas. In general, water bodies—lakes, rivers, and estuaries—are associated with greater landscape values than would be expected by landscape area.

Ecological and *social* values are geographically distributed and patchy across a variety of New Zealand landscape categories. The *historic* value map appears most different from the other value maps, with *historic* values occupying lower elevation agricultural areas to the exclusion of higher elevation, more mountainous reaches. Of all the values, *wilderness* value map reveals the greatest contrast across New Zealand with this value dominating natural landscapes with low intensity land use, while excluding agricultural and urban areas.

Discussion

Landscape value extrapolation from the Otago and Southland regions to the rest of New Zealand using PPGIS landscape values data produces results that, in general, align with logical expectations. Many of the high value extrapolated areas are protected conservation areas such as national parks, reserves, and recreation parks that are known to have high aesthetic, recreational, ecological, and wilderness values. The PPGIS survey identified the more mountainous landscapes with associated alpine and indigenous landcover to have high landscape values. These results are consistent with previous New Zealand studies on landscape perception that people have a preference for natural landscapes (Swaffield and

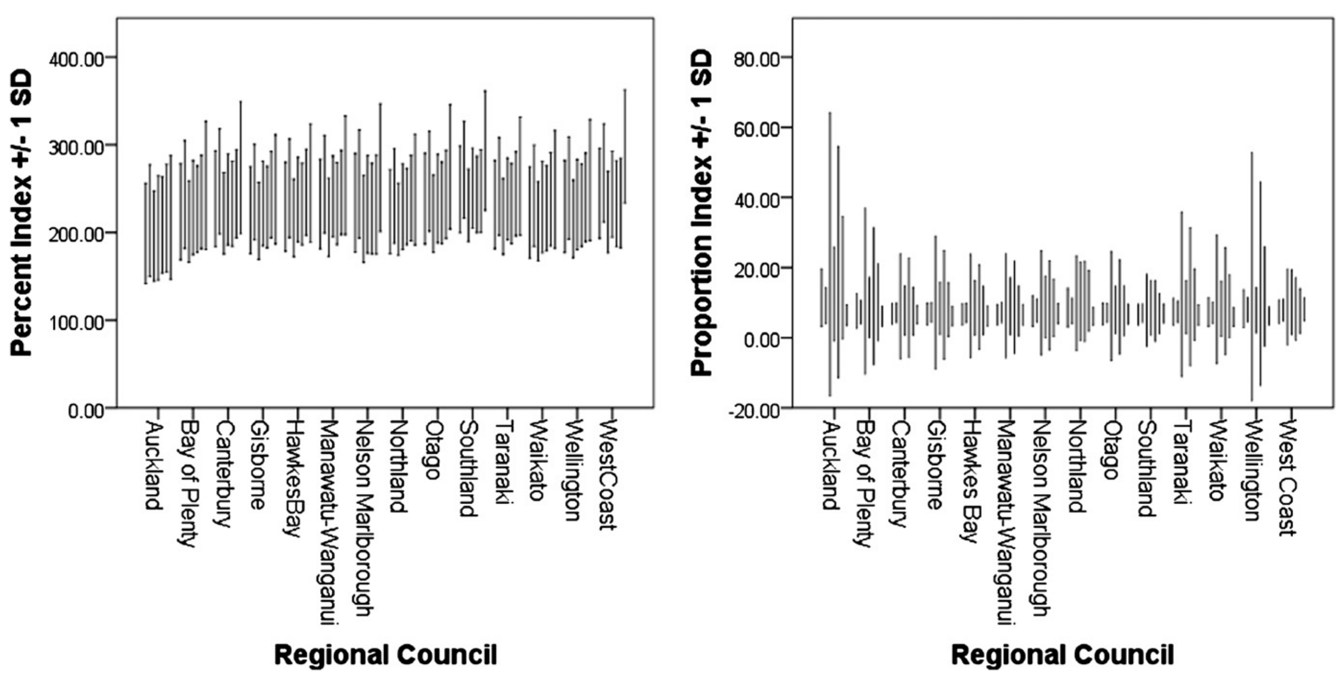

Fig. 2. Landscape value variability bars (±1 standard deviation) for aggregate percent count and spatial proportion indices for seven landscape values. Landscape values, from left to right in each regional cluster, are aesthetic, recreation, economic, ecological, social, historical, and wilderness value.

