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Assessing multiple approaches for modelling land-use conflict potential from participatory mapping data

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ABSTRACT

Spatial social data collected through participatory mapping are increasingly used to assess social dimensions for land use planning and management. However, there has been limited research to evaluate alternative approaches to identify potential land-use conflict. Using data from Queensland, Australia, we applied multiple approaches (land-use preferences, weighted preferences, combined place values and land-use preferences, and value compatibility scoring to identify land-use conflict potential and to assess these methods for four different land uses (residential development, tourism development, mining, and conservation). The performance of these approaches were evaluated using selected reference sites in the study area to determine which spatial attributes and methods were most predictive of conflict potential. Weighted preferences, and combined place values and land-use preferences were most effective for all land use types. The conflict mapping results for mining and conservation were sensitive to the number of place value and land-use preference points available for analysis and the number of individuals participating in the mapping process. To determine the inferential quality of conflict mapping results, we operationalised confidence levels based on the number of unique participants that mapped preferences in a given location. Overall, the highest confidence in mapped results was observed for tourism development, followed by mining, conservation, and residential development. Confidence levels varied across the study area and by reference sites. The findings of this study increase the external validity of preference-based conflict mapping methods while demonstrating a means to assess the inferential quality of conflict mapping results. The generation of confidence levels can assist in the prioritization and allocation of planning resources to places with both high conflict potential and high confidence.

1. Introduction

In a regional planning process, land uses should be allocated to meet multiple and sometimes incompatible community demands and expectations. Conflict over land use may emerge because proposed developments and land use changes can affect landscape qualities that are valuable for people (Bengston et al., 2004). Land-use conflict is also the result of different views and perceptions about landscapes and their services (Brody et al., 2004). Over the last two decades, a number of studies have explored new methods to identify regional and community values and land-use preferences to incorporate them into a land use planning process; however, there is limited research on how these spatially-explicit social data can be used to assess potential conflict over various land uses that could result in more socially acceptable decisions.

From a psychological perspective, land-use conflicts occur because of two factors, interpersonal and social values conflicts (Vaske et al., 1995). Interpersonal conflict occurs when different individuals or groups have different goals and sometimes these goals may interfere with the goals of other individuals or groups (Jacob and Schreyer, 1980). Social values conflict occurs between different groups of stakeholders who do not share the same norms and/or values (Vaske et al., 2007). In this study, we operationalise and analyse place-based values and land-use preferences to explore the practical implications of these theoretical arguments for land-use conflict that often characterises local and regional planning activity and outcomes.

Participatory mapping refers to a wide range of methods where spatial information is collected or used as part of a participatory process. Participatory mapping, as applied to land-use conflict, typically differs between *developed* and *developing* countries. In *developing* countries, participatory mapping, termed "participatory GIS" or PGIS, has been used to map indigenous lands and resources (Chapin et al., 2005;

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Ramirez-Gomez et al., 2013; Reyes-García et al., 2012), empower and build capacity in communities (Rambaldi et al., 2006), manage natural resources (McCall and Minang, 2005), and enhance conservation (Bernard et al., 2011; Ramirez-Gomez et al., 2016). In developing countries, participatory mapping is often engaged as a means to mediate contemporary land-use conflicts resulting from the inequitable distribution of natural resources. For example, Kyem (2006) used PGIS to manage conflicts between local groups competing for access to local forest resources in Ghana and Cronkleton et al. (2010) used participatory mapping to reduce conflict over access to forest resources in Bolivia.

In contrast, participatory mapping in *developed* countries, when applied to land-use conflict, seeks to identify the potential for conflict based on the expression of spatially-explicit values and land-use preferences that operationalize the psychological theories of conflict. The values in participatory mapping have been called *landscape values* (Brown, 2004), *social values for ecosystem services* (Sherrouse et al., 2011), or simply *place values*. Place values consist of both *held* and *assigned* values. Held values represent enduring beliefs about the importance of a specific mode of conduct or an end state of existence (Rokeach 1973). Assigned values express the importance of an object relative to other objects (Brown 1984). Held values can influence assigned values through the subjective evaluation of objects (Brown 1984; Lockwood 1999). Brown and Weber (2012) refer to mapped values as *relationship* values because they bridge held values and assigned values. In the process of mapping values, what is personally important to a participant (*held* value) is cognitively related to what appears important to the individual in the physical landscape (*assigned* value).

Mapping values have been used in multiple applications for natural resource and environmental planning and management (see Brown and Kyttä, 2014). For example, Reed and Brown (2003) described a process whereby place values can be incorporated into a national forest planning process using value suitability analysis (VSA), a variant of traditional land suitability analysis that includes mapped values data from PPGIS. In another example, PPGIS data was used to identify the compatibility of different types of place values with prospective land uses such as motorized recreation (Brown and Reed, 2012). This analysis was called values compatibility analysis (VCA) but appears similar to VSA. Both VSA or VCA provide a systematic method for incorporating human dimensions data into land use planning decision frameworks. In a recent study, Moore et al. (2017) also used value compatibilities to identify potential conflict to inform marine spatial planning in the Kimberly region in Western Australia.

The mapping of *preferences* seeks to identify the spatial locations where various types of land use appear acceptable (or not) to participants. In contrast to values, mapped land-use preferences are simpler psychological constructs that are used to identify where people agree or disagree with current or future land use. One of the earliest applications of mapping land-use preferences was to identify the spatial locations where tourism and residential development was acceptable to residents living on Kangaroo Island, South Australia (Brown, 2006). In another application, Nielsen-Pincus et al. (2010) assessed the social acceptability for residential development based on mapped pReferences

Brown and Raymond (2014) integrated both place values and land-use preferences to conceptualize land-use conflict and applied this approach to measure the potential conflict for residential and industrial development in the Lower Hunter region in Australia. According to the model, the level of agreement or disagreement in land-use preferences is a proxy for social value conflict while the intensity of place values mapped in the area is a proxy for interpersonal conflicts. The integration of PPGIS mapped place values and land-use preferences to identify land-use conflict potential has been applied in multiple geographic locations and contexts. For example, Brown and Donovan (2013) developed a conflict potential index for the Chugach National Forest (Alaska) that used both mapped place values and forest use preferences. In another study in Norway, Hausner et al. (2015) measured the level of land-use conflict potential using both mapped place values and land-use preferences to assess whether conflict potential differed by land tenure. The conflict indices were based on the differences between mapped preferences to increase or decrease a specific land use that were weighted by the number of mapped preferences or place values. In another PPGIS study in Finland, Brown et al. (2017) used both place values and land-use preferences to identify conflict potential for multiple land uses (e.g., mining and tourism development) and the effect of participant social group (resident, visitor, holiday home owner). That study found more similarities than differences in preferences by social group.

This study expands on previous conflict mapping research by applying and comparing four approaches to identify potential conflict for four land uses: residential development, tourism development, mining, and conservation using place values exclusively, land-use preferences exclusively, and both attributes combined to calculate aggregated scores as suggested by Brown and Raymond (2014). The data for this research were collected in a participatory mapping process located in the Baffle Basin in Australia. Using place values as indicators of potential conflict, we applied value compatibility analysis (VCA) as the fourth method that incorporates a broad range of place values mapped by different individuals and stakeholders into a land-use trade-off analysis. One of the key steps in VCA is assessing the relationship between place values and different types of land uses to assign compatibility scores to these relationships. Previous studies have used researcher judgement to determine the compatibility between place values and prospective land uses (Brown and Raymond, 2014). In this study, we used a new approach by assessing place value and land use compatibility relationships using an expert elicitation technique rather than researcher judgment. After generating output maps based on multiple conflict mapping approaches, we measured their spatial correlations to determine the extent to which conflict/compatibility models yielded similar or different results. We further evaluated how well these different approaches predicted conflict potential using reference sites identified by key informants in the participatory mapping process. To conclude this study, we discuss the performance of the different conflict mapping approaches relative to strengths and limitations in the participatory mapping data.

2. Methods

2.1. Study area

The Baffle Basin is located at the southern end of Great Barrier Reef (GBR) catchment and falls within the Burnett Mary Natural Resource Management (NRM) region in central Queensland, Australia (Fig. 1). The Baffle Basin covers a total of 4114 km^2 (Binney, 2008) with a population of 5822 people in 2011 (Australian Bureau of Statistics, 2013). The region encompasses two local government areas, Gladstone and Bundaberg and contains several coastal cities such as Agnes Water and Seventeen Seventy that attract tourists to this part of Australia.

The Baffle Basin, as part of GBR catchment, comprises multi-functional landscapes with multiple land uses such as residential areas, agriculture, protected areas (conservation), tourism, and mining. The major land uses of this region are grazing, intensive agriculture, water supply, road and rail infrastructure, and urban residential areas (Reef Water Quality Protection Plan, 2013). This region also contains areas of high ecological importance including near pristine estuaries, threatened species of fauna and flora, two critically-endangered ecological communities, and 26 protected areas, national parks, conservation, and forest parks (Great Barrier Reef Marine Park Authority, 2012a).

