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Assessing spatial associations between perceptions of landscape value and climate change risk for use in climate change planning

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Abstract This study examines spatially referenced perceived landscape values and climate change risks collected through public participation geographic information systems for potential use in climate change planning. Using survey data from the Southern Fleurieu Peninsula, South Australia, we present a method for identifying perceived landscape values and climate change risks to describe and quantify their spatial associations. Two spatial data models—vector and raster—and two analytical methods—Jaccard coefficients and spatial cross-correlations were used to describe the spatial associations. Results indicate that perceptions of climate change risk are driven, in part, by the values people assign or hold for places on the landscape. Biodiversity and intrinsic landscape values have strong spatial association with biodiversity loss risk while recreation values have strong spatial association with riparian flooding, sea-level rise and wave action risks. Other landscape values show weak to no spatial association with perceived climate change risks. The methodology described in this research provides a mechanism for government agencies to develop place-based adaptation strategies based on these associations.

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1 Introduction

The impacts of climate change on human well-being and ecosystem condition is of increasing concern to scientists, policy-makers and the general public. Significant research attention has been paid to the technical assessment of risk related to natural hazards and climate change in such areas as risk severity and adaptation (Kelly and Adger 2000; Parry et al. 2007), recovery after natural disasters (see Norris et al. 2002 for a detailed review) and equity and justice (e.g., Bowen 2002; Satterfield et al. 2004; Thomas and Twyman 2005). While the science community has an important role in identifying climate change risks, current scientific knowledge of adaptation is insufficient for rigorous evaluation of planned adaptation options (Smit et al. 2001; Yohe et al. 2007). Public perception of climate change and ecosystem risks can play an important role in assisting local communities' responses to climate change risks and in shaping environmental policy and programs in the light of this scientific uncertainty.

The risk perception literature focuses on the affective, cognitive and socioeconomic characteristics of risk perception using a psychometric paradigm (e.g., Slovic et al. 1982; McDaniels et al. 1995; Dietz 2001; Slovic 2001; Stedman 2004; Leiserowitz 2006; Slimak and Dietz 2006). Recent studies have found significant relationships between personal values and people's assessment of environmental risks (Bord et al. 1998; O'Connor et al. 2002; Stedman 2004; Leiserowitz 2006; Slimak and Dietz 2006; Etkin and Ho 2007). Those respondents with value orientations aligned with protecting the natural environment are generally more supportive of risk reduction efforts related to greenhouse gas emissions (O'Connor et al. 2002) and policies that address climate change (Bord et al. 1998). This biospheric value orientation is also a strong predictor of global risks such as global warming, ozone depletion, acid rain and human population growth (Slimak and Dietz 2006).

The interactions between personal values and risk perception have important implications for climate change adaptation planning. Adger et al. (2009) contend that risk perception interacts with underlying values to create subjective barriers to adaptation to climate change. What an individual may perceive as a desirable adaptation strategy to a climate change impact may be different from the values held by other members of the public or government agencies responsible for managing resources for collective benefit. Value conflicts may hamper efforts to implement suitable adaptation responses. Adger, among others, are now calling for a wider understanding of value and risk perception which embraces the dynamic interaction between the physical properties of the hazard as well as the social and spatial context in which the hazard occurs (Cutter et al. 2000; Davidson et al. 2003; Stedman 2004; Adger et al. 2009).

It is possible that ascription of climate change risks is influenced by additional dimensions of place, such as the values which individuals assign to them. The theory of social amplification of risk (Kasperson et al. 1988; Renn et al. 1992; Burns et al. 1993; Kasperson and Kasperson 1996) supports this view by positing that public responses to a risk may be amplified by psychological, social, institutional and cultural processes. Amplification occurs in the transfer of information about the risk and in human response to that risk. Because individuals cannot deal with the full complexity of risk and the multiple types of risks in their everyday life, individual and group values will determine the importance and severity of different risks and the actions which should be taken to reduce the risks (Kasperson et al. 1988).

An examination of the social and cultural basis of value may therefore be important to better understand the severity of risks and appropriate adaptation responses. The 'sense of place' literature provides spatial tools for measuring the distribution and intensity of perceived landscape values assigned by local residents and visitors to a region (e.g., Kliskey 1994; Brown and Reed 2000; Black and Liljeblad 2006; Tyrväinnen et al. 2007; McIntyre et al. 2008). Unlike the personal values measured using a psychometric paradigm, these values are embedded within a specific geographical context and are assigned to things such as goods, activities, and services. Such values may be symbolic/indirect that reflect ideas (e.g., intrinsic, future values) or instrumental in that they are linked to a direct use of the landscape (e.g., economic or recreation values).

The landscape values methodology (LVM) is one approach for measuring the spatial distribution and intensity of perceived landscape values (Brown 2005). Results from eight North American natural resource management (NRM) applications (see Brown 2005; Beverly et al. 2008; Brown and Reed 2009) and four Australian applications (Brown 2006; Raymond and Brown 2006; Pfueller et al. 2008; Raymond 2008) indicate that perceived landscape values are distributed heterogeneously across the landscape and tend to cluster around significant biophysical and social features within place. The spatial method is based on the transactional concept of human–landscape relationships (Zube 1987). Zube discusses three concepts of human–landscape relationships: "the human as an agent of biological and physical impacts on the landscape; the human as a static receiver and processor of information from the landscape; and the human as an active participant in the landscape—thinking, feeling and acting" (p. 37). Landscape perceptions are tied to patterns of land use activities and are mediated by needs and desires, social and cultural contexts. It is possible to distinguish between respondent's level of engagement in the landscape based upon the distribution, intensity and types of values assigned to place. For example, previous studies indicate that those respondents who have good or excellent knowledge of the study area assign more value locations to the map than those with fair or poor knowledge of the study area (Brown 2005; Brown and Reed 2009). The method is also a type of public participation geographic information system (PPGIS) because it engages broader public audiences with geographic information systems technology for land use planning (see Sieber 2006 for a review of PPGIS methods).

Whilst significant attention has been paid to the spatial distribution of perceived landscape values, no studies to date have directly assessed the spatial relationships between landscape values and spatial measures of risk perception to inform climate change adaptation planning. Such analysis could illuminate new insights into how perceived values influence risk perception, and could assist in the targeting of climate change adaptation responses to areas of local concern.

In this study, we present a spatial method, referred to as the landscape values methodology (LVM), for identifying and measuring public perceived landscape values and climate change risks. We include spatial measures of perceived climate change risk for places that may be subject to: (1) biodiversity loss; (2) land erosion; (3) bushfire; (4) sea-level rise; (5) riparian flooding; and (6) storm surges as a result of projected climate change by 2030. We use the LVM to examine the spatial associations between public perceptions of landscape value and climate change risk. After a preliminary investigation of the distribution and intensity of values and risks across the Southern Fleurieu Peninsula, South Australia (Southern Fleurieu), we use Jaccard and spatial cross-correlation analyses to determine the extent of spatial overlap between landscape values and climate change risks on the landscape. From our findings, we suggest the potential for integrating spatial measures of landscape value and climate change risk for climate change adaptation planning in the Southern Fleurieu and elsewhere.

1.1 Values, socio-cultural variables and risk perception

Many views exist on the definition and philosophical basis of values towards the environment (Rokeach 1973; Brown 1984; Kellert 1996; Lockwood 1999; McIntyre et al. 2008; Fisher et al. 2009). Brown (1984) classified the realm of values into three categories: held values, relationship values, and assigned values with preference relationships providing a linkage between held and assigned values. Assigned values incorporate a person's perception of the thing under valuation, their associated preferences, and the context of the valuation (Brown 1984). In the operationalisation of landscape values in PPGIS, individuals express preference relationships that link their held values with values assigned to the study landscape; there is no attempt to parse the relative influence of held values (based on life experiences) from assigned values (based on object attributes) as the process of mapping landscape values is best viewed as holistic (Brown and Reed 2009).