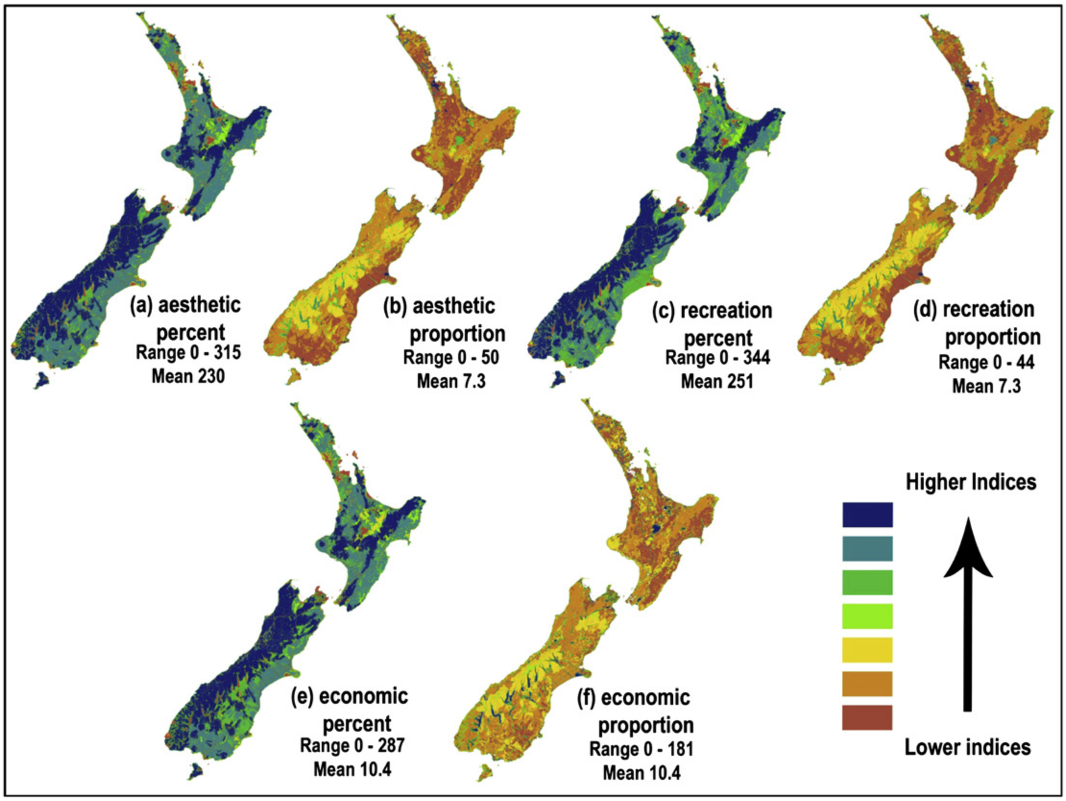

Fig. 3. Extrapolated landscape value maps generated from aggregate indices based on percent of values and proportion of values by area (Colour ramp is based on seven equal quantiles) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