Past development and current land uses such as intensive agriculture, grazing, mining, ports and industry in the GBR catchment have brought about a significant decline in water quality, coastal ecosystem functions and processes and hence, loss of inshore biodiversity. There

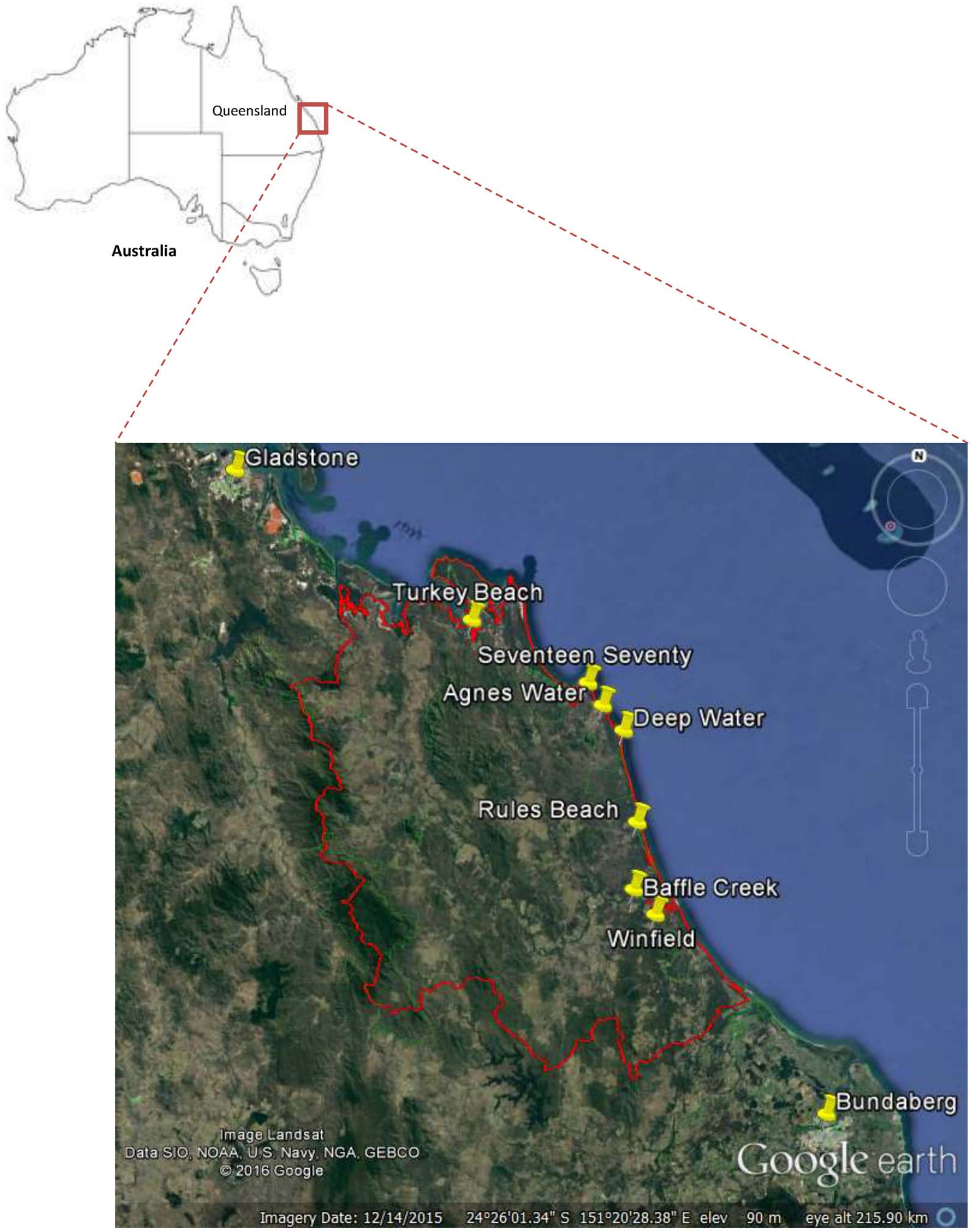

Fig. 1. Map of study area.

has been an increasing interest in coastal development in different part of this catchment resulting in biodiversity and water quality loss, contributing to a decline in resilience and health of the Great Barrier Reef (Great Barrier Reef Marine Park Authority, 2009). A variety of factors resulting from current land uses in this region have led to impacts on ecological processes and functions of the coastal areas (Great Barrier Reef Marine Park Authority, 2012b).

In the Baffle Basin, physical developments, economic growth and climate change have been identified as three major drivers influencing the environmental values of the region and its adjacent coastal ecosystems (Great Barrier Reef Marine Park Authority, 2012a).These drivers increase the human-induced effects on these ecosystems by increasing sediments, nutrients and toxic materials. The resulting water pollution threatens ecosystems and biodiversity and can also affect water-based tourism activities. Previous research shows that about 62% of visitors to the region participate in swimming and diving and 38% participate in boating recreation activities. Therefore, the tourism industry may be heavily affected by a loss of water quality (Binney, 2008).

2.2. Data collection and survey

A mixed-methods PPGIS survey was implemented to collect 13 spatially-explicit place values and four land-use preferences in the Baffle Basin. To increase the response rate, study participants were provided the option of completing an internet-based or mail-based survey. We developed a PPGIS website using a Google Maps Application Programming Interface (API) where participants were requested to drag and drop value and land-use preference markers onto a map of the Baffle region. Invitation letters for participating in this study were sent to 2200 residential addresses provided by a marketing agency (Yell123, 2014); however, the effective sample size was 1835 as 365 recruitment letters were undeliverable. More detailed information about the two methods applied for the social survey can be found in Karimi et al.

Table 1
Place values and their operational descriptions mapped in this study.

Place Values	Operational description
Aesthetic/Scenic	These areas are valuable because they contain attractive scenery including sights, smells, and sounds.
Economic	These areas are valuable because they provide timber, fisheries, minerals, or tourism opportunities such as outfitting and guiding.
Non water-based Recreation	These areas are valuable because they provide a place for my favourite non water-based recreation activities.
Water-based Recreation	These areas are valuable because they provide opportunity for water-related recreational activities such as boating, fishing.
Life sustaining/Ecological	These areas are valuable because they help produce, preserve, clean and renew air, soil and water.
Learning/scientific	These areas are valuable because they provide places where we can learn about the environment through observation or study.
Biological	These areas are valuable because they provide a variety of fish, wildlife, plants, or other living organisms.
Spiritual	These areas are valuable because they are sacred, religious, or spiritually special places or because I feel reverence and respect for nature here.
Intrinsic	These areas are valuable in their own right, no matter what I or others think about them.
Historic/Cultural	These areas are valuable because they represent history, or provide places where people can continue to pass down memories, wisdom, traditions, OR a way of life.
Future	These areas are valuable because they allow future generations to know and experience the area as it is now.
Wilderness	These places are valuable because they are wild, uninhabited, or relatively untouched by human activity.
Social	These areas are valuable because they provide opportunities for social interaction.

(2015).

A purposive sampling strategy was used to identify key informants with knowledge of land use issues in the study area. These key informants were selected from the staff of regional and local organisations and included Burnett Mary Natural Resource Management managers, planning and conservation officers from Bundaberg and Gladstone regional councils, Queensland Parks and Wildlife officers, and conservation council managers. An initial list of the key informants was prepared based on organisational directories and was modified by a snowball sampling technique to identify other key informants who might be interested in participating in the study. These key informants had expertise in different fields including biodiversity assessment, regional planning, land and water management, coastal conservation, and environmental management.

The typology of place values and land-use preferences used for the mapping activity was developed and revised after consultation with the key informants familiar with land use issues and concerns in the study area (Tables 1 and 2). We also consulted with the key informants about selecting some of the localities of the Baffle Basin as reference sites to evaluate the conflict mapping methods.

2.3. Modelling conflict potential using place values and land-use preferences

According to a conceptual model of land-use conflict potential (Brown and Raymond, 2014), two perceptual dimensions need to be measured: the level of participants' agreement with different types of land uses and an assessment of place importance, as expressed through place values. Land-use preferences and place values collected through a PPGIS process in the Baffle region were used to operationalise conflict potential in the study region. For the purpose of this study, we used four categories of land-use preference data to model conflict potential: mining, residential development, tourism development, and conservation. To be comprehensive, we applied the following methods to generate regional conflict maps for the four land uses.

We operationalised three alternative conflict mapping methods based on the conceptual model in Brown and Raymond (2014).To apply these methods, we used sampling grids to perform the spatial analyses and Geospatial Modelling Environment (Beyer, 2015) to count the total number of mapped values and land-use preferences in each grid cell. As discussed by Brown and Raymond (2014), we needed to define the size of the sampling grid for the point data to model conflict potential. After examining the number of mapped value and land-use preference points and spatial distribution relative to the size of the study area, we chose 2 km as an appropriate grid cell size which generated 1128 grid cells in the region. Selecting a smaller grid size (e.g., 1 km sampling grid) resulted in too few mapped points in the grid cells to generate sufficient variability in conflict indices. Selecting a larger grid size (e.g., 3 km sampling grid) did not provide sufficient spatial resolution to identify specific areas of conflict potential for certain types of land use such as residential development. The selected 2 km cell size provided a sufficient number of points mapped per grid cell to calculate conflict indices for comparison.

In the first method, we used spatial preferences as a direct measure of the level of agreement with a proposed land use in a particular location. In this method, the difference in supporting and opposing preferences, expressed as a ratio, is presumed to be related to the potential for conflict. We calculated a preference score (PS) for each grid cell based on the ratio between the number of mapped preferences for/against a given land use. This score varies between 0 and 1 and indicates the overall level of agreement with a proposed use in each grid cell (Eq. (1)).

$$PS = \frac{\mathrm{MAX}(\mathrm{MIN}(P_S, P_O), 0.1)}{\mathrm{MAX}(P_S P_O)} \tag{1}$$

where PS is the preference score per cell, P_S is the number of preferences supporting the land use, P_O is the number of preferences opposing the land use. A larger PS ratio (approaching the number 1) shows greater similarity in the number of points mapped to express support or opposition to a specific land use and hence, lower level of agreement and higher potential for land-use conflict; smaller scores represent higher degrees of preference agreement and less conflict potential for a given use.

