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Research Paper

# Methods for identifying land use conflict potential using participatory mapping

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## HIGHLIGHTS

- Conceptualizes and operationalizes methods for identifying and mapping land use conflict potential.
- Uses PPGIS data from a regional study in Australia to map potential conflict for residential and industrial development.
- Evaluates three different methods (values, preferences, combination) to map land use conflict potential.
- Describes the strengths and weaknesses of each mapping method with examples from the case study.
- Argues that conflict indices derived using both values and preferences are currently the best method but more research needed.

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## ABSTRACT

The number of public participation GIS (PPGIS) applications to inform local and regional land, use planning has increased significantly over the last decade. An important rationale for undertaking, participatory mapping is to anticipate and identify areas of potential land use conflict. To date, there, has not been a systematic evaluation of methods for identifying land use conflict potential with PPGIS data. This study uses data from a regional planning study in Australia to describe and evaluate alternative methods for identifying land use conflict potential. A simple, two dimensional model of land use conflict is presented and operationalized with spatial data to provide a heuristic device for regional land-use planning practitioners. Land use conflict is posited to derive from differences in landscape values and land use preferences that can be formulated into different conflict indices and presented in maps. We demonstrate application of the conflict mapping model using residential and industrial development in the region as examples. The spatial distribution of landscape values, values compatibility scoring, land use preference differences, and a combined values and preferences scoring index are all viable methods for identifying and mapping the potential for land use conflict. The preferred method for assessing the potential for land use conflict is one that integrates two dimensions: land use preference directionality (supporting or opposing) and the importance or intensity of landscape values. We discuss the strengths and limitations of each conflict mapping method.



## 1. Introduction

Land use conflict occurs whenever land-use stakeholders have incompatible interests related to land areas that result in negative effects (von der Dunk, Gret-Regamey, Dalang, & Hersperger, 2011). The sources of land use conflict are many and may include disagreement over fundamental values, resource scarcity, social power imbalances, and a lack of clear institutional arrangements including property rights, among others. At the extreme, conflict over land can escalate into violence (Alston, Libecap, & Mueller, 2000). An aspiration of land use planning is to meet current and future societal needs while keeping land use conflict bounded and functional. In Western societies, zoning ordinances and land use controls for private property seek to identify and separate potentially incompatible land uses while the development of comprehensive and regional plans identify broad land use allocations to harmonize expectations about future land use. But the rationalization of land use can never circumvent land use conflict because land and society are in a continual state of flux. Change in the social or physical environment (or both) is the catalyst for land use conflict. Thus, the question is not about land use conflict

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avoidance per se, but conflict management and amelioration. The methods described herein identify the potential for land use conflict so that social resources can be allocated to manage the conflict through communication and community engagement.

Two main types of conflict emerge in the psychology literature: social values and interpersonal conflict. Social values (i.e., social acceptability) conflict occurs between groups who do not share similar values or norms about an activity and can occur even when there is no direct physical contact between groups (Ruddell & Gramann, 1994; Vaske, Donnelly, Wittmann, & Laidlaw, 1995; Vaske, Needham, & Cline, 2007). For example, while not witnessed first-hand, residents may philosophically disagree with industrial development in a particular location within a region. This has been seen with respect to social conflict over rural growth priorities (Greider & Garkovich, 1994). Interpersonal conflict occurs when the physical presence or behaviour of an individual or group interferes with goals, expectations or behaviour of another individual or group (Jacob & Schreyer, 1980). In a land-use planning context, interpersonal conflicts can relate to clashes over the health impacts of mobile phone antennas (Marcus, 2007), visual blight of wind turbines (van der Horst & Toke, 2010), noise from road traffic (Joerin, Theriault, & Musy, 2001), rural and urban lifestyles in peri-urban landscapes (Hite, 1998), the demolition of historic buildings (Hunziker, Buchecker, & Hartig, 2007; Rollero & De Piccoli, 2010) and changes to the natural environment (von der Dunk et al., 2011; White et al., 2009).

Multiple, specific forms of land use conflict have been described in the literature. In a recent review, von der Dunk et al. (2011) identified six conflict types of noise pollution, visual blight, health hazards, nature conservation, preservation of the past, and changes to the neighbourhood. Most of these types of conflicts have been explored or examined in separate studies; for example, the visual blight of wind turbines (van der Horst & Toke, 2010), noise from road traffic (Joerin et al., 2001), and conflicts associated with land clearance for new residential developments (Young et al., 2005). Often these conflicts are associated with not-in-my backyard (NIMBY) reactions to new developments, as exemplified through studies on residential development (Pendall, 1999), commercial developments such as airports (Freestone, 2009), and sustainable energy developments such as wind power (Devine-Wright, 2013).

Despite conflict being associated with location and physical space, relatively few studies have mapped the potential for conflict spatially. Over the past two decades, spatial decision support systems (SDSS) that link multi-criteria analysis methods with geographic information systems have been used to facilitate understanding of conflict (Armstrong, 1993; Carver, 1991; Godschalk, McMahon, Kaplan, & Qin, 1992; Jankowski, Nyerges, Smith, Moore, & Hovarth, 1997; Malczewski, 1999; Thill, 1999). More recently, Brody et al. (2004) used a SDSS to map the potential for competing stakeholder values when establishing protected areas in Texas. Multiple values associated with a range of stakeholders were mapped and hotspots of potential conflict identified. Results indicated place-specific differences in potential conflict, with the greatest amount of conflict predicted to occur in the coastal environment. This work was expanded to include the value proxies of biodiversity, aesthetic, recreation, commercial fishing, marine transportation, coastal development, historical/cultural sites, and research and education within mining lease blocks in Texas (Brody et al., 2006). Those site blocks with the highest value score (a function of occurrence and coverage) were assumed to be the areas of highest potential conflict for oil/gas production. Brown and Weber (2011) used Internet-based public participation geographic information systems (PPGIS) methods to enable visitors to Alpine National Park, Australia, to map their park visitation experiences. A layer showing the diversity of park experiences was presented as a proxy for potential visitor conflict. Bourgoin, Castella, Pullar, Lestrelin, and Bouahom (2012) used participatory landscape simulation to help villages understand the implications of land zoning for their livelihoods. People drew areas of different land uses on a board made of 100 one-hectare cells and assigned economic and environmental returns (values) to different land-use types. The resulting values helped participants to negotiate land-use conflicts and adapt their plans until consensus was reached. Each of these mapping approaches assumes that the magnitude of value or activity assignment is a proxy for interpersonal conflict. However, these mapping approaches do not effectively identify areas of social values conflict or areas where groups do not share similar norms about development.