Conversely, values within the risk perception literature have been largely based upon individual held values and measured using a psychometric paradigm. Held values are modes of conduct, end-states or desirable qualities which affect choices and action (Brown 1984). Social psychologists have used Schwartz's (1992, 1994) value scale to measure 10 distinct value types organised along two dimensions: self-transcendence/self-enhancement and openness to change/conservation. Self-transcendence/self-enhancement reflects a conflict between concern for the welfare of others and pursuit of personal success. Several researchers have argued that the self-transcendent value dimension includes both *altruistic* and *biospheric* value orientations and the self enhancement dimension includes *egoistic* value orientations (Stern et al. 1993; Stern 2000). Altruistic value orientations represent a set of values for the welfare of others, biospheric value orientations represent a set of values for the environment and the biosphere, and egoist value orientations are values associated with maximising personal benefit.

Researchers have also examined the relationships between personal values, sociodemographic variables and specific beliefs about climate change risks. Analyses found that altruistic value orientations were consistently stronger predictors of risk perception than sociodemographic variables (Leiserowitz 2006), and that world views and personal values are greater predictors of perceived climate change risk than specific beliefs about climate change impacts (Stedman 2004). However, there is some disagreement on the contribution of values to risk perception. Studies have revealed that socio-cultural variables, such as familiarity with biodiversity issues, may amplify the relationships between values and risk perception (McFarlane 2005) and thus alternative paths of influence need to be considered.

Socio-demographic correlates of risk perception are one such path. One of the consistent findings is that older individuals and people with higher levels of education and income tend to be less concerned about environmental risks (Savage 1993; Kraus et al. 2000; Slovic 2000). In relation to gender differences, women are more aware of environmental risks and show greater support for environmental and climate change initiatives (Barkan 2004; Zelezny et al. 2000; Dietz et al. 1998).

1.2 Place, landscape values, and risk perception

Relatively little research has examined the role of physical and social characteristics of place on risk perception. Brody et al. (2008) tested the degree to which a person's level of physical vulnerability to climate change influences his or her perception of risk. The physical vulnerability variables only explained 4% of the variance in risk perception. Survey respondents who lived in areas most vulnerable to sea-level rise (low-lying areas close to the coast) or within the 100-year floodplain had significantly higher risk perceptions than those who lived in other areas, but six other physical vulnerability variables did not significantly predict risk perception. The authors attribute the low explanatory power of the risk perception model to the way in which the general public calculates risk. They suggest risk calculation is based on a limited understanding of the impacts of climate change and that education programs may increase public awareness about a broader range of physical vulnerability characteristics.

While Brody's work examined the relationships between physical place variables and risk perception, we examine the extent to which the social construction of place influences risk perception. Landscape values are a component of the "sense of place" construct (Brown 2005). Sense of place reflects an entire suite of thoughts (cognitions) and emotional (affective) sentiments held regarding a particular geographic locale (Altman and Low 1992; Jorgensen and Stedman 2001) and the meanings one attributes to such areas (Relph 1976; Fishwick and Vining 1992; Kaltenborn 1998; Stedman 2003a, b). A large body of work has shown that people who are strongly attached to place are more likely to show high levels of environmental concern (e.g., Vorkinn and Riese 2001; Kyle et al. 2004); however, few studies have examined the relationships between environmental risks and sense of place and none to our knowledge have attempted to spatially quantify these associations. To fill this knowledge gap, this study explores the spatial relationships between eight perceived landscape values and areas perceived to be at risk from the following natural hazards as a result of climate change by 2030: (1) biodiversity loss; (2) land erosion; (3) bushfire; (4) sea-level rise; (5) riparian flooding; (6) storm surges. An integrated assessment of climate change impacts in the Adelaide and Mount Lofty Ranges (AMLR) region (Bardsley 2006) was the starting point for the selection of these natural hazards.

Brown (2005) and colleagues developed the concept of landscape values as an operational bridge between the geography of place and sense of place. The starting point for the selection of landscape values was work by Rolston and Coufal (1991) who identified 10 basic landscape values: life support, economic, scientific, recreation, aesthetic, wildlife, biotic diversity, natural history, spiritual and intrinsic.

The typology was modified to include subsistence, cultural and therapeutic values (Brown and Reed 2000). In this study, a subset of the landscape value typology was used and included the following landscape value measures: (1) aesthetic; (2) recreation; (3) biological diversity; (4) learning; (5) heritage; (6) intrinsic; and (7) future values.

1.3 The spatial measure of perceived climate change risk

The United Nations Department for Humanitarian Affairs (UNDHA 1992) defines risk as the product of hazard and vulnerability while Crichton (1999) defines risk as the probability of a loss which depends on the type of hazard and vulnerability. A hazard is the probability of occurrence of a potentially damaging phenomenon within a given time period and area (Downing et al. 2001). Vulnerability refers to a system's exposure, sensitivity and capacity to adapt to the adverse climate change impacts, including climate variability and extremes (based on IPCC 2001). The determinants of vulnerability and risk are essentially the same—both are ultimately interested in the outcomes of physical hazards that threaten human systems (Brooks 2003). In this study, survey participants were asked to identify places in the Southern Fleurieu region that are perceived to be vulnerable to climate change by 2030, i.e., where the potential natural hazards of biodiversity loss, land erosion, bushfire, riparian flooding and sea level rise appear inevitable. Thus, the spatial measure of perceived climate change risk is a combination of the specific hazard and the subjective respondent characterization of vulnerability.

1.4 Research hypotheses—comparing perceived landscape values and climate change risks

We first test the hypothesis that there are significant spatial associations between perceived landscape values and climate change risks. With rejection of the null hypothesis for some value/risk pairings, we determine the strength of the association using two different methods of spatial analysis—Jaccard coefficients for determining the degree of spatial overlap between landscape value and climate change risk polygons (vector approach), and spatial cross-correlation analysis for determining the spatial relationships between landscape value and climate change risk grid cells (raster approach). We then examine whether the method of analysis (i.e., vector vs. raster) affects the degree of spatial overlap of landscape values and climate change risks. Finally, we generate a map to illustrate the associations between places of low, medium and high landscape value and climate change risks and show how the results may be used to prioritise climate change adaptation responses.

2 Methods

2.1 Study location—Southern Fleurieu Peninsula, South Australia

The Southern Fleurieu Peninsula region, as defined in this study, is a plateau bordered by the townships of Mount Compass, Cape Jervis and Goolwa (Fig. 1). While the Goolwa, Hindmarsh Island and Coorong sub-regions are not formally