We then used the total number of place values mapped in each grid cell to weight the preference score in the second method (Eq. (2)). This

Table 2
Land-use preferences and their operational descriptions mapped in this study.

Land use preferences	Operational description
Tourism development	Use appropriate markers to identify where tourism development could occur with a good plan and where tourism development should not occur.
Mining development	Use appropriate markers to identify where mining development could occur with a good plan and where mining development should not occur.
Residential development	Use appropriate markers to identify areas where rural residential development could occur with a good plan and where residential development should not occur.
Conservation	Use appropriate markers to identify areas (excluding national parks and conservation reserves) where conservation or restoration could occur with a good plan and where conservation or restoration should not occur.

method combines both values and land-use preferences as two independent factors contributing to the identification of land-use conflict potential. According to Brown and Raymond (2014), weighting the preference ratio by values may be conceptually stronger because it considers two dimensions of land use conflict—the level of land use agreement and place importance as determined by the number of mapped values.

$$PVS = \frac{\mathrm{MAX}(\mathrm{MIN}(Ps,\ Po),\ 0.1)}{\mathrm{MAX}(PsPo)} * Vc \tag{2}$$

where *PVS* is the preference and value score per cell, P_S is the number of preferences supporting the land use, and P_O is the number of preferences opposing the land use, and V_C is the total count of all place values in the cell.

In the third method (Eq. (3)), the total number of points mapped for supporting or opposing a given land use in each grid cell was used to weight the preference scores (PS). This method accounts for different land use saliencies across the landscape by distinguishing between otherwise similar levels of agreement or disagreement. According to Brown and Raymond (2014), land use conflict should be significantly higher where more preferences were expressed because the location appears more salient to individuals sampled in the study.

$$WPS = \frac{\mathrm{MAX}(\mathrm{MIN}(P_S,\ P_O),\ 0.1)}{\mathrm{MAX}(P_S P_O)} * (P_S + P_O) \tag{3}$$

where *WPS* is the weighted preference score per cell, P_S is the number of preferences supporting the land use, and P_O is the number of preferences opposing the land use.

The magnitude of the indices resulting from these methods indicates the degree of conflict potential where scores show the ratio of supporting and opposing preferences (Eq. (1)), that are optionally amplified by the number of place values or preferences (Eqs. (2) and (3)). The (0.1) constant in the numerator of the equations is intended to handle the special case where there is only a single preference marker in a grid cell. In the absence of a small, positive constant to keep the numerator non-zero, the ratio would evaluate to 0/1 which would indicate no potential for conflict, an inaccurate conclusion. Any expressed preference, even a single marker, should be distinguished from the case where zero preference markers appear in a grid cell.

2.4. Modelling potential conflict based on value compatibility analysis (VCA)

In this study, value compatibility scoring was used as the fourth method to assess potential conflict over land uses. VCA examines the extent to which land uses appear compatible with the perceived values mapped in multiple place locations. The supporting rationale for VCA is that the more compatible prospective land uses are with stakeholders' values, the less likely the potential for land use conflict. The most critical step in VCA is making a judgment about the compatibility of the different place values with the prospective land use. These compatibility judgments can be made by individual analysts (Brown and Raymond, 2014), by members of a land use planning team (Reed and Brown, 2003), or through assessment of individuals not directly involved in the VCA analysis (Brown and Reed, 2012). To operationalise place value/land-use compatibility judgments, we used an expert elicitation method. A convenience sample of 16 academics located at a major research university with expertise in land use planning were asked to score each place value/land use pair on a scale of −5 (highly incompatible) to +5 (highly compatible). The mean values of compatibility scores used in this study are presented in Table 3. To calculate the compatibility score of each grid cell, the mean value compatibility scores were multiplied by the number of associated values in each cell. Aggregated compatibility scores were generated by summing the scores of cells using the following equation:

$$VCS = \sum_{i=0}^{n} r_i c_i$$

where VCS is the aggregate value compatibility score per cell, n?? is the number of unique place values in each cell, r_i is the mean value of compatibility rating for the ¡??th value with each land-use which ranges from −5 to +5, and c$_i$??$_{??}$ is number of points for ¡??th value in each cell. The aggregated compatibility scores are based on the spatial distribution and composition of mapped place values and can take on both positive (compatible) and negative (incompatible) scores.

2.5. Evaluating the performance of conflict mapping methods

We examined the similarities and differences in the results of the different conflict mapping approaches using the phi (φ) correlation coefficient (Chedzoy, 2006). The phi coefficient is a variation of the Pearson correlation coefficient used for binary data where the statistical significance of the relationship is evaluated with the chi-square statistic. The phi coefficient falls within the range of +1.0 and −1.0 with stronger relationships found at either extreme. Fitz-Gibbon and Morris (1987) suggest the following interpretation: $\varphi < 0.2$ little or no association; $0.2 \leq \varphi < 0.4$ weak association; $0.4 \leq \varphi < 0.6$ moderate association; and $\varphi \geq 0.6$ strong association. For fair comparison using the phi coefficient, the same percentage of grid cells need to selected for each land use and method. To measure the similarity in results, we chose the top 15% as a threshold and identified the grid cells with the largest conflict potential scores. This threshold allowed for the generation of different conflict mapping outputs for comparison, with the exception of the preferences-only method (PS) for conservation and mining land uses. These two land uses had too many empty cells, or cells containing a single preference marker, to compare the results using the phi correlation coefficient.

We also evaluated the performance of the different conflict approaches by examining whether they identified selected reference sites within the Baffle Basin known to be controversial for mining, residential, or tourism development. The reference sites for conservation consisted of familiar natural areas such as national or conservation parks in the region. These reference site locations were selected through consultation with key informants familiar with land-use issues in the Baffle Basin. The spatial analysis consisted of determining which conflict methods identified the reference sites using a "hit" or "miss" criteria, i.e., whether the reference sites were identified in top 15% of the grid cells with the highest scores in the outputs. For the preferences-only method (PS), the highest threshold that was possible to assess reference sites for conservation and mining was the top 30% of grid cells given the large number of cells containing a single preference marker.

In the next step, we determined how sensitive conflict mapping methods are to the quantity of spatial data and number of participants at each reference site. One of the characteristics of participatory mapping methods is that spatial data will be unevenly distributed (i.e., clustered) across the study region. It is common practice in participatory mapping to allow participants to map a variable number of points to express their values and land-use preferences, with the resulting mapping behaviour influenced by their familiarity with the study region and their mapping effort (Brown, 2017). Thus, any given place or location within the study region will be represented by a fractional proportion of the total number of study participants, with some locations represented by a relatively small number of individuals. One can ascribe greater confidence to the mapped conflict results with larger sample sizes represented at a given location. In other words, conflict mapping should account for both the quantity and type of spatial data in a given location, as well as the number of individuals (site specific sample size) who mapped in the location. For each reference site, we assessed the number of unique participants (sample size) that mapped preferences in each reference site to compare with the total proportion

Table 3
Mean compatibility scores used for modelling place values/land-use relationships.

Place Value	Mining development	Conservation	Residential development	Tourism development
Scenic	−4.06	4.66	−0.2	1.46
Economic	4.46	0.26	2.73	4.53
Non water-based Recreation	−3.3	2	−0.13	3.53
Water-based Recreation	−2.8	1.4	0.06	3
Life sustaining/Ecological	−3.06	4.93	−0.4	1.2
Learning/scientific	0.4	4.2	−0.13	0.4
Biological	−3.33	4.93	−1	0.4
Spiritual	−4	4.13	0	0.93
Intrinsic	−2.26	4.33	−0.86	0.2
Historic/cultural	−1.66	3.8	1.06	1.8
Future	−2.4	4.8	0.86	1
Wilderness	−4.33	4.86	−3.4	−1.73
Social	−0.53	1.93	3.66	3.8