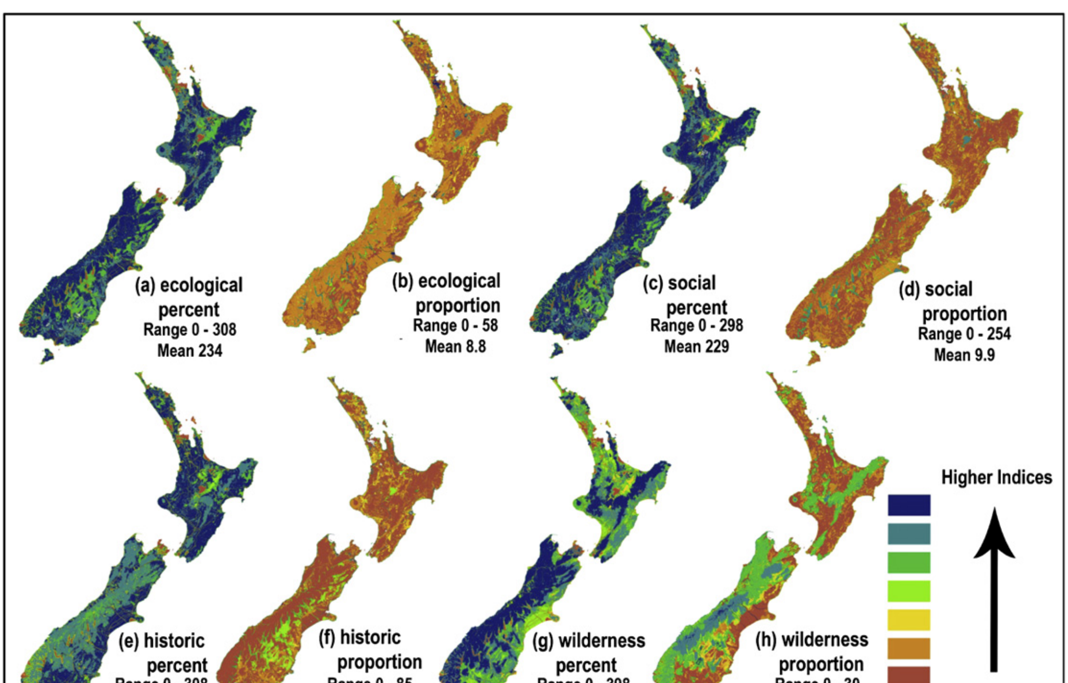

Fig. 4. Extrapolated landscape value maps generated from aggregate indices based on percent of values and proportion of values by area (Colour ramp is based on seven equal quantiles) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

Fairweather, 2003). These landscapes have been mostly protected in New Zealand. The South Island shows more high landscape value areas than the North Island but this is to be expected given the topography and the fact that 10 of the 14 National Parks in New Zealand are located in the South Island.

The extrapolation of economic, ecological, social, and historic values using the percent count index also produced expected outcomes, although these values are complex and there are some anomalies. The ecological value shows a similar distribution to aesthetic and recreation values with high values associated with mountainous areas that have protected indigenous landcover. However, there are many flat areas that also show high ecological value, such as the Canterbury Plains (located near Christchurch) which has very little indigenious landcover. In New Zealand, there is awareness of the ecological importance of wetlands (both freshwater and saltwater). Wetlands by their physical nature tend to be located in low, flat areas, and this explains why lowland areas have ecological value in this survey. Most of the wetlands in Canterbury Plains have been drained for agriculture; therefore the extrapolated results are erroneous in this case.

The distribution of social values is found in both highland and lowland areas, reflecting that a range of landscapes provide relaxation and enjoyment that people like to share with friends. Many of the participants in the landscape values survey were visitors to national parks or conservation areas where the mapped social values likely reflect social interaction with other visitors or tourists rather than socialising within communities as would be more common among New Zealand residents. Thus, social values may appear over-represented in the natural areas.

Tourist destinations with economic value were clearly identified and are located in lowland tourist sites, such as Queenstown, as well as mountainous locations such as ski fields. Historic values are located mostly in lowland, working landscapes. This can be explained by the fact that most historical relics in New Zealand are associated with economic production, such as mining, grazing, farming, and coastal ports.

This research experimented with two methods of extrapolation—percent count and spatial proportion. The spatial proportion index normalised the percent count for the area of the landscape component category. Both indices provide insight into perceived landscape values. One could argue the spatial area of landscape categories influences the distribution of landscape values within landscape categories because all else being equal, larger area landscapes would have a higher probability of attracting landscape value placement in PPGIS. Conversely, smaller area landscape categories would have less probability of landscape value placement. Normalising the percent count for landscape category area reveals where landscape values appear disproportionately over or under represented. The spatial proportion index revealed relatively high landscape values associated with islands, lakes, and urban areas that occupy a relatively small area of New Zealand. The identification of large index values associated with islands and lakes is not surprising given water has long been known to have high landscape value in New Zealand (Swaffield and Fairweather, 2003) and other countries such as Norway (Dramstad, Tveit, Fjellstada, & Fry, 2006; Kaltenborn and Bjerke, 2002).

The identification of urban areas as having high landscape values may appear surprising given that many people demonstrate preferences for natural landscapes. One would logically expect greater representation of social, economic, and historical/cultural values proximate to urban areas but the over-representation of other values, such as aesthetic and ecological value, merit further discussion.

Located within the survey region are several world-renowned tourist towns—Queenstown and Wanaka—that have outstanding scenery. These towns received a large number of landscape values. The results also show that areas proximate to the cities of Dunedin and Invercargill had large landscape value indices. These cities do have distinctive historical character but the disproportionate representation of the other landscape values in these urban-proximate landscapes can be explained by the theory of spatial or place-based discounting (Norton & Hannon, 1997; Perrings & Hannon, 2001). This theory posits that people prefer landscapes with positive attributes that are closer in distance than landscapes further away. Place value and attachment develop through proximity and familiarity. Because many survey participants were from more populated cities, one would expect to see significant numbers of landscape values associated with these urban and semi-urban landscapes. An additional complexity associated with urban landscapes is that they tend to be located near the coast, lakes and rivers, all of which attract significant numbers of landscape values in their own right. We think that spatial discounting is likely to occur throughout New Zealand, as has been evidenced in more natural landscapes such as Alaska (Brown et al., 2002). Therefore, extrapolated results that might appear anomalous such as high value landscapes in and around the larger urban areas of Auckland and Wellington on the North Island, may be consistent with putative results if landscape values were actually collected for these areas.