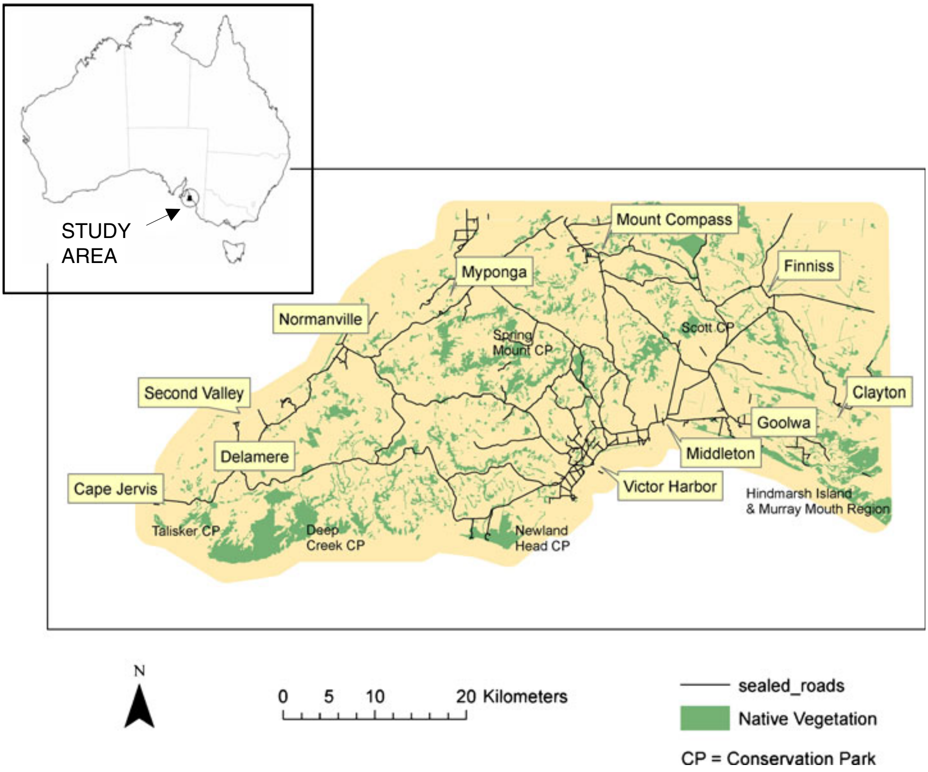


Fig. 1 The Southern Fleurieu Peninsula Region (Southern Fleurieu) as defined in this study

part of the Southern Fleurieu, they were included considering the important NRM and climate change issues being experienced in these places. The region contains 10.3% of its pre-European (pre-1788) vegetation cover, and 85.0% of the remaining vegetation is fragmented into patches of less than 1,000 ha (National Land and Water Resources Audit 2001). The Fleurieu Peninsula swamps are rated as a nationally threatened plant community under the Environment Protection and Biodiversity Conservation Act (EPBC) Act 1999 and are home to populations of the nationally endangered Mount Lofty Ranges Southern Emu-wren (Hill and Duffield 2002).

The region has a mosaic of land uses. Farming activities comprise approximately 73% of the total land use, followed by conservation (21%) and residential living (6%; DWLBC 2006). Residential development is undergoing major growth along the coastal fringe. The regional hub of Victor Harbor, for example, is amongst the fastest growing communities in the State, with an average growth in excess of 3% per annum for the past 10 years and a population of 30,000 at peak tourist season from December to February (City of Victor Harbor 2007). A total of 13 individual conservation and recreation parks and reserves are encompassed by the study boundary. The most popular park in the region is Deep Creek Conservation Park with approximately 32,104 visitors in 2003 (Urban and Regional Planning Solutions 2007).

2.2 Sampling

Two sampling techniques were used in this study—a snowball sampling technique to identify workshop participants and a systematic random sampling technique to identify postal survey participants. In the snowball sampling technique, a list of key NRM organisations was obtained from the AMLR NRM Board. Organisations were grouped and then selected by interest (i.e., coastal development, education, conservation, primary production). Each organisation was invited to participate in the study through the chair or secretary. Additionally, the chair or secretary was asked to suggest names and contact details of other individuals and groups who may have been interested in participating in the study. Victor Harbor, Goolwa, Mount Compass and Yankalilla secondary school students were invited to participate in the study through the school principal. Only Years 10–12 Geography and Society and Environment Studies were asked to complete the surveys because the LVM assumes basic skills in map reading and the climate change concept requires some understanding of world climate systems. The snowball sample is not assumed to be representative of the Southern Fleurieu resident population; however, it does represent the major NRM interest groups in the region, all of whom are critical to engage in climate change issues and adaptation responses, and the ongoing management of natural resources, especially biodiversity.

A random sample of Southern Fleurieu property owners was collected by examining the 2007 cadastral file (DEH 2007) cropped using GIS to the exact dimension of the study area. Property owners were selected from 14 Southern Fleurieu communities at an interval of 120 from a random starting point. A census of property owners in Delamere and Clayton communities was attempted because a proportional sample of each community would have not yielded enough observations for subsample statistical analysis. All selections with company or trust names were removed from the database because the postal survey was tailored to individuals and their families. The sampling frame was representative of most residents over the age of 18; but it under-represented residential and commercial lessees whose details were omitted from the cadastral file.

2.3 Survey instruments

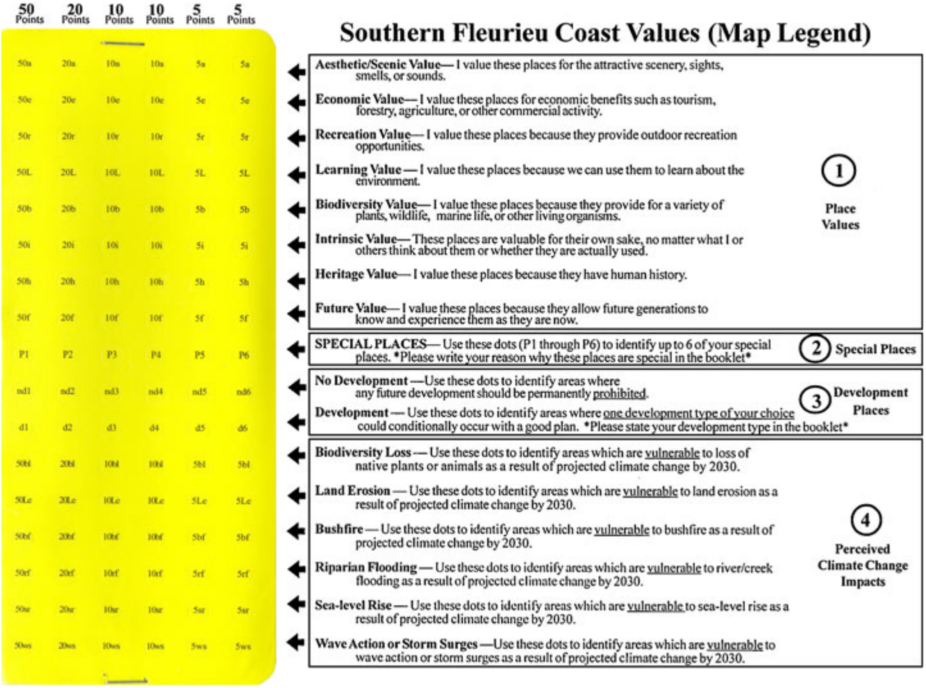
Workshop and postal surveys were administered during this study to encourage response from a broad cross-section of the Southern Fleurieu community.

2.3.1 Workshop survey

Between March and May 2007, 15 workshops were conducted with school students and adults residing in the Southern Fleurieu region. Workshops occurred in all major townships across the region, including Goolwa, Victor Harbor, Mount Compass, Normanville, Yankalilla and Second Valley. We conducted two workshops in each township, except for Victor Harbor (four workshops). The number of participants involved in each workshop ranged from 5 to 30, with a median attendance of 17 people. A total of 16 workshop surveys were completed with an equal spread of responses across each major township except Victor Harbor considering its high population.

The workshop survey contained questions in five sections: (1) familiarity with the Southern Fleurieu and perceived threats to quality of life; (2) climate change knowledge and level of concern; (3) preferred climate change adaptation responses; (4) respondent characteristics (e.g., interest group, age, gender, level of formal education, employment category); and (5) identification of landscape values and climate change risks. To encourage attendance, workshop participants were provided a 20 min presentation on recent climate change trends. International climate change trends were distilled from the 2007 IPCC report (IPCC 2007), and the national and state trends from two CSIRO reports (McInnes et al. 2003; Suppiah et al. 2006). The potential regional and local climate change risks and associated adaptation options were not discussed during the workshop to minimise response bias.