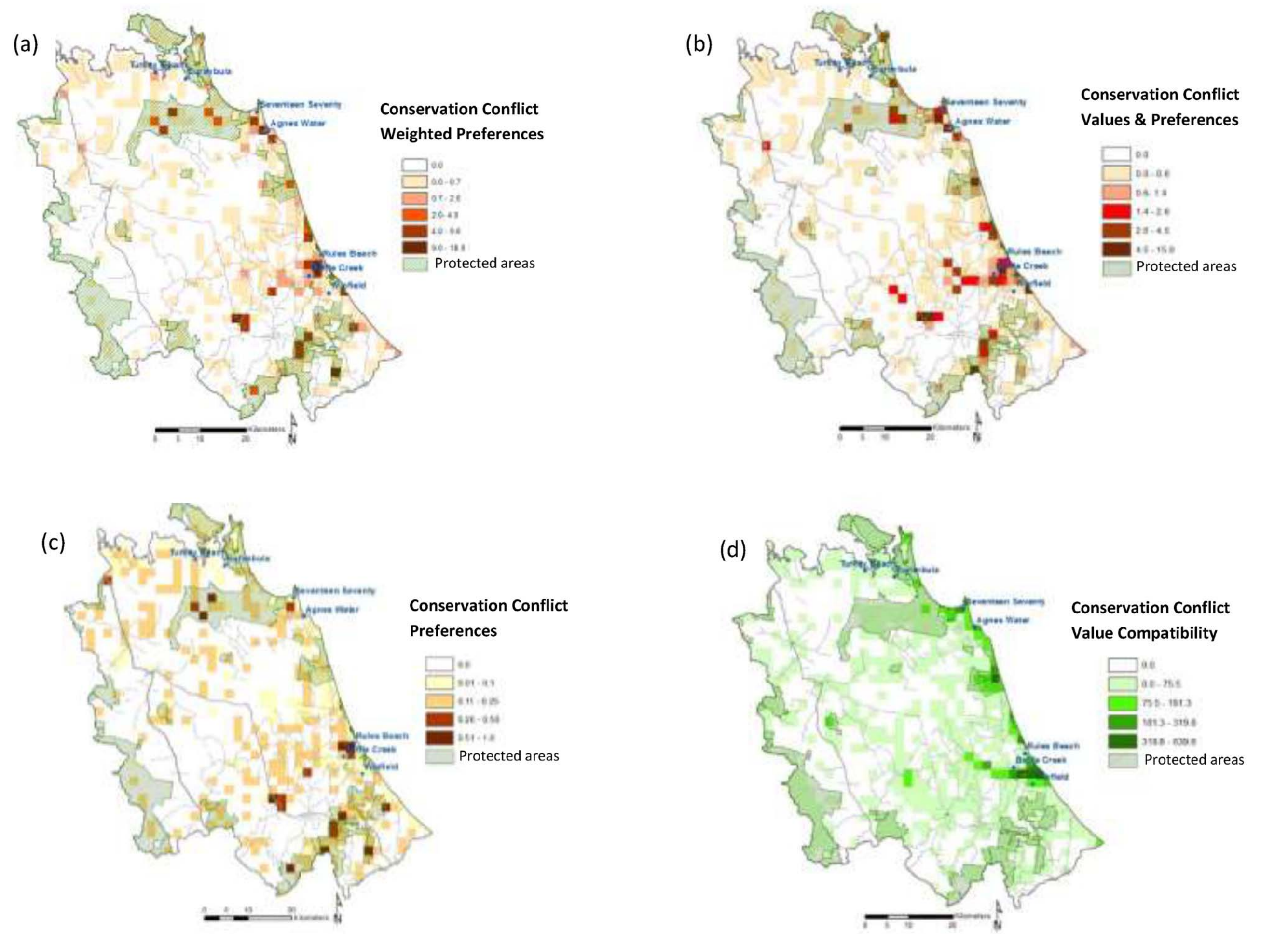

Fig. 2. Mapped conflict potential for conservation using (a) weighted preference index, (b) combined place value and land-use preference index, (c) preferences method, and (d) value compatibility scoring.

of markers.

2.6. Evaluating the level of confidence in conflict mapping results

The final analysis was designed to operationalise a method for ascribing confidence in the place-specific mapping results. To do this, we defined confidence levels based on the number of unique individuals mapping preference points for/against a land use in each grid cell. The supporting rationale is that higher confidence in place-specific conflict results are associated with more independent observations, i.e., more participants. These operationalized confidence levels are simpler than those used in statistical analysis and consist of nominal categories. For simplicity, confidence levels were classified into high and low categories based on the number of unique mappers for each land use. For the purpose of this study, grid cells in which more than three unique individuals mapped preference points was classified as a high confidence level. This heuristic choice for a confidence level was the same as the distribution of the cells using four or five unique mappers as a cut-off. To associate confidence with conflict potential results, we selected conflict maps using the weighted preferences method to illustrate one of many possible approaches. We reclassified conflict potential output maps containing the top 15% of the grid cells with highest

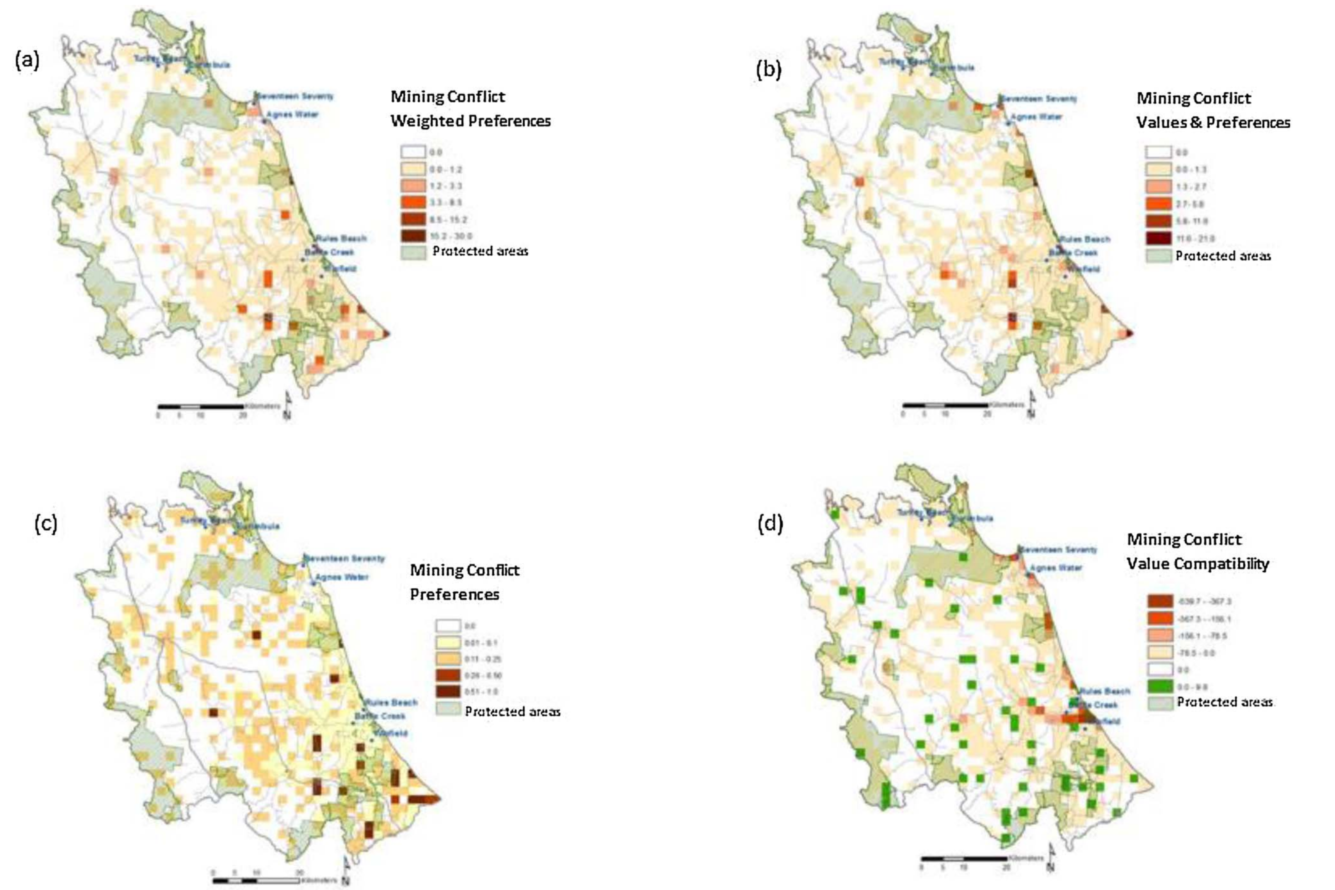

Fig. 3. Mapped conflict potential for mining using (a) weighted preference index, (b) combined place value and land-use preference index, (c) preferences method, and (d) value compatibility scoring.

conflict scores into two classes of high and low conflict potential. These categorical (high/low) conflict maps were then spatially intersected with the categorical confidence maps (high/low) to identify areas where high conflict potential overlapped with areas of high confidence.

3. Results

3.1. Survey results and respondent characteristics

The number of households invited to participate in Baffle Basin study was 1835. The response rates for the two PPGIS survey methods, internet-based and hard-copy maps, were 11.7% and 44.6% respectively, providing 264 total responses for analysis. The total number of place values and land-use preferences mapped by respondents was 8900 (72% internet and 28% hardcopy). The point distributions of place values and land-use preferences mapped by the internet and hardcopy respondents were similar, a finding consistent with other mixed methods mapping studies (see Pocewicz et al., 2012). Therefore, data from these two groups were combined for spatial analyses.

We performed a non-response bias check by sending postcards to non-participants and asked their reason(s) for non-participation. The dominant reason (38.2%) given by non-participants was lack of knowledge of the region. Other frequent reasons given for non-participation were living outside the Baffle region (12%), not having enough time (10%), and retired or no longer living in the area (5.3%).

The non-spatial survey questions accompanying the value and land-use preference mapping activity were completed by 199 participants. The majority of respondents (58%) were male with ages ranging from 19 to 90 (mean 59). The majority of internet respondents (60%) assessed their self-rated knowledge about the places in the Baffle region as excellent or good, while 37% of participants believed their knowledge about the area was average or below average. About 52% paper-based survey participants self-assessed their knowledge as excellent or good and about 35% reported their knowledge as average or below average.

3.2. Mapping conflict potential using multiple approaches by land use

We calculated conflict potential indices using preferences (PS), combined place values and land-use preferences (PVS), weighted preferences (WPS) and value compatibility scoring (VCA) approaches for each land use type. The results are presented as maps in Fig. 2 (conservation), Fig. 3 (mining), Fig. 4 (residential development) and Fig. 5 (tourism development). For conservation and mining, the conflict indices using PS, PVS and WPS methods show that the areas of conflict potential were distributed across the entire region (Figs. 2 a–c, 3 a–c), while for residential and tourism development, potential conflict was more concentrated in coastal areas (Figs. 4 a–c, 5 a–c). These results reflect underlying participant mapping behaviour wherein preferences for conservation and mining were more geographically distributed across the study region compared to tourism and residential development preferences which were mapped with higher intensity in smaller geographic areas.