Application and limitations

An important question for landscape change, anthropogenic or otherwise in origin, is what values are going to be affected by the change? The extrapolation of social landscape values from participatory GIS to wider areas provides the potential for social and environmental impact assessment for landscapes that lack direct value measurement. The extrapolated maps provide benchmarks for identifying values at risk due to climate change, human development, or other large-scale land use changes. Furthermore, with a sufficiently large PPGIS sample, different landscapes can be extrapolated for subpopulations of interest such as visitors and residents, urban and rural dwellers, and even individuals that express different land use preferences. Because landscape values appear to be relatively stable over time (Brown & Weber, 2012), landscape value assessment can be completed at periodic intervals such as every five to 10 years, similar to population census efforts.

The social landscape value maps described herein are particularly relevant to New Zealand where the Resource Management Act (1991) explicitly requires the “protection of outstanding natural features and landscapes from inappropriate subdivision, use, and development” (s6(b)). Further, this Act requires regional councils to establish, implement and review objectives and policies to achieve the integrated management of natural and physical resources in their regions that include landscape and amenity values (s30(1)(a)). To achieve this outcome, regional councils need to assess the relative values of landscapes within their region including identifying any landscapes or natural features considered to be outstanding. The extrapolated maps provide the location of particular landscapes with outstanding values.

But we urge caution in the reliance on extrapolated models of landscape values for important land use decisions. The associations between particular landscape values and particular landscape characteristics may not hold true for all regions. As an example, in the Otago and Southland regions there appears to be a strong association between lowland areas and ecological values. This is because wetland areas are often found in the lowlands in these regions. The extrapolation of ecological values based on this association does not hold true for the whole of New Zealand.

The variability of relationships within specific landscape components can mask important conclusions about the effects of landscape changes on values in specific locations. In other words, scale matters. Significant changes to landscapes from anthropogenic activities such as expanded urbanization warrant place-specific, empirical measurement of landscape values. Perhaps most important, the validity of extrapolated results is bounded by the quality of the empirical PPGIS results that are used to generate the indices.

This leads to the question of what is the appropriate sample size for PPGIS data collection? Clearly, population sampling must be broad and representative. Our research has shown two separate landscape value surveys for neighbouring areas that have a mix of similar landscapes. A comparison of results in Tables 2 and 3 shows that similar landscapes were valued. The Spearman rank correlations were large—six landscape components were 0.7 or above, four were above 0.8, and two were above 0.9. The sample sizes for the two PPGIS surveys were adequate, although it is unclear what the minimum sample size needs to be.

Future research

The extrapolated maps presented herein were based on aggregate indices where the six landscape components were weighted equally. Alternative weighting systems would produce different indices and maps. Future research could identify the sensitivity of extrapolated landscapes to changes in the landscape component weightings using simulation techniques. With sufficient data, regression analysis could also be used to identify extrapolation model coefficients. However, we urge restraint in the development of more complex, extrapolated models as is the natural tendency of academics. An important limiting factor in the acceptance of models for social and political decision making is the transparency and comprehensibility of model parameters and assumptions. There is considerable social scepticism to black-box approaches where the model parameters drive the results, but cannot be easily explained. Our choice to use indices based on simple landscape value counts was intentional to keep the map extrapolation process accessible to broader audiences. The cliché about the need to walk before running appears apt here. Landscape values collected through participatory GIS must first be accepted as legitimate and useful measures for examining land use tradeoffs. Overly complex models will undermine this necessary and important first step.

The classification of landscapes necessarily involves generalisation and it is difficult to know *a priori* what level of generalisation is best. The NZLC is hierarchical so analysts can experiment with the level of generalisation. Our research analysed the most detailed level of landscape classes. From the results, it appears that some classes could be combined (e.g., high hills and low hills, low producing grassland and high producing grassland). One avenue for future research would be to explore how the level of landscape class generalisation affects the results. Generalisation could also be applied to the set of landscape values. For example, there is spatial association between recreation, wilderness, and aesthetic values. Could some landscape values be combined in the PPGIS survey to simplify the process for participants? Research that investigates the appropriate number and type of landscape values for efficient data collection would be beneficial.

This research shows the benefits of using PPGIS surveys of landscape values combined with the NZLC system. Application of these research methods to other regions in New Zealand would be highly beneficial. For example, a PPGIS survey on the North Island of New Zealand, which contains a higher density of population and less natural landscapes compared to the South Island, would provide a strategic test of the validity of the landscape value extrapolation methodology. Additional PPGIS landscape value surveys would provide a more complete and robust assessment of landscape values to inform future social and environmental impact assessments.

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