Other studies highlight the potential for conflict based on development preferences as mapped by residents of, or visitors to a region. When aggregated, these preferences are a useful proxy for social values conflict because they enable the identification of areas where acceptable and inappropriate types of development overlap (a form of social acceptability), as perceived by different groups. In 2004, a baseline study of residential and tourism development preferences was conducted on Kangaroo Island (KI), South Australia, using paper-based PPGIS (Brown, 2006) and in 2010, a follow-up internet-based PPGIS monitoring study was conducted to examine whether residents' tourism development preferences had changed over the last six years (Brown & Weber, 2013). Locations of preference conflict were identified where tourism development hotspots were spatially coincident with "no development" preference hotspots. In 2010, the conflict areas had expanded to new coastal areas in the north and south of KI (Brown & Weber, 2013). PPGIS techniques have also been used to assess the social acceptability of three residential development policies (protecting productive lands, growth boundaries, targeted protection of conservation lands) with respect to rural agricultural regions experiencing exurban development (Goldberg et al., 2011; Nielsen-Pincus et al., 2010). Results demonstrate a complex set of conflicting trade-offs which need to be considered by rural planning authorities. Urban growth boundary policies produced the most socially acceptable development patterns and supported habitat for a wide range of species (Goldberg et al., 2011).

Each of these development preference mapping studies do not identify where social values conflict may be magnified by interpersonal values conflict. An exception is recent work in the Chugach National Forest, Alaska, which generated a conflict potential index that combined acceptable and inappropriate forest use preferences within each forest management area and the number of landscape values mapped in the area (Brown & Donovan, 2013). Understanding the interactions between social values and interpersonal conflict is important to enable land management agencies to identify the location, nature, and intensity of potential conflict from the public and stakeholders to ensure that prospective land use allocation or management decisions are informed about the trade-offs and potential consequences of those decisions.

We present a new conceptual model of land use conflict potential (Fig. 1) for use by planning practitioners who are employed in state agencies or local government and are responsible for developing and revising regional land-use planning strategies. This model is an empirical and spatial approach to land-use conflict assessment and combines the elements of social conflict (operationalized as land use preference agreement/disagreement) with interpersonal conflict (operationalized as place value intensity) and relies upon potential conflict emerging through the mapping of values and preferences. We propose that the highest potential for land use conflict will occur in areas where there is development preference disagreement (a large difference between areas of acceptable and inappropriate development preference) and high place importance (high landscape value intensities). High potential for land-use

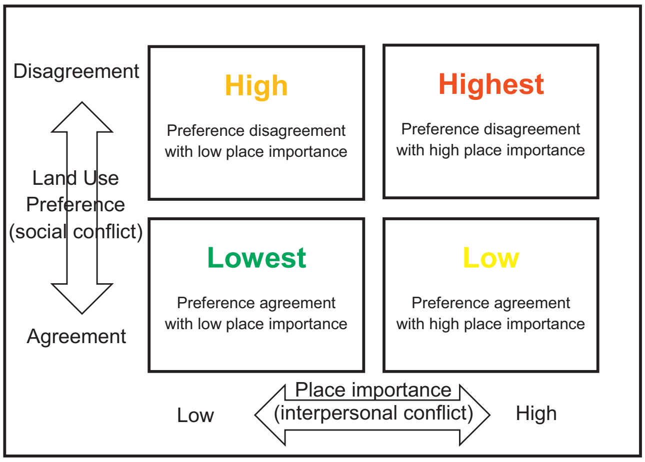


**Fig. 1.** Land use conflict potential as a function of the level of agreement on land use preferences and place importance.

conflict will remain in areas with land use preference disagreement, but with lower place importance (low landscape value intensities). The lowest potential for land use conflict will occur in areas where there is agreement on land use combined with low place importance. Low potential for land use conflict will occur in areas with land use preference agreement but high place importance. Although these four categories are presented as discrete conditions for purposes of illustration, the two dimensions of land use agreement and place importance are best characterized as continuous variables.

Our purpose in this research is to demonstrate how this conceptual model of conflict potential can be operationalized using spatial information obtained from a participatory GIS case study from the Lower Hunter region in New South Wales, Australia. We select two prospective types of land use—residential and industrial development—as examples to show how land use conflict potential can be identified and mapped in the region. We describe the calculation of value and preference indices (scores) from spatial data that measure the two dimensions of conflict potential separately, as well as an index that combines both dimensions. We present regional maps developed from the value and preference scores and calculate their spatial association to determine if these variables function independently or appear to be spatially related. To evaluate the predictive power of conflict mapping methods, we select 13 current or proposed large residential and industrial developments in the region as reference sites to assess whether the conflict mapping methods identify these areas. Finally, we discuss the strengths and limitations of the methods and approaches for mapping land use conflict potential.