Comparing the means of compatibility scores derived from the expert elicitation method reveal that the scores varied by land use type (Table 3). For example, mining activity was perceived as incompatible with all place values (negative scores) with the notable exception of economic value. For conservation land use, the majority of place values were perceived as compatible (positive scores), with economic value having the lowest mean compatibility score. Tourism development was

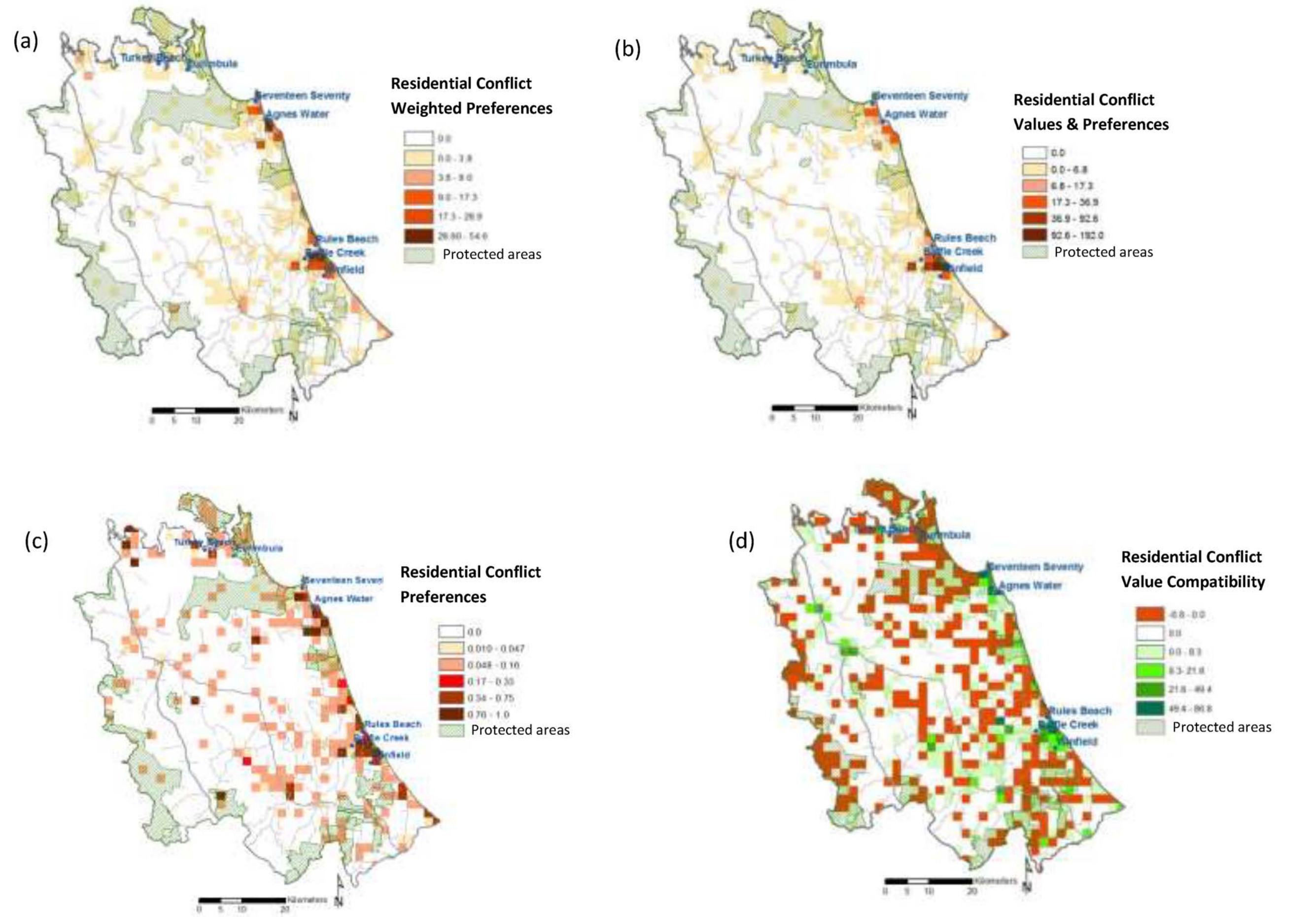

Fig. 4. Mapped conflict potential for residential development using (a) weighted preference index, (b) combined place value and land-use preference index, (c) preferences method, and (d) value compatibility scoring.

perceived as highly compatible with recreation and economic values, but incompatible with wilderness and biological values. Residential development was perceived as highly compatible with social and economic values, but incompatible with wilderness value.

Composite compatibility scores were generated from the spatial distribution of place values and displayed as map outputs for each land use. The different place values in the typology were assumed equally important and were given a weight of one when calculating the compatibility scores. The resulting value compatibility indices were then normalized on a continuous scale with scores ranging from negative to positive. If a particular grid cell contained more place values that were rated as incompatible with the associated land use, the compatibility scores would be negative. Positive scores represent greater compatibility between the perceived place values and proposed land-use types. The outcomes of VCA analyses show areas where a particular land use appears compatible or incompatible with public perceived values.

The results of this analysis were spatially variable for different types of land uses in the Baffle Basin. For example, compatibility analysis for conservation indicates that the whole region was identified as compatible with this use type with areas of highest compatibility located in coastal areas where place values were mapped with the higher intensity relative to other parts of the region (Fig. 2d). In the case of mining, Fig. 3d shows that grid cells with positive and negative scores were located adjacent to each other in the region, making results for these locations somewhat ambiguous, a likely artefact of the grid cell size selected for analysis. Mining activity in coastal areas, where most of the regional population is located, was identified as incompatible based on VCA scores, while areas where mining was identified as compatible were spatially dispersed, predominantly in inland areas. The VCA results for residential development shows that areas with negative compatibility scores were predominantly distributed in non-coastal, rural areas, with some smaller coastal and inland areas revealing perceived compatibility with residential development (Fig. 4d). Of all the land uses, the spatial area of negative compatibility was largest for residential development. In the case of tourism development, most of the region, including coastal areas, was identified as compatible. The incompatible areas for tourism development were geographically dispersed and appear on the map as single grid cells (Fig. 5d).

3.3. Comparing the outputs of different methods

We compared the similarities and differences in the different approaches used for identifying the potential for conflict for each type of land use: mining, tourism and residential development, and conservation. The spatial association between each pair of conflict maps for different land uses is presented in Table 4. We observed variability in the performance of the different methods for identifying conflict potential locations by land-use type.

The strongest associations, based on phi coefficients, were observed between weighted preferences (WPS) and combined place values and land-use preferences (PVS) approaches for tourism, conservation and mining, and between PVS and preferences scores (PS) for residential development (see highlighted results in Table 4). These results indicate that the distributions of the conflict areas were most similar when using these approaches compared with other methods. These spatial relationships were very strong between the outputs of the two methods

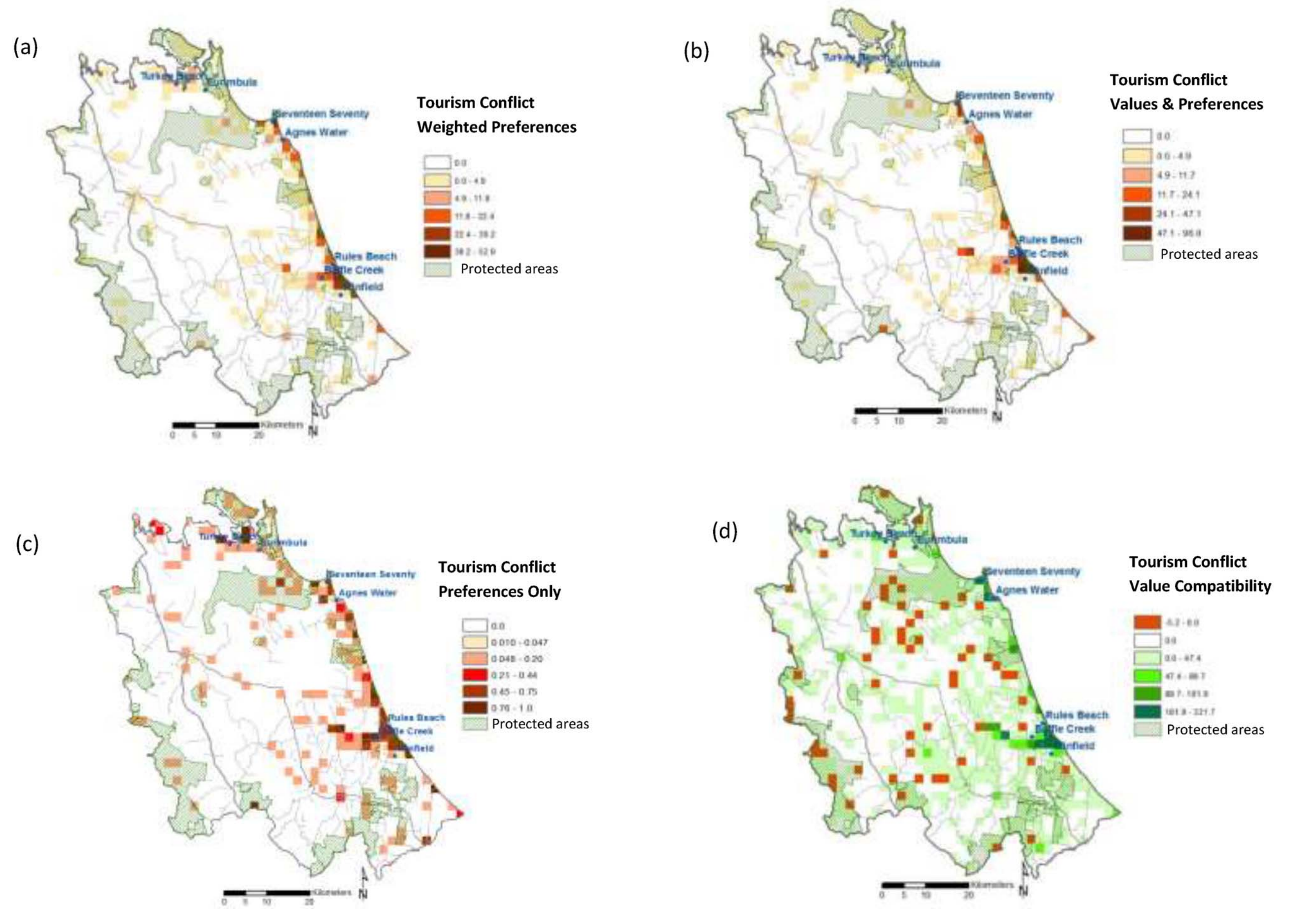

Fig. 5. Mapped conflict potential for tourism development using (a) weighted preference index, (b) combined place value and land-use preference index, (c) preferences method, and (d) value compatibility scoring.

for tourism (phi = 0.986) and residential development (phi = 0.907), and were strong for conservation (phi = 0.657) and mining (phi = 0.606).