Most relevant to this study was participant identification of perceived landscape values and climate change risks. During the workshop, participants were provided a map legend and 1:125,000 greyscale map of the Southern Fleurieu region. The map legend included 17 rows of sticker dots for use in identifying the location of landscape values, development preferences and perceived climate change risks (Fig. 2). An operational definition for each value and risk appeared adjacent to the respective row of sticker dots. Each value and risk was assigned six sticker dots weighted from 50 to 5, with the larger numbers reflecting subjectively more of the landscape attribute, e.g., more scenic, more recreation value, higher biodiversity loss or higher bushfire risk. Participants were requested to place their sticker dots on the map locations that



50 Points	20 Points	10 Points	10 Points	5 Points	5 Points
50a	20a	10a	10a	5a	5a
50e	20e	10e	10e	5e	5e
50r	20r	10r	10r	5r	5r
50L	20L	10L	10L	5L	5L
50b	20b	10b	10b	5b	5b
50i	20i	10i	10i	5i	5i
50h	20h	10h	10h	5h	5h
50f	20f	10f	10f	5f	5f
P1	P2	P3	P4	P5	P6
nd1	nd2	nd3	nd4	nd5	nd6
d1	d2	d3	d4	d5	d6
50bl	20bl	10bl	10bl	5bl	5bl
50Le	20Le	10Le	10Le	5Le	5Le
50bf	20bf	10bf	10bf	5bf	5bf
50rf	20rf	10rf	10rf	5rf	5rf
50sr	20sr	10sr	10sr	5sr	5sr
50ws	20ws	10ws	10ws	5ws	5ws

Southern Fleurieu Coast Values (Map Legend)

① Place Values

Aesthetic/Scenic Value—I value these places for the attractive scenery, sights, smells, or sounds.

Economic Value—I value these places for economic benefits such as tourism, forestry, agriculture, or other commercial activity.

Recreation Value—I value these places because they provide outdoor recreation opportunities.

Learning Value—I value these places because we can use them to learn about the environment.

Biodiversity Value—I value these places because they provide for a variety of plants, wildlife, marine life, or other living organisms.

Intrinsic Value—These places are valuable for their own sake, no matter what I or others think about them or whether they are actually used.

Heritage Value—I value these places because they have human history.

Future Value—I value these places because they allow future generations to know and experience them as they are now.

② Special Places

SPECIAL PLACES—Use these dots (P1 through P6) to identify up to 6 of your special places. *Please write your reason why these places are special in the booklet*

③ Development Places

No Development—Use these dots to identify areas where any future development should be permanently prohibited.

Development—Use these dots to identify areas where one development type of your choice could conditionally occur with a good plan. *Please state your development type in the booklet*

④ Perceived Climate Change Impacts

Biodiversity Loss—Use these dots to identify areas which are vulnerable to loss of native plants or animals as a result of projected climate change by 2030.

Land Erosion—Use these dots to identify areas which are vulnerable to land erosion as a result of projected climate change by 2030.

Bushfire—Use these dots to identify areas which are vulnerable to bushfire as a result of projected climate change by 2030.

Riparian Flooding—Use these dots to identify areas which are vulnerable to river/creek flooding as a result of projected climate change by 2030.

Sea-level Rise—Use these dots to identify areas which are vulnerable to sea-level rise as a result of projected climate change by 2030.

Wave Action or Storm Surges—Use these dots to identify areas which are vulnerable to wave action or storm surges as a result of projected climate change by 2030.

Fig. 2 The map legend containing eight landscape values and six perceived climate change risks held the landscape values or climate change risks. They could place as many or as few dots on the map as they liked.

We recognise that the landscape area associated with a given respondent value or risk is indeterminate. Each dot is assumed to represent a polygon area, but the size and shape is not known. One respondent could be referencing wave action to a particular dune in a township, while another may be referencing an entire shoreline. To address this problem, the method relies on the spatial aggregation of multiple points to delineate areas of value or risk concentration. Polygonal areas are inductively generated from point distributions. Nonetheless, the analyst must still subjectively determine a density threshold to determine a polygon boundary. To reduce some subjectivity, we generated 95% and 75% probability polygons for each of the value and risk layers using the kernel home range function available within Hawth's Tools (Worton 1987). The kernel home range mathematically converts the points into areas with varying probabilities of occurrence and presents these graphically.

In part 5, participants were asked to identify places on the map which may be vulnerable to the natural hazards of biodiversity loss, land erosion, bushfire, riparian flooding, sea level rise, wave action and storm surges as a result of climate change by 2030. Thus, the mapping process measures perceived climate change risk as the combination of specific climate change hazards and a subjective assessment of place vulnerability. Respondents were encouraged to interpret vulnerability in terms of places on the landscape that are susceptible to or unable to cope with the aforementioned climate change hazards. The 2030 climate change scenario was based upon a moderate annual warming of 0.3°C–1.2°C and a decrease in rainfall of 35–105 mm by 2030 (McInnes et al. 2003). Participants were instructed to place as many dots or as few dots on the map of the Southern Fleurieu region as they liked, taking into account the above definitions. They were also asked to place the highest weighted dots on the places most vulnerable to climate change and were allowed to place multiple climate change hazard dots of the same type in the one place to indicate the degree of vulnerability. The relative degree of vulnerability was then calculated by measuring the density of hazard dots within a 500 × 500 m grid cell and 3 km search radius. The risk scores could range from 0.001 (low risk) to 1 (very high risk). The density of dots assigned by all participants to a 500 × 500 m grid cell and 3 km search radius was used as the measure of vulnerability during the analysis. To provide a baseline, part 3 of the survey asked participants to rate the extent to which the aforementioned natural hazards were a threat to their quality of life currently and the extent to which these hazards will affect their quality of life by 2030.

2.3.2 Postal survey

In May 2005, a postal survey of Southern Fleurieu property owners was conducted using a modified total design method (Dillman 1978). Survey administration involved four mailings: (1) introductory letter informing of the purpose of the research; (2) complete survey packet; (3) handwritten reminder postcard; and (4) second complete survey packet to non-respondents from the first round.

The postal survey contained the same questions as the workshop survey, with the exception being the length of residence, interest group affiliation and community of residence questions. The postal survey participants were not provided a presentation on climate change and its risks.

2.4 Analysis techniques

When the maps and questionnaires were returned, we entered the data into SPSS® Version 16 and digitised the landscape value and climate change risk points into ESRI ArcMap® software. We then joined the spatial data to the table data using a unique identifier, enabling descriptive and inferential statistics to be performed on both data sets.

2.4.1 Landscape values, climate change risks and respondent variables

After comparing respondent characteristics from the survey sample to 2006 Australian Bureau of Statistics regional census data (ABS 2006), we used a combination of *t*-tests and ANOVA in SPSS® to examine differences in the mean number of landscape values and climate change risk points (0–6) mapped by survey participants across age and knowledge sub-groupings. We divided participants into school student and adult groupings. School students were under the age of 18 and were enrolled in Geography or Environmental Studies courses. Additionally, we asked all participants to rate their knowledge of places of the Southern Fleurieu on an "excellent," "good," and "fair" scale and to identify their level of attention paid to climate change issues facing South Australia on a "no attention," "little attention," "moderate attention" and "close and constant attention" scale.

2.4.2 General distribution of landscape values and climate change risks

We examined hypotheses about the general distribution of landscape value and climate change risk points using nearest neighbour analysis. Specifically, hypotheses were tested whether specific sets of point locations were completely spatially random (CSR) on the landscape. The nearest-neighbour statistic (R) is a simple measure of the spatial distribution of points. It is calculated by dividing the average Euclidean distance of all points within a specified polygon by the expected distance of points under an assumption of random distribution. The more clustered the points, the closer to 0 the value of R will be. The more randomly distributed the points are, the closer the R value is to 1.