## 2. Methods

### 2.1. Study area

The Lower Hunter Region (Fig. 1) is located in Eastern New South Wales, Australia, and covers approximately 430,000 ha, 60% of which is covered in native vegetation (DECCW, 2009). In 2006, the population of the region was estimated at 515,000 and is projected to grow to 675,000 persons by 2031 (Department of Planning, NSW). In 2010–11 the region had the fastest population growth outside Sydney, with an annual level of growth of 1.2% (ABS 2012). The Lower Hunter includes the five local government areas of Cessnock, Lake Macquarie, Maitland, Newcastle and Port Stephens. The largest city in the region is Newcastle, which is located approximately 118 km north of Sydney. Newcastle traditionally was a steel processing centre; however, today much of its economic activity stems from the shipping of coal to international ports, including China. The wider Lower Hunter region supports a variety of land uses including open-cut coal mining, residential, and industrial development. The alluvial flats of the major rivers and creeks in the region are used for intensive farming such as dairying and vegetable growing, graduating to viticulture, cereal crops, beef cattle, horses, and sheep production further inland (Mcdonald et al., 2008). The area also contains a number of areas of national environmental significance, including estuaries that are of significance for migratory shorebirds, and one of the largest coastal saltwater lakes in the southern hemisphere (Fig. 2).

Demand for residential dwellings is a major challenge in the Lower Hunter Region considering existing land-use constraints. In 2006, the Lower Hunter had approximately 205,000 dwellings. It was estimated that an additional 115,000 dwellings will be required to house the region's growing population over the next 25 years. Of this number, 80,000 dwellings will be needed to house the additional population (160,000 people), while an extra 35,000 dwellings will be needed to meet changing housing demands (NSW Department of Planning, 2006). Population growth has been attributed to the region's close proximity from the business centre of Sydney, the affordability of land, and lifestyle assets (Department of Planning, NSW, 2006). Population growth and the demand for new housing in urban release (greenfield areas), is leading to increasing pressure on the region's natural environment. Developers have a preference for greenfield developments over urban infill because they are able to build more houses per unit area. However, greenfield development results in substantially more clearance of native vegetation, often in areas of national environmental significance, and raise issues associated with infrastructure provision (e.g., roads, sewer and water) (Department of Planning, NSW, 2006).

A recent survey of rural and urban landholders has identified additional land-use planning issues and opportunities in the Lower Hunter including:

(1) Widespread opposition to the exploration of coal-seam gas in the Lower Hunter;
(2) Perception that there is insufficient co-ordination among government agencies responsible for land-use, conservation, infrastructure and transport planning;
(3) Concern about biodiversity decline as a result of development;
(4) General belief that the region is too dependent on the coal mining industry for its economic prosperity;
(5) General support for the restoration of brownfield (e.g., old coal mining sites) for residential development ahead of the expansion of greenfield areas (Raymond & Curtis, 2013).

### 2.2. Sampling

To ensure the survey addressed local issues and concerns, we conducted a community appraisal early in the project. A total of 15 planning practitioners participated in the community appraisal, representing the following groups: (1) state agency land use planning; (2) state agency NRM/conservation planning; (3) Local Government Association; (4) Conservation NGO; (5) agriculture; (6) tourism; (7) regional planning consultant; (8) coal seam gas exploration; (9) transport (including rail) planning; and (10) economic development/commerce.

We used a stratified random sampling technique to stratify potential study participants as being part of a "community of place". A community of place includes rural landholders (individuals who own more than 10 ha of land) and urban landholders (individuals who own or rent less than 10 ha of land and live within an urban or regional centre). Using lists of property owners provided under