For tourism and residential development, the top 15% of conflict scores from the PS method were strongly correlated with the top 15% of conflict scores from both WPS and PVS. In terms of the VCA method, we found that the place value compatibility scores were moderately associated with the combined place value and land-use preference indices (phi = 0.59) and were weakly related to the weighted preference conflict scores (phi = 0.387) for mining. There was weak or no significant relationships between VCA and conflict scores resulting from WPS and PVS approaches for tourism and residential development, and conservation.

3.4. Evaluating the performance of different methods using reference sites

We evaluated the performance of different methods for identifying potential conflict by examining whether the reference sites were identified by the conflict method (i.e., a "hit"). A "hit" occurs when the reference site is spatially coincident with cells falling in the top 15% of conflict scores. The results of this analysis appear in Table 5. Mapped conflict potential using land-use preferences only (PS) identified all the reference sites associated with residential, tourism, and mining development, as well as conservation. Similarly, the combined place values with land-use preferences (PVS), and weighted preferences (WPS) approaches also identified all reference site locations. In contrast, the value compatibility method (VCA) was less reliable, identifying less than half of the reference sites in the top 15% of grid cells with large incompatibility scores.

For tourism and residential development, the preferences (PS), combined place values and land-use preferences (PVS), and weighted preferences (WPS) approaches identified all six reference sites (Table 5 and Fig. 6a–c). For tourism development, the VCA method identified three out-of-six reference sites including Baffle Creek, Deep Water, and Agnes Water (Table 5 and Fig. 6c). Of the five reference sites for residential development, only two (Rules beach and Baffle Creek) were definitively identified by value compatibility scoring (Table 5 and Fig. 6a).

For mining, the single reference site of Winfield was identified using PVS and WPS methods (top 15% of conflict scores in Fig. 7a and b) and the PS method (top 30% of scores in Fig. 7c). The VCA method was able to identify the Winfield reference site for mining with negative VCA scores indicating value incompatibility with mining activity in this location (Table 5 and Fig. 7a).

For conservation, all four reference sites were identified using PVS and WPS approaches (top 15% of scores in Fig. 7d and e) and the PS method (top 30% of cells with highest conflict scores in Fig. 7f). The VCA approach generated only positive scores for all grid cells for conservation, so we considered the top 15% of cells with the lowest, but positive scores. None of the conservation reference sites were identified using this criterion (Table 5 and Fig. 7d).

The amount of spatial data available for assessing whether the conflict mapping methods identified the reference sites varied by site location (see Table 5). The number of preferences mapped by unique participants for/against different types of land uses was greatest for Rules Beach and lowest for Turkey Beach. Preferences in support of mining in Winfield were mapped by only two individuals, while preferences against conservation in Agnes Water and Seventeen Seventy

Table 4
Pairwise associations between different conflict scores for highest 15% of grid cells. The colour ramp shows the strength of the relationship between the results of the two methods, the darker the colour of the cell represents the stronger associations between the results of the two method.

Land use		Weighted pref. (WPS)	Combined value & pref. (PVS)	Preferences [a] (PS)
Tourism development				
	Combined value & pref. (PVS)	**0.986*** **		
	Preferences (PS)	0.944***	0.958***	
	Value compatibility (VCA) [b]	−0.056	−0.05	−0.045
Residential development				
	Combined value & pref. (PVS)	0.841***		
	Preferences (PS)	0.808***	**0.907*** **	
	Value compatibility (VCA) [b]	0.102***	0.12***	0.108
Conservation				
	Combined value & pref. (PVS)	**0.657*** **		
	Value compatibility (VCA)	−0.055	−0.16	
Mining				
	Combined value & pref. (PVS)	**0.606*** **		
	Value compatibility (VCA) [b]	**0.387*** **	**0.59*** **	

[a] This method was used in the comparative analysis only for residential and tourism development.
[b] Least compatibility scores were used.
*** Significant at 0.001 level.

were also mapped by only two participants (Table 5)

3.5. Evaluating the level of confidence in conflict mapping results

To operationalise confidence levels with the conflict mapping results, we categorized conflict scores into high/low categories based on weighted preferences (WPS) and overlayed with grid cells categorized as high/low confidence levels based on the number of individuals that placed markers in each cell. The graphical results of the spatial overlays for the four land uses appear in Fig. 8 while the quantitative results appear in Table 6. Most of the study area was classified as low confidence as indicated by green-shaded cells. Areas with high potential for conflict are indicated by magenta-shaded cells. Overall, the greatest confidence was observed for tourism development with 40.6% of high conflict potential areas overlapping with areas of high confidence (Fig. 8c), followed by mining (12.2%–Fig. 8a), conservation (11.7%–Fig. 8b), and residential development (9.6%–Fig. 8d). Visually, these results appear in Fig. 8 as dark-coloured magenta cells (high conflict/high confidence) and light-coloured magenta cells (high conflict/low confidence).

All the reference sites selected for the four land uses were classified as having high potential for conflict, confirming their initial selection as reference sites. In most cases, there was high confidence, i.e.,more unique individuals mapping preferences in the location of these reference sites. Some reference site exceptions include tourism development in Baffle Creek and Rules Beach (Fig. 8c) where there was lower confidence in the results. Also noteworthy were areas with high confidence and low potential for conflict as indicated by dark green cells. These areas occurred mainly with mining and conservation land uses (Fig. 8a and b) and indicate that many individuals mapped similar (rather than different) preferences for these areas. Specifically, there appears to be low potential for conflict in the lower Baffle Creek area for mining activity (Fig. 8a) due to a large number of individuals indicating preferences that mining not occur in this area.

4. Discussion

The purpose of this paper was to evaluate different approaches for identifying land-use conflict potential using participatory mapping data from a regional study in Queensland, Australia. We expanded on previous conflict mapping research by evaluating four different types of land use, by experimenting with expert elicitation of value compatibility scores, and by operationalising confidence levels for conflict mapping results. Our findings show that mapped preferences (PS), combined place values and land-use preferences (PVS), and weighted preferences (WPS) methods identified all reference sites predicted to have high conflict potential. An alternative method, value compatibility analysis (VCA), was less effective in identifying selected reference sites. Our results were consistent with other studies that applied these methods in different geographical locations in Australia (Brown and Raymond, 2014) and northern Finland (Brown et al., 2017).

With the PS, PVS and WPS approaches, areas of high conflict potential were predominantly located in coastal areas of the study region, a result consistent with contemporary land-use discussions about development and conservation in the region. For example, in the Baffle Creek and Agnes Water locations, there are conflicts between residents seeking to accommodate larger numbers of tourists and conservationists that prefer to limit development to protect these areas of high natural significance. Similar to Moore et al. (2017) who found tourism development to be a key driver of conflict potential in the coastal environment of Kimberley region in Western Australia, our study also found that coastal areas contained the highest levels of conflict potential for all prospective land uses, but especially tourism and residential development.

Our findings indicate that mapped preference data provide the most effective model foundation for identifying conflict potential. Weighting the mapped preferences, either by number of values or preferences serves to amplify and clarify the findings, but does not appear to significantly alter the locations of mapped results. This conclusion is consistent with Hausner et al. (2015) who reported that the weighting of conflict potential derived from mapped preferences, either with the number of mapped preferences or place values, did not fundamentally change the spatial location of the results. Our results also confirm the performance of WPS and PVS methods in identifying reference sites for different land uses. Brown et al. (2017) suggest there may be some benefit to using the weighted preferences approach (WPS) to evaluate land uses that are project or site-based such as mining and tourism development and the place value and land-use preference approach (PVS) to evaluate more spatially distributed land uses such as forestry and grazing. The supporting rationale is that interpretation of spatial results is less ambiguous for site-specific land uses such as mining and tourism development because the WPS method is not affected by proximate values that may or may not be compatible with the proposed land use. In contrast, distributed land uses such as forestry where conflict potential may cover large spatial areas, weighting the preferences by mapped values has the effect of narrowing conflict potential to areas where place values could be incompatible with the land use. Although the WPS and PVS approaches generated similar conflict potential maps for all land uses examined in our study, we suggest future studies using the WPS approach for identifying conflict potential for project or site-based uses and applying the PVS method for those land uses that occur in larger geographical areas.

In the previous study by Brown and Raymond (2014), the value compatibility analysis (VCA) method was able to identify about 40% of the locations of controversial development as reference sites for residential and industrial development. Our findings also highlight the limitation of VCA analysis for identifying conflict reference sites in the study region. Only two out of five reference sites for residential development, and three out of six reference sites for tourism development, were identified as incompatible with perceived values. None of the four reference sites associated with conservation were identified as areas

Table 5
Evaluating the performances of multiple approaches of conflict mapping using reference sites. The marks indicate the reference sites have been identified as areas of high conflict potential in the output maps.