After identification of significant spatial clusters, we sought to compare and contrast the values and risks assigned to general land use classifications: residential areas, conservation reserves, plantation areas and irrigated pastures. We intersected the landscape values and climate change risk layer to the land-use layers for cross-tabulation analyses. The actual numbers of landscape value and climate change risk points falling within each of the identified land-uses were compared to an expected distribution.

2.4.3 Spatial and non-spatial associations between landscape values and climate change risks

Because participants were instructed to map as few (i.e., 0) or as many values and risk locations (i.e., up to 6 points per value or risk), participants had choice in the mapping activity. One empirical question is whether there exists a latent, non-spatial association between an individual's choice of landscape values and climate change risks to be mapped. We examined this potential non-spatial relationship between landscape values and climate change risks using multiple regression analyses. In the regression model, the landscape value counts (0–6) for all respondents were treated as independent, predictor variables and the climate change risk counts (0–6) for all respondents were treated as the dependent variables. We used the *enter* method to force all landscape value counts into the regression model.

We used vector and raster analyses to determine the spatial overlap of each landscape value and perceived climate change risk. In the vector approach, we used the Jaccard coefficient (van Jaarsveld et al. 1998; Leroux et al. 2007) where:

$$J = \text{area of intersection between value and risk polygons} \Big/ \\ \left(\left(\text{area of value polygon} + \text{area of risk polygon}\right) - \text{area of intersection}\right).$$

Calculation of the J coefficient required some preliminary spatial analysis. Because the J coefficient is sensitive to scale effects, we generated 95% and 75% probability polygons for each of the value and risk layers using the kernel home range function available within Hawth's Tools (Worton 1987). The kernel home range mathematically converts the points into areas with varying probabilities of use and presents these graphically. In this study, it represents the minimum area in which 95% and 75% of the value or risk points are likely to be located. We then calculated the areas of each value and risk polygon at 95% and 75% intervals. To determine the area of intersection, we intersected each value and risk polygon and appended the area of intersected polygons to the table.

In the raster approach, we examined the spatial relationships between landscape value and climate change risk densities using spatial cross-correlation analysis. Cross-correlation analysis calculates the Pearson's product-moment correlation between the density of two raster coverages at randomly selected points, in this case 1,000 points. Calculation of the r values also required some preliminary data analysis. We used Hawth's tools in ArcMap® to generate a kernel density for each value and risk coverage using a 500 m grid cell size with no search radius. We then extracted and associated the density values at the 1,000 points to calculate Pearson's coefficients.

To identify priority areas for climate change adaptation, we generated a map displaying the associations between high, medium and low point densities for the aggregated landscape value and climate change risk point themes. We generated density grids for the eight landscape values and six climate change risks using a 500 m grid cell and 3 km search radius. This grid cell size and search radius was used to enable comparisons with US values data sets which used identical density thresholds. Further, a recent study has shown that a 500 m grid cell and 3 km search radius provides a reasonable threshold for measuring the density of landscape value points (Nielsen-Pincus, in process) with our study's map scale. The landscape value and climate change risk themes were classified using the standard deviation classification method. This method places class breaks above and below the mean grid cell density at intervals of one standard deviation until all the data values are contained within the classes. Values that are beyond the three standard deviations from the mean were aggregated into two classes; greater than three standard deviation above the mean and less than three standard deviation below the mean. We then reclassified the landscape value and risk themes into high (>2 standard deviations) and low (≤ 2 standard deviations) grids and used the raster calculator to generate spatial intersections between low and high value and risks. The result is a new raster layer with 4 classifications: low value, low risk; low value, high risk; high value, low risk;

and high value, high risk. We developed a climate change adaptation priority matrix by associating planning options with the value/risk landscape classifications.

3 Results

3.1 Survey response

We ran two surveys concurrently as part of the Southern Fleurieu study—a workshop survey and postal survey. We received 245 workshop surveys consisting of 127 secondary school student and 118 adult responses.

A total of 210 postal surveys were sent to a random sample of Southern Fleurieu property owners. Property owners were defined as people over the age of 18 who either lived in the Southern Fleurieu ($n = 153$) or owned one or more properties in the region ($n = 57$). We received 130 postal survey responses for a response rate of 61%. Overall, we received 375 workshop and postal survey responses, resulting in a spatial data set of 16,025 digitised points.

3.2 Respondent profile

To facilitate comparison with regional data (ABS 2006), we separated the adult survey population into resident and non-resident sub-groups (Table 1). There were more males (65.8%) in the resident sample compared to ABS statistics for the region (48.8%). The majority of resident survey respondents were over 40 years of age (53.6%) which is consistent with the region (60.0% ABS). However, there were proportionately fewer respondents 21–40 years of age (5.6% resident sample vs. 17.1% ABS) and proportionately more youth respondents younger than 20 years of age (40.8% resident sample vs. 22.9% ABS). The high number of youth respondents is to be expected considering school students were targeted as part of the snowball sample.

The majority of the sample had completed either primary or secondary school (54.7%). Of the resident sample, 28.4% had completed secondary education, 14.5% tertiary education and 10.4% postgraduate education, all higher than the regional education profile. Non-residents were more educated than residents with 34.6% having completed tertiary and 32.7% postgraduate education. The majority of participants identified with education (32.3%), conservation (21.7%) or primary production (21.2%).

Overall, the demographic profile of respondents indicates that the sample was skewed towards male respondents who were better educated than the regional population and aligned with education, conservation or primary production interests.

3.3 Relationships between respondent variables and the number of value and risk points assigned to the Southern Fleurieu

We ran independent samples t-tests and one-way ANOVAs to compare the mean number of value and risk locations assigned to the Southern Fleurieu map across different age and knowledge level sub-groups. The variables of life stage (student or adult), level of formal education (primary/secondary or tertiary), knowledge of

Table 1 The socio-demographic profile of school students and adults compared to the resident and non-resident survey population

Socio-demographic characteristics	*N*	Overall (%)	Students (%)	Adults (%)	Resident overall (%)	Non-resident overall (%)	ABS regional results[a] (%)
Sex							
Male	235	65.9	67.5	65.0	65.8	71.4	48.8
Female	118	34.1	32.5	35.0	34.2	28.6	51.2
Total	353	100.0	100.0	100.0	100.0	100.0	100.0
Age							
Younger than 20 years	127	34.6	100.0	0.0	40.8	2.0	22.9
21–40 years	21	5.7	0.0	8.8	5.6	2.0	17.1
41–60 years	114	31.1	0.0	47.5	26.3	57.1	29.2
60 years+	105	28.6	0.0	43.7	27.3	38.9	30.8
Total	367	100.0	100.0	100.0	100.0	100.0	100.0
Education level							
Primary	97	27.8	0.0	6.7	30.9	8.2	8.1
Secondary	94	26.9	93.5	26.8	28.4	18.4	17.9
Vocational	40	11.6	0.0	17.2	12.5	6.1	55.4
Tertiary	60	17.3	0.0	27.2	14.5	34.6	13.1
Postgraduate	47	13.5	0.0	21.3	10.4	32.7	2.2
No response	10	2.9	6.5	0.8	3.3	0.0	3.3
Total	348	100.0	100.0	100.0	100.0	100.0	100.0
Interest group							
Coastal development	25	11.1	12.3	9.7	11.1		
Conservation	49	21.7	7.3	38.8	21.7		
Primary production	48	21.2	8.1	36.9	21.2		
Recreation/tourism	31	13.7	20.3	5.8	13.7		
Education	73	32.3	52.0	8.8	32.3		
Total	226	100.0	100.0	100.0	100.0		

[a] Based on the 2006 Census for the Fleurieu Statistical Subdivision (ABS 2006)

region (fair, good, or excellent) and attention paid to climate change (little, moderate, or close) had no significant effect on the number of landscape value or risk points assigned by respondents. However, there are some trends in the relative frequency of value and risk assignment. Aesthetic values were most frequently assigned to the Southern Fleurieu region by all respondent sub groups (=4.07), followed by economic (=3.38) and recreation (=3.32). Bushfire was the most frequently assigned risk across most sub-groups (=3.33), followed by sea-level rise (=2.88) and wave action (=2.86).