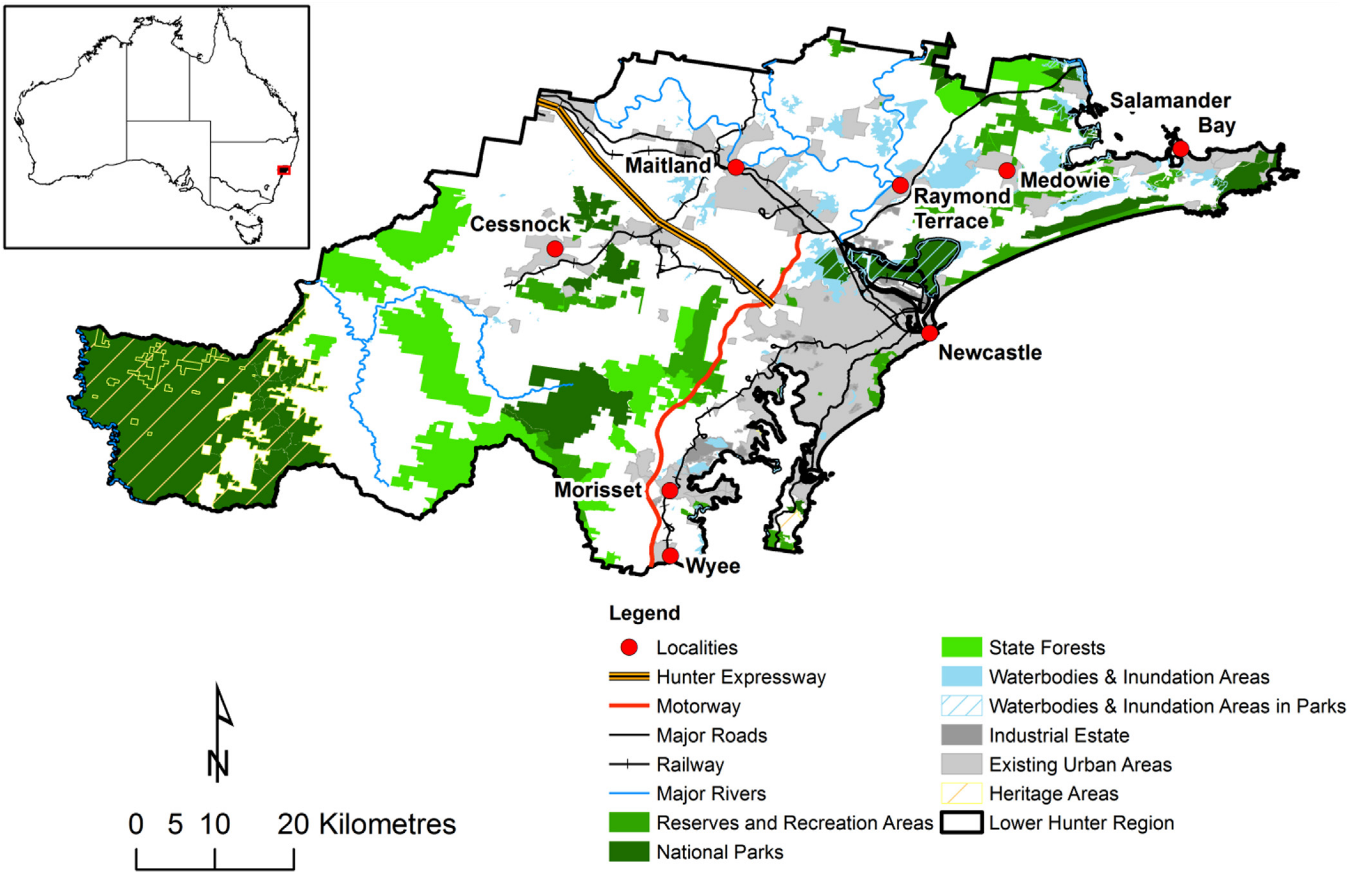


**Fig. 2.** The Lower Hunter region of New South Wales, Australia.

licence by the NSW Government, we generated a randomized list of approximately 500 rural landholders who owned >10 ha of land in the Lower Hunter region and a list of approximately 500 urban landholders who live in urban or regional centres and own < 10 ha of land. We also invited 75 planning practitioners involved in land-use planning in the Lower Hunter to participate in the survey.

### 2.3. The spatial attributes

The spatial attributes were collected using a mail-based survey administered to a random sample of 1000 rural and urban landholders between September and October 2012. We categorized the informants by hectares of land to systematically and representatively capture the views of both rural and urban landholders. The respondents were reached by following the Dillman (2007) tailored design method which involved multiple mailings: an introductory letter informing of the purpose of the research; complete survey packet; three reminder postcards to non-respondents from the first complete survey packet; a second complete survey packet to non-respondents from the first round; and two reminder postcards to non-respondents from the second complete survey packet.

The survey collected 11 landscape values and six development preferences (see Table 1). The landscape values typology included the following values: aesthetic, recreation, biodiversity, natural significance, cultural significance, food, water, natural materials, science/education, health/therapeutic, and intrinsic. Each landscape value was assigned six sticker dots and participants were instructed to place their dots on the map locations that held the 11 landscape values. They could place as many or as few dots on the map as they liked. The values typology was based on previous

**Table 1**
The spatial attributes mapped in the Lower Hunter regional study.

| |
|---|
| Landscape values |
| **Aesthetic** – I value these places because they have attractive or pleasing landscapes. |
| **Recreation** – I value these places because they provide recreation opportunities. |
| **Biodiversity** – I value these places because they provide for a variety of plants, wildlife, marine life, or other living organisms. |
| **Natural significance** – I value these places because of the significance of the native animals, native plants, ecosystems or geological features found there. |
| **Cultural significance** – I value these places because they provide opportunities to express and appreciate culture or cultural practices such as art, music, history and Indigenous tradition. |
| **Food** – I value these places because they provide plants or animals to eat, including meat, fish, fruits or vegetables, or mushrooms. |
| **Water** – I value these places because they provide fresh water for households, for irrigating farmland, or for industry. |
| **Natural materials** – I value these places because they provide, or could provide for, coal, wood products, animal feed, firewood, or other useful natural materials. |
| **Science/education** – I value these places because they provide opportunities to understand and learn about the natural world. |
| **Health/therapeutic** – I value these places because they make me feel better, physically and/or mentally. |
| **Intrinsic** – I value these places for their own sake, regardless of human needs and/or wants. |
| Development preferences |
| **Residential development** – Use **rd** + dots to identify areas where residential development could occur with a good plan and rd- dots to identify areas where residential development should not occur. |
| **Industrial development** – Use **id** + dots to identify areas where industrial development (e.g., shopping centres, electricity and water services) could occur with a good plan and id- dots to identify areas where industrial development should not occur. |

empirical work (Raymond & Brown, 2006, 2007), with the exception of natural significance and cultural significance. We added these values to be able to compare the matters of national environmental significance identified by the Australian Government with areas of perceived significance.

The map legend also included six types of development preferences. Two development preferences (residential and tourism development) were included based on previous research (Brown, 2006; Brown & Weber, 2011; Raymond & Brown, 2007). The preferences for transport and agricultural development were included because these development themes emerged consistently during a community appraisal that preceded the participatory mapping study. A number of interviewees also supported or advocated for increased formal protection of biodiversity in the Lower Hunter, whereas other participants did not want any further formal protection. In response, we included a development preference related to areas that should or should not be reserved for conservation.

To evaluate alternative approaches for identifying land use conflict potential, we focused our analysis on the most frequently mapped preferences in the study—residential and industrial development. In the Lower Hunter, residential development refers to areas acceptable for new housing subdivisions, often referred to as greenfield developments, as well areas acceptable for urban infill. Industrial development refers to development related to commercial activity such as shopping centres, or energy-intensive industries such as electricity and water supply services.