Land use		Value compatibility analysis (VCA)		Place value & pref. (PVS)	Weighted pref. (WPS)	Preferences (PS)	Total # pref. points for Land use (Total # individuals)	Total # pref. points against Land use (Total # individuals)	# pref. points for land use (# individuals) in reference site	# pref. points against land use (# individuals) in reference site
		In negative scores (or least compatibility scores)	In top 15%	In top 15%						
Residential development							232 (63)	347 (74)		
	Rules Beach		*	*	*	*			32 (23)	61 (26)
	Baffle Creek		*	*	*	*			29 (17)	27 (11)
	Agnes Water	–	–	*	*	*			53 (29)	44 (20)
	Seventeen Seventy	–	–	*	*	*			17 (14)	53 (22)
	Turkey Beach	*	–	*	*	*			16 (11)	6 (3)
Tourism development							218 (67)	235 (64)		
	Rules Beach	–	–	*	*	*			43 (27)	39 (22)
	Baffle Creek		*	*	*	*			19 (14)	18 (10)
	Deep Water		*	*	*	*			16 (10)	31 (17)
	Agnes Water		*	*	*	*			44 (36)	16 (9)
	Seventeen Seventy	–	–	*	*	*			25 (23)	8 (7)
	Turkey Beach	–		*	*	*			10 (8)	3 (3)
Conservation						In top 30%	865 (97)	53 (19)		
	Rules Beach	*	–	*	*	*			107 (39)	9 (7)
	Deep Water	*	–	*	*	*			51 (20)	5 (3)
	Agnes Water	–	–	*	*	*			68 (17)	3 (2)
	Seventeen Seventy	–	–	*	*	*			45 (21)	2 (2)
Mining							50 (17)	938 (95)		
	Winfield	*	–	*	*	*			2 (2)	38 (17)

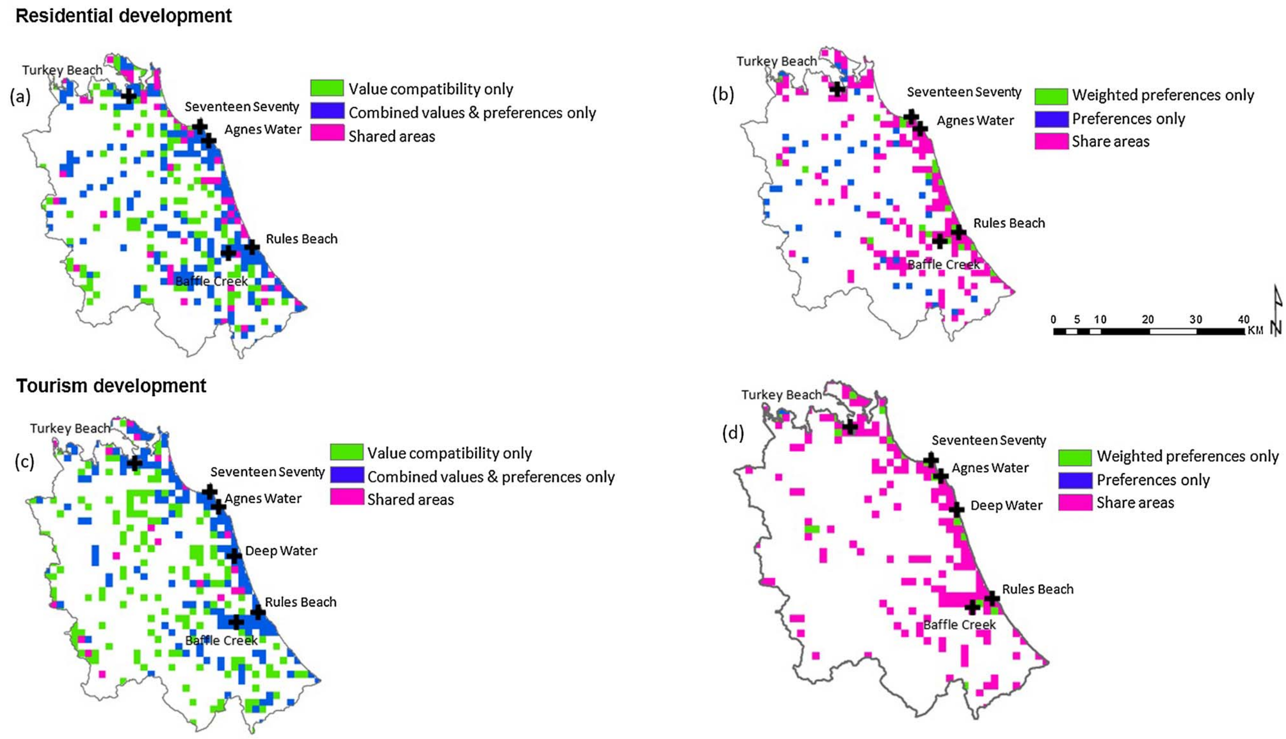

Fig. 6. Outputs of conflict mapping methods showing the locations of reference sites with a) value compatibility scoring and combined value & land-use preference scoring (top 15%); (b) weighted preferences and preferences only scoring for residential development (top 15%); (c) value compatibility scoring and combined value & land-use preference (top 15%); and (d) weighted preferences and preferences only for tourism development (top 15%).

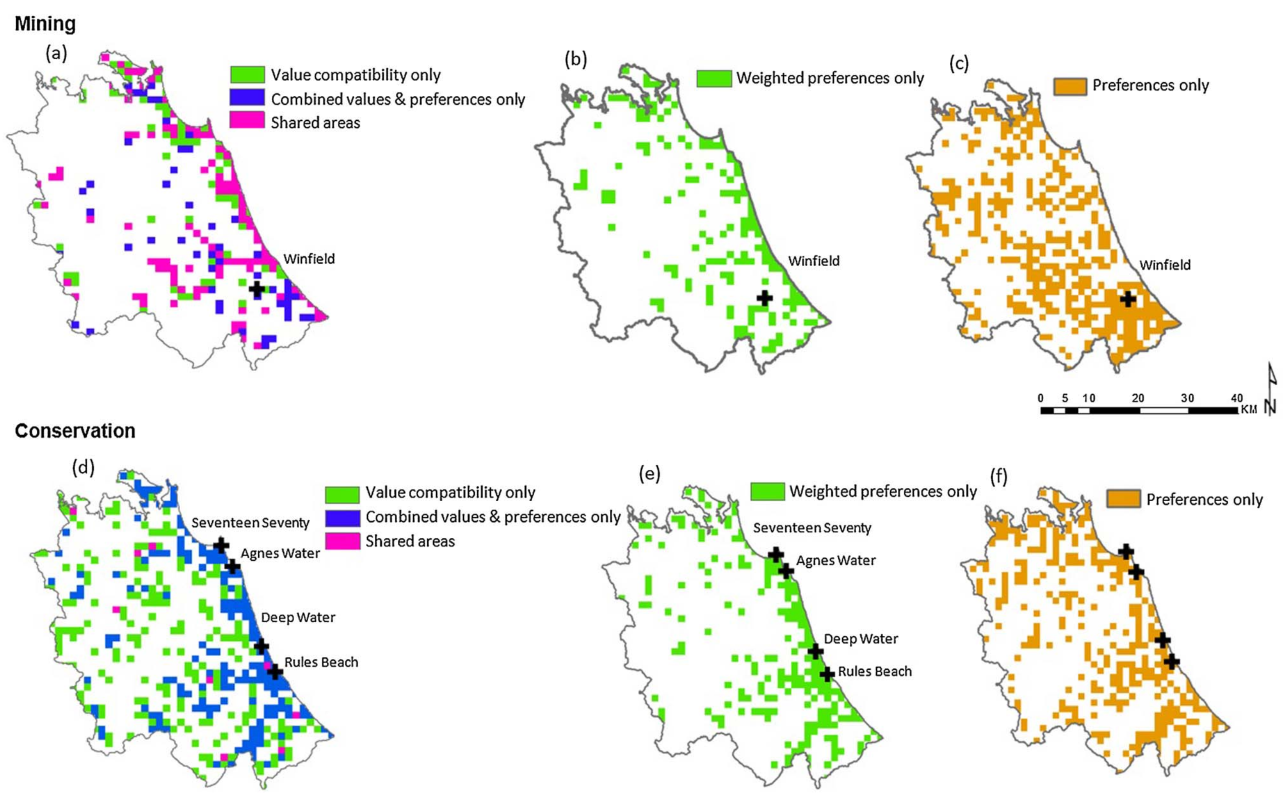

Fig. 7. Outputs of conflict potential mapping methods showing the locations of reference sites with a) value compatibility scoring and combined values & land-use preferences scoring (top 15%); (b) weighted preferences (top 15%); (c) preferences only for mining (top 30%); (d) value compatibility scoring and combined values & land-use preferences (top 15%);(e) weighted preferences (top 15%); and (f) preferences only for conservation (top 30%).