3.4 Spatial distribution of landscape values and climate change risks in the Southern Fleurieu region

Table 2 shows the results of nearest neighbour analysis. For each value or risk, the null hypothesis of complete spatial randomness is rejected, indicating significant clustering of points. Heritage, aesthetic and recreation values are the most clustered on the landscape ($R = 0.46$, 0.48 and 0.48 respectively), while intrinsic, learning and future values are the most randomly distributed ($R = 0.55$, 0.52 and 0.51 respectively). In relation to climate change risks, sea-level rise, wave action and bushfire risks ($R = 0.43$, 0.44 and 0.54 respectively) are more clustered than land erosion, biodiversity loss and riparian flooding risks (0.62, 0.60 and 0.54 respectively). Overall, landscape values tend to be more clustered than climate change risks.

We then examined the distribution of landscape values and climate change risks by general land-use classification (Table 3). The general land-use classification system consisted of 4 categories (residential, conservation, irrigated pasture and plantation). While the overall observed distribution of landscape values by land-use do not deviate from expected results ($X^2 = 19.83$, $p > 0.05$), there were statistically significant associations between land-use classification and perceived climate change risks ($X^2 = 36.1$, $p < 0.05$). The perceived climate change risks of biodiversity loss

Table 2 CSR hypothesis testing of landscape values and risks by value and risk using nearest neighbour analysis

	N	*R* value (rank)	*z*-value	Ho: values are CSR
Landscape value				
Aesthetic	1,377	0.48 (2)	−36.4	Reject
Economic	1,072	0.50 (5)	−31.0	Reject
Recreation	1,137	0.48 (3)	−33.0	Reject
Learning	929	0.52 (7)	−27.9	Reject
Biodiversity	1,006	0.49 (4)	−30.4	Reject
Intrinsic	831	0.55 (8)	−24.3	Reject
Heritage	909	0.46 (1)	−31.2	Reject
Future	876	0.51 (6)	−27.7	Reject
Climate change risk				
Biodiversity loss	817	0.60 (5)	−21.8	Reject
Land erosion	704	0.62 (6)	−19.1	Reject
Bushfire	938	0.54 (3)	−27.0	Reject
Riparian flooding	618	0.54 (4)	−21.5	Reject
Sea-level rise	793	0.43 (1)	−30.4	Reject
Wave action	799	0.44 (2)	−30.0	Reject

Table 3 Relative proportion of landscape values and climate change risks by land-use classification

	N	Land use classification (% by category)			
		Residential	Conservation	Irrigated pasture	Plantation
Landscape values					
Aesthetic	496	16.8	16.2	15.3	14.4
Economic	384	12.5	11.7	12.3	16.4
Recreation	398	14.0	12.1	14.3	12.4
Learning	344	11.6	10.7	12.3	10.4
Biodiversity	420	13.1	14.5	11.9	12.4
Intrinsic	349	11.9	11.0	12.3	9.7
Heritage	335	10.6	10.7	10.6	12.8
Future	364	9.5	13.1	10.9	11.4
	3,090	100	100	100	100
			$X^2 = 19.83$, $p > 0.05$		
Climate change risks					
Biodiversity loss	315	15.6	21.0	21.4	11.9
Land erosion	220	12.4	12.3	17.5	14.1
Bushfire	355	16.3	22.9	21.8	22.6
Riparian flooding	207	14.6	10.7	14.1	13.6
Sea-level rise	276	18.8	16.1	11.2	19.2
Wave action	303	22.3	17.0	14.1	18.6
	1,676	100	100	100	100
			$X^2 = 36.1$, $p < 0.05$		

and bushfire are proportionately more associated with “conservation” land use, while biodiversity loss is least associated with “plantation” land use. Also noteworthy is the relatively high proportion of wave action risk associated with “residential” (coastal) areas.

3.5 Relationships between landscape values and climate change risks

We used a regression model to help identify the landscape values that might be non-spatially associated with measures of perceived climate change risk (Table 4). The number of mapped landscape values were moderate predictors of the number of mapped climate change risks, regardless of spatial location (R^2 ranges from 0.36 to 0.62). For example, individuals who mapped more intrinsic, aesthetic and recreation landscape values also tended to map more biodiversity loss risk locations. Similarly, individuals who mapped more recreation, historic, economic and aesthetic values also tended to map more riparian flooding risk locations. The number of mapped intrinsic values was the most significant predictor of the number of mapped biodiversity loss ($\beta = 0.37$) and bushfire risks ($\beta = 0.32$); and the number of mapped recreation values was the most significant predictor of the number of mapped riparian flooding ($\beta = -0.48$) and sea-level rise risks ($\beta = -0.32$). The collinearity diagnostics on the regression models suggest a tolerable level of multicollinearity in the independent variables with diagnostics for four of the six models having VIF values below the general threshold of 10 for obvious concern (Myers 1990). The maximum VIF value in the other two models was 10.6.

Table 4 Linear regression results for the number of mapped landscape values regressed against the number of mapped perceived climate change risks

Landscape values (as predictor variables)	Perceived climate change risks (as dependent variables; standardized β coefficients)					
	Biodiversity loss	Land erosion	Bushfire	Riparian flooding	Sea-level rise	Wave action
Aesthetic	0.25	NS	NS	0.22	NS	NS
Economic	NS	NS	NS	0.23	NS	0.28
Recreation	−0.25	NS	NS	−0.48	−0.32	−0.27
Learning	NS	NS	NS	NS	NS	NS
Biodiversity	NS	NS	NS	NS	NS	0.34
Intrinsic	0.37	NS	0.32	NS	NS	NS
History	NS	NS	0.25	0.35	NS	0.25
Future	NS	NS	NS	NS	NS	NS
R	0.79	0.75	0.63	0,75	0.60	0.70
R^2	0.62	0.56	0.39	0.57	0.36	0.46
F	33.3	24.4	13.1	22.1	10.7	18.7
P	0.000	0.000	0.000	0.000	0.000	0.000

NS not significant ($p > 0.05$)

3.6 Spatial overlap of landscape values and climate change risk places

Jaccard's coefficients were calculated to quantify the degree of spatial overlap between landscape values and climate change risk vector-based polygons that were created to capture 95% and 75% of the mapped points, respectively (Tables 5 and 6). At both intervals, biodiversity and intrinsic values were most strongly associated with biodiversity loss and bushfire risks, aesthetic and intrinsic values were most strongly associated with land erosion risk, and recreation and aesthetic values were most closely associated with sea-level rise and wave action risks. The size of the polygons, reflected in the percentage of points included, did not have a major influence on the spatial associations, with few changes in the rank order of Jaccard coefficients across 95% and 75% polygons.