### 2.4. General considerations for spatial analysis

Spatial analysis with point data requires a judgement to be made regarding the appropriate scale (i.e., the size of the sampling grid relative to the size of the study) to calculate point densities. We examined the distribution of development preference points and determined the largest scale that could be reasonably used for analysis would be 2 km sampling grid cells based on a Lower Hunter map scale of 1:200,000. This grid cell size is consistent with previous studies that have used map scales of similar size. At this scale, a sufficient number of points were mapped per cell to generate point densities for comparison. At a larger scale (e.g., 1 km sampling grid), there were too few points to generate sufficient variability in density values. At a smaller scale (e.g., 3 km sampling grid), the results would lack sufficient resolution for the land use being evaluated, in this case, residential and industrial development.

A second consideration is the quantitative threshold to determine when point densities become research or application significant. That is, when does a point density become large enough to be considered a "hotspot" worthy of attention? For point data, one heuristic is to designate hotspots from standardized point densities derived from kernel estimates that fall in the highest third of the distribution (Alessa, Kliskey, & Brown, 2008; Brown & Reed, 2012). Another method is to use the Getis-Ord Gi*spatial statistic to identify statistically significant clusters of points (Zhu, Pfueller, Whitelaw, & Winter, 2010). The Gi* statistic indicates whether high density values or low density values (but not both) tend to cluster in the area. A high value for the Gi* statistic indicates that high density values—that is, densities higher than the mean density for the study area—tend to be found near each other. A low value indicates that densities lower than the mean density tend to be found together. A third method is to use simple point densities per sampling grid cell. In our analyses, we used both simple density and clustering methods (Getis-Ord) for landscape values to demonstrate how the choice of method can influence the areas identified for potential land use conflict.

### 2.5. Values as an indicator of conflict potential

With this approach, the distribution of mapped values from participatory mapping is assumed to be related to the potential for land use conflict. We examined two different treatments of values within the study area: (1) the aggregate spatial distribution of all landscape values with the highest density areas assumed to have the greatest potential for conflict, and; (2) the creation and application of a numeric index that reflects the compatibility between a proposed land use (in this study, residential and industrial development) and the values mapped in the study region. Negative, aggregate compatibility scores are assumed to have greater potential for land use conflict.

The density of landscape values as a proxy for the potential of land use conflict was calculated two ways. The first approach calculated simple point density of values per sampling grid cell and then selected the highest point densities for comparison. The second approach used the Getis-Ord Gi* statistic ($z$ values) to identify significant clusters of values.

Hypothetical value/land use compatibility scores were generated for each value/land use pair. For example, how compatible is industrial development with aesthetic value? These compatibility scores can be derived using a variety of methods including analyst judgement, planning team consensus, or group surveys. We chose analyst judgement in this study given that we focus on the applicability of the general method for land-use planning rather than trying to implement a tool for on-ground application. The scores for each pair range on a numeric scale from highly compatible (+1) to highly negative (−1). Scores of zero indicate there is no obvious relationship between the landscape value and proposed land use. The value compatibility scores used in this study for demonstration purposes were derived by the authors and appear in Table 2. An aggregate compatibility score *VCS* was generated for each sampling grid cell by summing individual value/land use compatibility scores for each cell. The calculation is

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

where *VCS* is the aggregate value compatibility score per cell, $n$ is the number of unique landscape values in the cell, $r_i$ is the compatibility rating for the $i$th value with the proposed land use that ranges from −1 to +1, and $c_i$ is the count of points for the $i$th value in the cell.

### 2.6. Development preferences as indicator of conflict potential

With this approach, the numeric *difference* between the number of mapped preferences (supporting and opposing) for a particular land use is used to measure the overall directionality of the land use preference as well as the level of agreement with the proposed land use. A preference score (*PS*) is generated for each sampling grid cell. The magnitude of the preference difference is assumed to be a proxy for conflict potential with larger quantitative differences between supporting and opposing uses indicative of greater agreement (less ambivalence) on the land use and hence, less potential conflict. For each sampling grid cell, the number of opposing preferences is subtracted from supporting preferences. The resulting sign (positive or negative) determines the directionality of the land use preference (supporting or opposing). The level of agreement for a particular land use within a sampling grid cell (which could be either supporting or opposing) is computed as a ratio of preference points that varies between 0 and 1. The smallest number of the supporting or opposing land use preferences becomes the numerator in the ratio while the largest number becomes the denominator. A ratio value of 1 (equal number of supporting and

**Table 2**
Value compatibility scoring used to assess residential and industrial development. Scores range from −1 (highly incompatible) to +1 (highly compatible). A score of 0 would indicate no apparent relationship. These scores are hypothetical and used for illustration purposes only.

| Value | Residential development | Industrial development | Comment |
|---|---|---|---|
| Aesthetic | −0.5 | −0.5 | Beauty is in the eye of the beholder, but many consider human development to detract from more natural scenery. |
| Recreation | +0.5 | −0.5 | Residential development can actually enhance recreation opportunities with neighbourhood parks and walking/biking trails. Industrial development is generally not attractive for recreation. |
| Biodiversity | −0.5 | −1.0 | Human development is negative for biodiversity but residential development can benefit some species with increased planting of vegetation. |
| Natural significance | −1.0 | −1.0 | By definition, development will displace natural features. |
| Cultural significance | +0.5 | −0.5 | Residential development can increase opportunities for social interaction and appreciation of culture while industrial development is generally antagonistic to cultural expression. |
| Food | −0.5 | −0.5 | Development is generally negative towards agriculture and food production. However, gardens in residential development can provide food while industrial development can process food. |
| Water | −1.0 | −1.0 | Development will use water, not provide water. |
| Natural materials | −1.0 | +1.0 | Industrial development is often associated with providing natural materials such as coal. |
| Science/education | −1.0 | −1.0 | Development reduces opportunities to understand and learn about natural world. |
| Health/therapeutic | +0.5 | −0.5 | Residential areas are "home" and promote positive feelings while industrial development is often alienating. |
| Intrinsic | 0 | 0 | Relationship to development is ambiguous. |