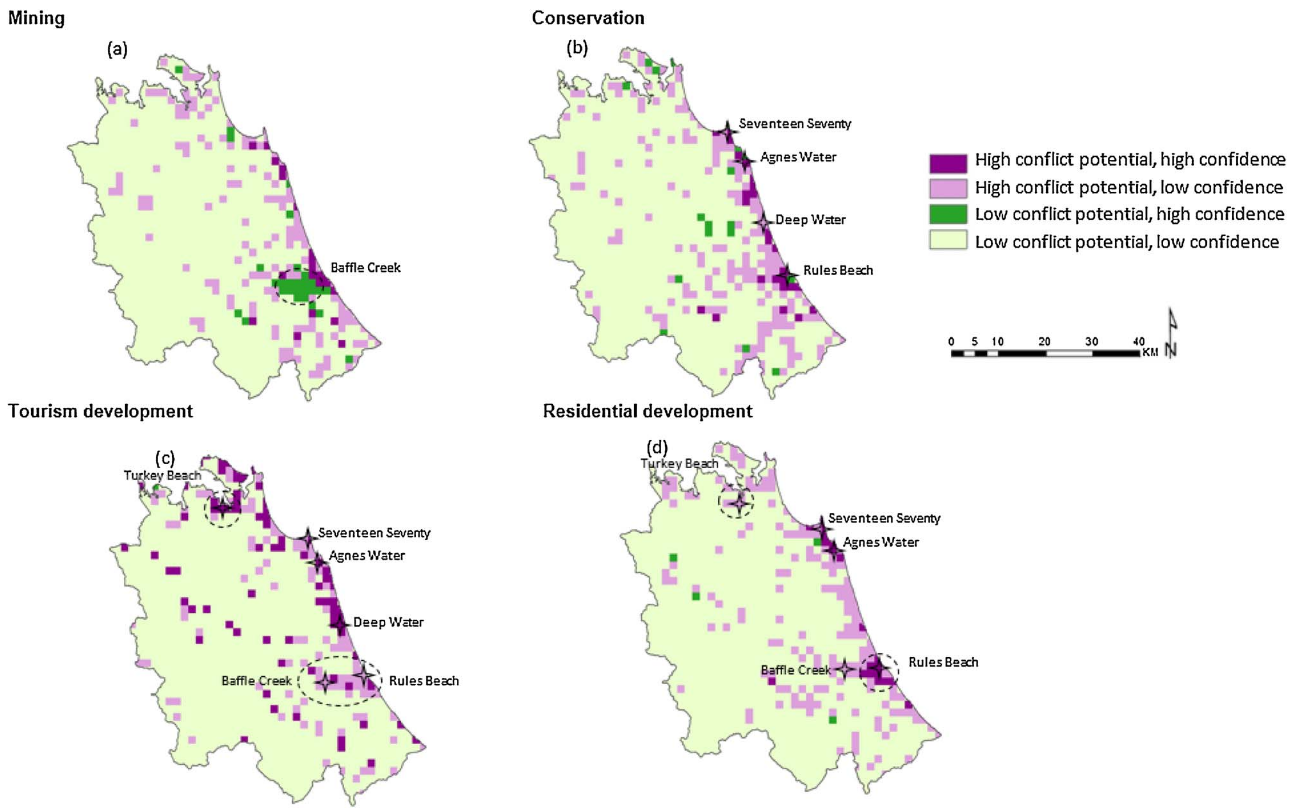

Fig. 8. Overlays of conflict mapping results with confidence levels based on the number of participants for (a) mining, (b) conservation, (c) tourism and (d) residential development.

where conflict for conservation is most likely to arise. The conflict results using weighted preferences (WPS), and combined place values and land-use preferences (PVS), were only moderately associated with value compatibility scores for mining land use, and there was relatively little association between these methods for land uses associated with tourism and residential development, and conservation. While the mapping of place values is likely to be less controversial for planning authorities than the mapping of preferences given the more indirect and ambiguous relationship between place values and land use, our findings reinforce the importance of explicitly collecting land use preference data for identifying conflict potential.

The use of mapped preference data, however, has limitations especially when the data are very unevenly distributed between preferences in support or opposition to a proposed land use. In our study, the preferences only (PS) method failed to yield clear results when using a 15% threshold for identifying the highest conflict potential areas for mining and conservation because of the large differential in the number of preference points supporting or opposing these land uses. The difference in the number of points mapping for/against mining and conservation was very large, whereas the number of preferences supporting/opposing residential and tourism development were more balanced. Specifically, mapped preferences for/against mining and conservation were 938/50 and 865/19 respectively, compared to tourism (218/255) and residential development (232/347). The unbalanced distribution of preferences can mask the actual level of disagreement over land uses in specific locations, especially when using the preferences only method (PS). Weighting mapped preferences using the WPS and PVS methods clarified the results, enabling the identification of the top 15% of conflict potential locations for mining and conservation. Thus, conflict mapping approaches that include weighting can help compensate for highly unbalanced preference data.

A second limitation when using mapped preferences is the need to make assumptions about conflict with grid cells containing a single mapped preference. In this and previous studies, a constant of 0.1 was assigned to non-empty grid cells containing a single mapped preference to differentiate these cells from empty cells. However, there are situations where mapped preferences containing both supporting and opposing land uses in the same cell can generate a smaller conflict score than the assigned 0.1 constant. For example, 11 preferences for and one preference against the same land use in a cell would generate a conflict score of 0.09, lower than the assigned 0.1 constant. This outcome is counter-intuitive as the cell contains direct evidence of conflicting preferences. Our suggestion would be to examine the distribution of conflict scores and assign a smaller constant, if necessary, to ensure the constant is smaller than the conflict score for every grid cell containing contrasting pReferences

Identifying potential land use conflict requires sufficient spatial data to make valid inferences. The larger the study area, the greater the quantity of spatial data required to make place-specific inferences about conflict. In our study, the number of points available in spatial locations for some reference sites was limited. Moreover, in some cases, these limited numbers of points were mapped by a few unique participants. For example, only two individuals mapped points for mining and against conservation for some of the references sites. To assess the inferential quality of conflict mapping from participatory data, we operationalised the concept of confidence levels based on the number of individuals that mapped preferences in a given location. Our findings revealed that not all areas identified as high conflict potential have the same inferential strength based on the quantity of preference data and number of participants. Confidence levels varied spatially in the region with overall confidence in tourism development conflict mapping being significantly higher than other land uses analysed in this study. Further, the high conflict potential identified for some reference sites was based on relatively few participants. This does not mean that conflict mapping results with low confidence are inaccurate, but that the results should be interpreted cautiously. We suggest that land use planning resources first target places with both high conflict potential and high confidence.

Table 6
Study area distribution (cross-tabulation) of mapped conflict potential (high/low) using weighted preferences (WPS) with confidence levels (high/low) based on number of individuals mapping each cell.

Land use					
Conservation		**Confidence level**			
			High	Low	Total
Conflict potential	High	Number of cells	353	2669	3022
		% within conflict potential	11.7%	88.3%	100%
	Low	Number of cells	240	12770	13010
		% within conflict potential	1.8%	98.2%	100%
	Total	Number of cells	593	15439	16032
		% within conflict potential	3.7%	96.3%	100%
Mining		**Confidence level**			
			High	Low	Total
Conflict potential	High	Number of cells	296	2140	2436
		% within conflict potential	12.2%	87.8%	100%
	Low	Number of cells	439	13157	13596
		% within conflict potential	3.2%	96.8%	100%
	Total	Number of cells	735	15297	16032
		% within conflict potential	4.6%	95.4%	100%
Tourism development		**Confidence level**			
			High	Low	Total
Conflict potential	High	Number of cells	1055	1541	2596
		% within conflict potential	40.6%	59.4%	100%
	Low	Number of cells	8	13428	13436
		% within conflict potential	0.1%	99.9%	100%
	Total	Number of cells	1063	14969	16032
		% within conflict potential	6.6%	93.4%	100%
Residential development		**Confidence level**			
			High	Low	Total
Conflict potential	High	Number of cells	260	2458	2718
		% within conflict potential	9.6%	90.4%	100%
	Low	Number of cells	64	13250	13314
		% within conflict potential	0.5%	99.5%	100%
	Total	Number of cells	324	15708	16032
		% within conflict potential	2%	98%	100%

5. Conclusion

This study provided the opportunity to systematically evaluate and visually compare the performance of the alternative approaches to identify areas of potential land-use conflict. This study also increased the external validity of previous conflict mapping studies by applying the conflict mapping methods to a new geographic context. Our results show that preference-based spatial data, especially weighted approaches that include values, are reliable approaches to identify conflict potential at site-specific locations. However, limitations in the quantity of spatial data can limit the inferential quality of conclusions about land use conflict potential. The generation of confidence levels for the mapped results, operationalised for the first time in this study, can assist in the prioritization and allocation of planning resources to places with high conflict potential and high confidence. Most agencies with planning authority have finite resources (human, financial, time) to engage in community consultation and public participation processes to the fullest extent they would prefer. In this situation, agencies should prioritise conflict management (e.g., more extensive stakeholder engagement and collaboration) in areas where the potential for conflict is high and where there is also high confidence in the results. In places identified as having high potential for land-use conflict, but low confidence based on the number of mapping participants, it would be prudent to gather more information about public preferences for the proposed land use. This can be achieved by focusing participatory mapping or other public participation methods on a smaller area.

Although we used an enhanced expert method for identifying land use and value compatibilities to identify conflict potential, the values compatibility analysis (VCA) method did not perform as well as preference-based approaches. However, as indicated by Moore et al. (2017), the VCA method can be useful for engaging groups of stakeholders in discourse about the value/use compatibilities that underpin land use conflict.

As indicated by Brown et al. (2017), the systematic evaluation of conflict potential based on participatory mapping data remains a nascent area of social research with little guidance for linking mapped conflict potential levels with real-world locations or the construction of the confidence levels. Our study has incrementally increased the validity of preference-based conflict mapping methods through extension to a new geographic context, while providing a means to assess the inferential quality of the results through the operationalisation of confidence levels. Future research would benefit from further refinement and calibration of methods that impute confidence levels to the conflict mapping results that are accessible to land planners and managers.

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