Table 5 Jaccard coefficients for 95% landscape value and climate change risk polygons

	Biodiversity loss	Land erosion	Bushfire	Riparian flooding	Sea-level rise	Wave action
Aesthetic	0.499	0.510 (1)	0.343	0.395	0.400 (2)	0.411 (2)
Economic	0.438	0.425	0.350	0.396	0.313	0.306
Recreation	0.480	0.453	0.315	0.408	0.411 (1)	0.417 (1)
Learning	0.523	0.463	0.372	0.418 (1)	0.381	0.384
Biodiversity	0.572 (1)	0.443	0.377 (2)	0.402	0.360	0.361
Intrinsic	0.541 (2)	0.497 (2)	0.382 (1)	0.408	0.364	0.367
Heritage	0.426	0.425	0.274	0.379	0.379	0.351
Future	0.505	0.460	0.336	0.414 (2)	0.397	0.392

Ranks appear in parentheses

Table 6 Jaccard coefficients for 75% landscape value and climate change risk polygons

	Biodiversity loss	Land erosion	Bushfire	Riparian flooding	Sea-level rise	Wave action
Aesthetic	0.376	0.379 (1)	0.153	0.239	0.376 (2)	0.385 (2)
Economic	0.308	0.270	0.184	0.277	0.305	0.266
Recreation	0.376	0.331	0.126	0.309 (1)	0.430 (1)	0.408 (1)
Learning	0.490	0.338	0.250	0.262	0.306	0.284
Biodiversity	0.505 (1)	0.304	0.269 (1)	0.215	0.257	0.269
Intrinsic	0.485 (2)	0.362 (2)	0.242 (2)	0.278 (2)	0.298	0.290
Heritage	0.287	0.278	0.063	0.268	0.364	0.320
Future	0.455	0.329	0.210	0.247	0.323	0.317

Ranks appear in parentheses

The spatial relationships between landscape value and climate change risk was also examined using a raster spatial model. Spatial cross-correlation analysis was performed on density grids generated for landscape values and climate change risks. Pearson's product-moment correlations between the density of raster coverages were calculated for 1000 randomly selected points (Table 7). There are larger, significant spatial associations between perceptions of biological diversity value and risk of biodiversity loss ($r = 0.81$), learning value and biodiversity loss ($r = 0.75$), future value and risk of biodiversity loss ($r = 0.73$), recreation value with risk of wave action ($r = 0.71$), intrinsic value with risk of biodiversity loss ($r = 0.69$) and recreation value with risk of sea-level rise ($r = 0.67$).

In comparing the vector and raster analyses, there is more consistency than difference in the results. In both spatial approaches, there are significant spatial associations between biodiversity value and biodiversity loss risk and intrinsic value and biodiversity loss risk. The relatively strong spatial associations between recreation value and the risks from wave-action and sea-level rise are also consistent. The weakest spatial associations between heritage and recreation values and bushfire risks are also consistent in both analyses. One difference in the results is that the spatial association between economic value and the risk of riparian flooding is relatively high in the raster analysis, but less in the vector analysis.

Table 7 Spatial cross correlations (r-values) between densities of landscape values and climate change risks with 1,000 randomly generated points in study area

	Biodiversity loss	Land erosion	Bushfire	Riparian flooding	Sea-level rise	Wave action
Aesthetic	0.47	0.54 (2)	NS	0.29	0.54	0.63 (2)
Economic	0.40	0.39	0.09	0.55 (1)	0.47	0.43
Recreation	0.50	0.64 (1)	0.10	0.48	0.67 (1)	0.71 (1)
Learning	0.75 (2)	0.460	0.30 (2)	0.40	0.41	0.38
Biodiversity	0.81 (1)	0.33	0.45 (1)	0.20	0.29	0.30
Intrinsic	0.69	0.53	0.24	0.38	0.48	0.52
Heritage	0.38	0.46	NS	0.54 (2)	0.56 (2)	0.54
Future	0.73	0.55	0.23	0.47	0.55	0.54

Grid values (500 m) were generated from kernel density using kernel density method

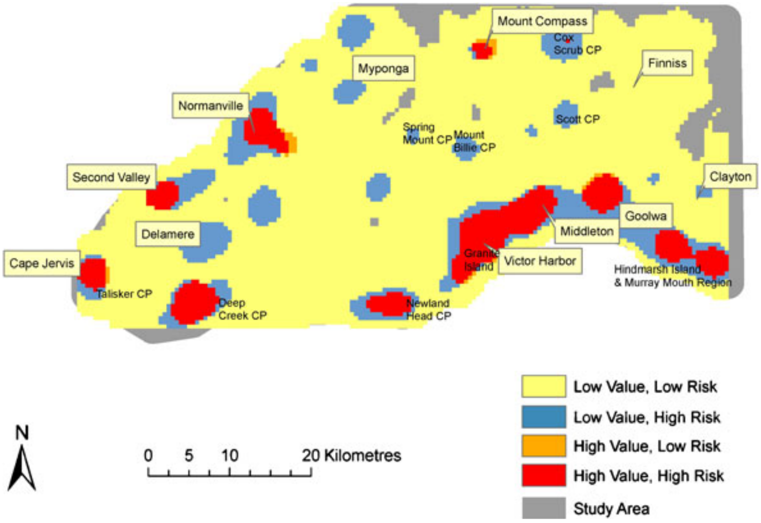


Fig. 3 Density map showing the spatial associations between areas of low and high perceived landscape value and climate change risk

3.7 Mapping of landscape value and perceived climate change risk associations

In Fig. 3, we present a map to illustrate the spatial associations between landscape values and perceived climate change risk point densities. Deep Creek and Newland Head Conservation Parks, and Victor Harbor, Goolwa, Cape Jervis, Second Valley, Normanville and Mount Compass townships were identified as landscapes of high perceived value and risk at the 95% confidence level. The neighbouring townships of Delamere are Myponga were perceived as areas of low value and high risk, whereas the majority of lands were identified as low value and low risk.

We then generated a climate change adaptation priority matrix (Table 8) which translates the associations between perceptions of landscape value and climate change risk into potential agency responses. Areas of high landscape values and high climate change risks are priority areas for climate change adaptation and agency resources need to be directed to these areas. Conversely, areas of low landscape value and low climate change risks are discount areas where agency resources can be reallocated or diverted from these sites. Areas of high landscape value and low risk

Table 8 Potential agency responses to landscape value and climate change risk scenarios

	Low climate change risks	High climate change risks
High landscape values	Maintenance areas: maintain agency resources sufficient to protect existing landscape values	Priority areas: direct agency resources to these areas
Low landscape values	Discount areas: reallocate agency resources away from these areas	Sacrifice areas: reallocate or divert agency resources away from these areas

are maintenance areas and areas of low landscape values and high risks are sacrifice areas.

4 Discussion

The purpose of this study was to present a method for identifying and measuring the spatial relationships between public perceived landscape values and climate change risks for climate change adaptation planning. Analysis of the data suggests that perceptions of climate change risk are, in part, spatially related to the values people assign to or hold for places on the landscape in the Southern Fleurieu region. This finding may prove useful to assess climate change risk in Australia and elsewhere. Previous international research indicates that risk perception is correlated with an individual's physical location (Brody et al. 2008) and environmental value orientations (Stedman 2004; Leiserowitz 2006; Slimak and Dietz 2006; Etkin and Ho 2007). Our findings suggest that researchers need to expand the list of variables to include psychological correlates of risk perception at the place-specific scale when undertaking climate change adaptation studies to gain a more comprehensive understanding of risk drivers and their management.

Although there is a high degree of variability in the mapping process among individuals, collective spatial patterns do emerge from the mapping process. Perceived landscape values and risks are not randomly distributed across the landscape, but rather cluster to varying degrees. Significant spatial associations exist between some climate change risk perceptions and major land-use classifications, as well as some geographic areas with higher perceived landscape values.

The respondent decision to map more of certain types of landscape value yielded moderately predictive results about the number of certain climate change risks mapped. However, the landscape values that best predict the number of climate change risk locations mapped such as recreation value (Table 4), were seldom the same landscape values with the highest level of geographic spatial association with the mapped climate change risks, such as biodiversity or intrinsic values (Tables 5–7). These results suggest that the participant choice about the number and type of values and risks to map involves a different or unrelated cognitive process to the choice of where to map the value and risk locations.