opposing preferences) reflects the lowest level of agreement, or alternatively, the highest degree of ambivalence towards the land use in that location, while values approaching 0 represent the highest degree of land use preference agreement. For example, a sampling grid cell with three points favouring residential development and three points opposing residential development would have a ratio of 3/3 or 1, the largest ratio possible and thus, the least agreement as to the prospective land use. In contrast, a sampling grid cell with one supporting land use preference point and five opposing points would have a ratio of 1/5 or .2 indicating a higher level of agreement or concurrence with the prospective land use. The supporting logic is that the greater the mapped ambivalence regarding a particular land use, the larger the preference difference ratio, and the greater the potential for conflict for the particular land use in that area. To handle the case where the numerator preference may be zero but the denominator is not, the numerator value is set to a small, non-zero value of 0.1. A cell with no preference data would have a true ratio of 0 which equates to no information about land use preferences. The preference score equation is

$$PS = \frac{MAX(MIN(P_S, P_0), 0.1)}{MAX(P_S P_0)}$$

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, and *MAX* and *MIN* are functions to select to largest and smallest of two numbers, respectively.

An alternative to this approach is to weight the preference scores by the number of total mapped preferences (both supporting and opposing) found within each sampling grid cell. The rationale for weighting preference scores by the number of mapped preferences is to account for different land use saliencies across the landscape. Without weighting, a sampling grid cell with one supporting and one opposing land use preference (*PS* = 1) would be given the same numeric importance as a sampling grid cell with 10 supporting and 10 opposing preferences. Logic suggests that although the preference score would be the same in both cases, the potential for land use conflict is significantly higher in the cell where more preferences were expressed because the prospective land use in that location appears more salient to individuals sampled in the study. To weight the preference scores by the number of preferences, the equation is

$$WPS = \frac{MAX(MIN(P_S, P_0), 0.1)}{MAX(P_S P_0)} * (P_S + P_0)$$

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.

### 2.7. Values and preferences combined as indicator of conflict potential

With this approach, land use preferences which identify the level of agreement (supporting or opposing) in an area, are amplified by the number of landscape values expressed in the same area. To operationalize, the preference scores (*PS*) in each sampling grid cell are multiplied by the number of landscape values located in the sampling grid cell. The resulting preference and value score (*PVS*) for each cell represents a conflict potential index on a continuous scale with higher scores associated with higher conflict potential.

$$PVS = \frac{MAX(MIN(P_S, P_0), 0.1)}{MAX(P_S P_0)} * V_c$$

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 landscape values in the cell.

### 2.8. Evaluating the conflict potential mapping approaches

We evaluated the different approaches to mapping conflict potential two ways. In the first analysis, we examine the overall similarity and differences in mapped results within the study region. In other words, how similar or different are the results produced by each method. In the second analysis, we chose a set of current, controversial development sites or projects within the region to determine which mapping approaches identified these areas as potential areas for land use conflict.

To determine the similarity or difference in mapped results, we generated the sampling grid cell indices using the methods described above. To provide a fair comparison between the methods, we selected and mapped the top 10% of sampling grid cells generated by each method (121 out of 1209 sampling grid cells). The top 10% was a heuristic chosen by the researchers to show the areas with the greatest conflict potential using each method. For each pair of methods, we used the phi-coefficient ($\varphi$) statistic to determine to the degree of spatial accordance (spatial overlap) between the mapped results using a $2 \times 2$ contingency table where cell values represent the presence or absence of the sampling grids cells identified from the methods. The phi-coefficient is a variation

**Table 3**
Strength of association (phi-coefficient) between different conflict indices for highest 10 percent of cells indicated by each index.

| | Value Density | Value Hotspot (Getis-Ord) | Prefs Residential | Prefs Industrial | Weighted Prefs Residential | Weighted Prefs Industrial | Prefs & Values Residential | Prefs & Values Industrial | Value Comp. (Res) |
|---|---|---|---|---|---|---|---|---|---|
| Value Hotspot (Getis-Ord) | .623*** | | | | | | | | |
| Preferences Residential | .045 | .063 | | | | | | | |
| Preferences Industrial | .054 | .027 | .412*** | | | | | | |
| Weighted Prefs Residential | .036 | .054 | .991*** | .421*** | | | | | |
| Weighted Prefs Industrial | .027 | .027 | .504*** | .844*** | .513*** | | | | |
| Prefs & Values Residential | .421*** | .311*** | .614*** | .302*** | .605*** | .311*** | | | |
| Prefs & Values Industrial | .366*** | .330*** | .118*** | .541*** | .118*** | .458*** | .238*** | | |
| Value Compatibility[a] (Res) | .587*** | .385*** | .045 | .054 | .036 | .027 | .284*** | .348*** | |
| Value Compatibility[a] (Ind) | .789*** | .596*** | .045 | .109*** | .036 | .036 | .403*** | .431*** | .660*** |

*** Significant at .001 level.
[a] Least compatible scores used.

of the Pearson correlation coefficient that is used for binary data and is related to the chi-square statistic ($\chi^2$), where $\chi^2 = n\varphi^2$ (Chedzoy, 2006; Zhu et al., 2010). The phi-coefficient measures the strength of the relationship on a scale from 0 to 1 and the statistical significance of the relationship can be evaluated with the chi-square statistic. Larger phi-coefficients would indicate that the two methods are identifying similar areas of potential conflict. In interpreting the phi-coefficients, we follow the interpretation proposed by Fitz-Gibbon and Morris (1987) where $\varphi < 0.2$––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. In total, we examined 45 pairs of spatial distributions using this method.

We selected $n = 13$ reference sites within the study area from the Lower Hunter Regional Strategy (NSW Department of Planning, 2006) to examine which of the conflict potential mapping methods identified these locations. These proposed development projects comprise a geographically diverse mix of residential ($n = 9$) and industrial developments ($n = 4$) that given their size and location, may be indicators of local and/or regional land use conflict. Some of the development projects have been the subject of local media stories reflecting their controversial nature. Our evaluation method was to examine whether or not a particular conflict mapping method identified the reference site by spatially intersecting the top 10% of the cells from each method with the proposed development location. The number and types of "hits" and "misses" by the various conflict mapping methods may be suggestive of the method's capacity to identify future potential land use conflict.

## 3. Results

### *3.1. Response rate and data available for analysis*

The overall survey response rate was 40%. A total of 10,206 landscape value points were available for analysis. For residential development, there were 547 mapped preferences in support of development, and 573 preferences opposed to development. For

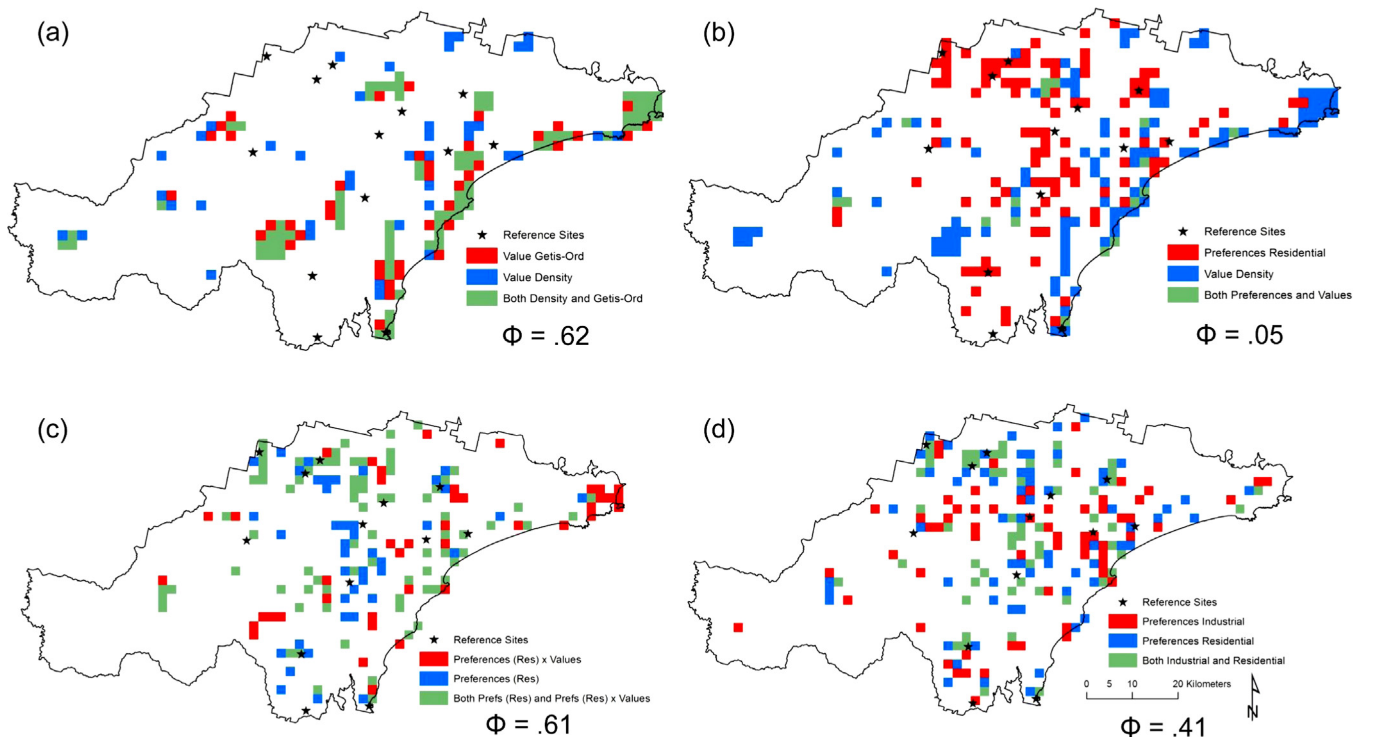


**Fig. 3.** Maps showing the spatial association between different methods of mapping land use conflict potential with the top 10 percent of sampling grid cells indicated by each method: (a) landscape value density and value clusters indicated by Getis-Ord statistic; (b) landscape value density and preferences for residential development; (c) preferences for residential development and residential preferences amplified by landscape values; (d) residential preferences and industrial preferences. The phi-coefficient ($\varphi$) indicates the degree of spatial association and ranges from 0 (none) to 1 (highest).

industrial development, there were 468 preferences in support of development, and 445 preferences opposed to development.

### 3.2. Landscape values as indicators of conflict potential

Two measures of the landscape value distribution were first evaluated—the highest densities of landscape values by sampling grid cell and clusters (hotspots) of landscape values as determined by the largest *z* scores derived from the Getis-Ord Gi* statistic. These two landscape value measures were strongly spatially associated ($\varphi = .62$, see Table 3). The difference in the two spatial distributions (see Fig. 3a) results from the Getis-Ord method favouring selection of neighbouring cells with relatively high densities, but whose densities are not as large as more distant point densities. Given the strong spatial association, either method appears acceptable for analysing the distribution of landscape values. Because the preference methods reported herein are not influenced by point counts in neighbouring cells, we used the simple density analysis method in subsequent analyses.