From a climate change adaptation perspective, it is important to understand which values are most likely to be affected by a range of risks and the associated consequences of these losses. Economic values are likely to be highly affected by wave action ($\beta = 0.28$, Table 4) as a result of property loss, devaluation of coastal properties, and changing visitor patterns to coastal environments. Recreation value is likely to be affected by a range of risks including riparian flooding ($\beta = 0.48$) and sea-level rise ($\beta = 0.32$) as a result of reduced access to recreation infrastructure along river corridors and coastal boulevards, and wave action ($\beta = 0.27$) as a result of damage to dune systems and access infrastructure along the coast, such as jetties. Values are also likely to be affected by certain ecological conditions. For example, recreational value is likely to be affected by biodiversity loss ($\beta = 0.25$) given reduced opportunities to bushwalk through protected areas and to observe flora and fauna in natural environments. Intrinsic value could be affected by biodiversity loss ($\beta = 0.37$) and bushfire

($\beta = 0.32$) considering the intrinsic worth of native flora and fauna found within protected areas. Some losses to natural assets may be effectively irretrievable such as losses to biodiversity value as a result of the time required for biodiversity to recover after human disturbance; the loss of physical artifacts associated with heritage value is also generally a permanent loss. The consequence of losing recreation values such as trail segments through erosion or flooding will be less catastrophic than losing rare or endemic species (biodiversity value), and the loss of recreational property is not as severe as losing a historic property or property where people live permanently. However, the value consequences of landscape modification from climate change is complex, and in some cases, unpredictable because human valuation is a dynamic and subjective psychological process. For example, while landscape modification from climate change is often assumed to imply a net loss of human value, landscape changes resulting from climate change may actually increase the value of some places that remain unchanged based on the scarcity of resources principle. And while some landscape values may decline, others may increase.

Climate change risks are not equal in terms of human or ecological impacts. Intense and frequent bushfires are likely to be the greatest threat to biodiversity because the losses are irretrievable, and arguably, the greatest threat to quality of life is the loss of coastal area inhabitation through rising sea-levels considering the vast array of recreational and economic opportunity sets provided by coastal environments.

Not all landscape values were strongly associated with perceived climate change risks. For example, we found weak spatial associations between all eight landscape values and bushfire and land erosion risks. Historic events may explain this particular finding. In recent years, there have been a series of bushfires across inland conservation parks and forestry reserves on the Southern Fleurieu peninsula, possibly leading to the assignment of high bushfire risk to inland areas.

The bushfire example raises an interesting question for scientists and policy makers: do people assign risks to the landscape based on their understanding of likely climate change by 2030 or are they based on past experience/interaction with the landscape? Brody et al. (2008) suggest that the general public assigns risk based on a limited set of vulnerability variables. Similarly, our results suggest that respondent characteristics such as the level of attention paid to climate change, formal education level and perceived knowledge of the study area do not significantly influence the number of climate change risk points assigned to the map. These findings are consistent with a number of American studies on climate change where members of the public tend to calculate their risk level based on a limited understanding of the impacts of climate change (Bell 1994; Kempton 1991). These findings also support the social amplification of risk. Individuals cannot deal with the full complexity of risks and multiple types of risks in everyday life and therefore individual values determine the importance and severity of different risks.

One methods-related research question in this study is whether the type of analysis (vector or raster) influences the spatial associations between perceived values and risks. Both data models, vector and raster, produced similar spatial associations with Jaccard coefficients and spatial cross-correlation analyses and thus appear to provide reasonable measures of spatial association. However, because there is inherent uncertainty and variance associated with the extrapolation of point data for both landscape values and climate change risks, we suggest conducting both vector and raster analysis to assess the reliability of the resulting spatial associations.

4.1 Implications for government agencies and land managers

Government agencies and land managers should engage in proactive land use planning which we would define as: (1) identifying lands with significant ecological, economic and social values; (2) identifying potential risks to these values; and (3) planning and coordinating activities to minimize the risks to these values. The growing awareness of the risks from climate change has accelerated the need for agencies to expand their temporal planning horizons. The method identified in this research provides a mechanism for agencies to identify landscape values and climate change risks to develop place-based planning strategies.

Government resources are limited and choices must be made regarding how planning and management resources will be targeted. The mix of landscape value and climate risk scenarios (see Table 8) is suggestive of the allocation of land use planning and management resources for government agencies under the new reality of climate change. Agency planning resources should be directed to priority areas—landscapes that have both high levels of value as well as risk from climate change—and away from areas that have high risk, but relatively low value. In this study, areas of high priority include the landscape between Victor Harbor and Middleton, the Lower Murray, Newland Head and Deep Creek Conservation Parks. Areas of lower priority include the Finniss township. Areas that currently have high value but are at lower risk for climate change should be managed to maintain the quality of landscape values, which generally translates into managing these lands to reduce human conflict over existing landscape values. Landscapes that have relatively low value and low risk may be sacrificed at the present as a necessary resource trade-off. Nonetheless, we caution the use of Table 8 as a prescriptive management tool. As previously discussed, the interactions between values and landscape modifications from climate change have complex and variable consequences to human quality of life and ecological health, and thus may carry different levels of priority. For example, landscapes that have high biodiversity value and high bushfire risk may arguably be more important to manage for in the shorter term than landscapes with high recreational value and high sea-level rise because the losses in the former are effectively irretrievable. Engineered solutions can be developed to protect physical infrastructure, but not natural capital.

Yet the matrix and associated LVM analysis has value for climate change adaptation in that it encourages environmental managers to reconsider how they prioritise and reallocate agency planning and management resources. The approach will be controversial because it explicitly seeks public engagement in the climate change planning process while acknowledging the limited resources of government to addresses public needs. The prioritisation of agency resources is viewed by many as best reserved for political and administrative systems that are informed by expert opinion. But public participation in climate change planning to this point has been ‘shallow’ in that there has been a tendency to focus on informing the public rather than seeking their advice and direction through collaborative planning outcomes. The landscape values methodology presented in this study provides a tool for soliciting a wide variety of values and risks at the place-specific scale early in the planning process.

While we believe PPGIS mapping of landscape values and climate change risks offers the potential to improve climate change planning, especially at the local and regional planning levels of government, the method should not be viewed as supplanting the need for expert opinion, especially regarding the assessment of risks from climate change. The methods presented herein should be viewed as part of an iterative and transactive planning process wherein both public and expert knowledge coalesce into a shared understanding of the risks and value tradeoffs involved in climate change. Soliciting landscape values early in the planning process may increase trust in agency decision-making and increase community support for and involvement in climate change adaptation responses, particularly when current expert knowledge of adaptation at local and regional scales is insufficient for planned adaptation responses. It also may enable the identification of the level of agreement and disagreement between the risks and values identified by government and the risks and values perceived by citizens. The results can be used to systematically identify perceptual gaps and streamline efforts to implement adaptation responses which are based on shared values and common objectives.

To develop a comprehensive understanding of climate change adaptation priorities, future research could examine the spatial relationships between locally perceived and expert assessed landscape values and climate change risks similar to the method used to compare lay and expert biological diversity conservation priorities (see Brown et al. 2004). Land managers could use the results to develop and refine their community engagement strategies. Information and consultation programs, for example, may need to be established in places of high expert assessed value and risk but low public perceived value or risk. Conversely, collaboration and empowerment programs may be required in areas of low expert assessed value and risk but high public perceived value or risk if the goal is to encourage local involvement in climate change adaptation planning. Perhaps most important, the methods described herein provide a reasonable operational bridge between perceived landscape values and climate change risks that can be used in a collaborative planning process to rationally allocate limited public resources.

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