The distribution of landscape values was not spatially associated with either residential ($\varphi = .045$) or industrial ($\varphi = .054$) development preferences. The measures of association were even smaller with weighted preferences. The lack of spatial association is visually apparent in Fig. 3b which shows value density with residential development preferences. These results indicate the spatial distribution of the highest densities of landscape values is largely independent of the spatial distribution of the largest development preference scores. Thus, landscape values appear to assess a different dimension of potential land use conflict from development preferences, which we posit to be a form of potential interpersonal conflict.

Value density was strongly associated with landscape value compatibility scores (*VCS*) for both residential ($\varphi = .59$) and industrial ($\varphi = .79$) development. This result was expected given how compatibility scores were calculated in this study. The value compatibility scores are dependent on the positive and negative weightings assigned to each value/use pairing (see Table 2). Value compatibility scoring will create both positive and negative scores but the overall distribution of value compatibility scores in this study reflects disproportionately negative scores given the landscape values included in the typology. The value compatibility scores for residential development were mapped and appear in Fig. 4. Negative rather than positive compatibility scores are assumed to be associated with increased land use conflict potential.

### 3.3. Preferences as indicators of conflict potential

The mapping of spatial preferences is a direct measure of the level of agreement with a proposed land use in a specific location. The difference in supporting versus opposing preferences is presumed to be related to the potential for conflict. There was a moderate association between residential and industrial preferences ($\varphi = .42$, Fig. 3d) suggesting that place preferences for residential and industrial share some common place attributes. In other words, development preferences appear to be significantly related to the desirability of development *in general* in a given location, regardless of the type of development, residential or industrial.

The weighting of preference differences in each cell by the number of preferences (*WPS*) did not materially affect the spatial distribution of land use conflict potential from the locations identified by preference scores alone. The spatial association between residential preference scores and weighted residential preferences scores were almost identical ($\varphi = .99$) while the association between industrial preference scores and weighted industrial preference scores was also strong ($\varphi = .84$). Thus, the most important information about the location of potential land use conflict is captured in the preference scores. However, weighting by the number of preferences functions as a “tie-breaker” for preference scores that

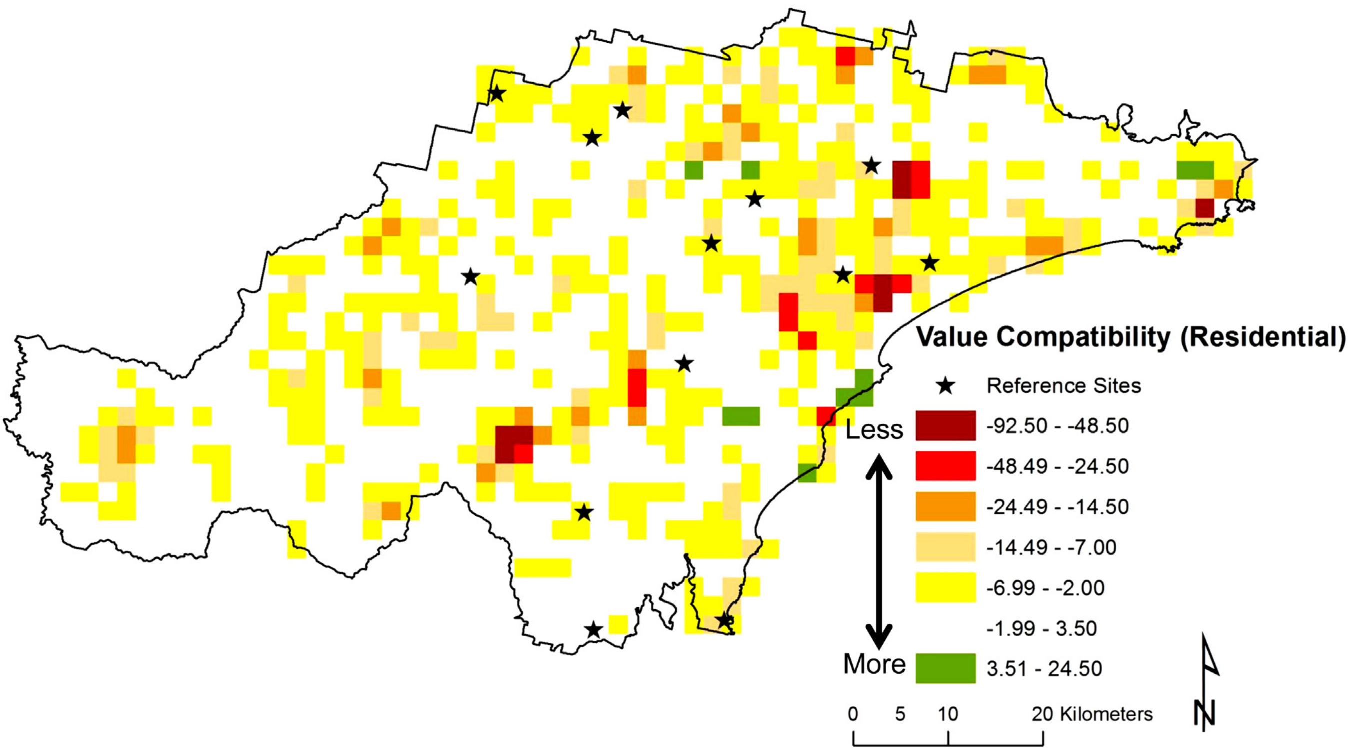


**Fig. 4.** Values compatibility map for residential development in Lower Hunter Valley. Value compatibility scores range from positive (green), where residential development appears compatible with mapped landscape values, to negative (yellow to red), where residential development appears incompatible with mapped landscape values. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

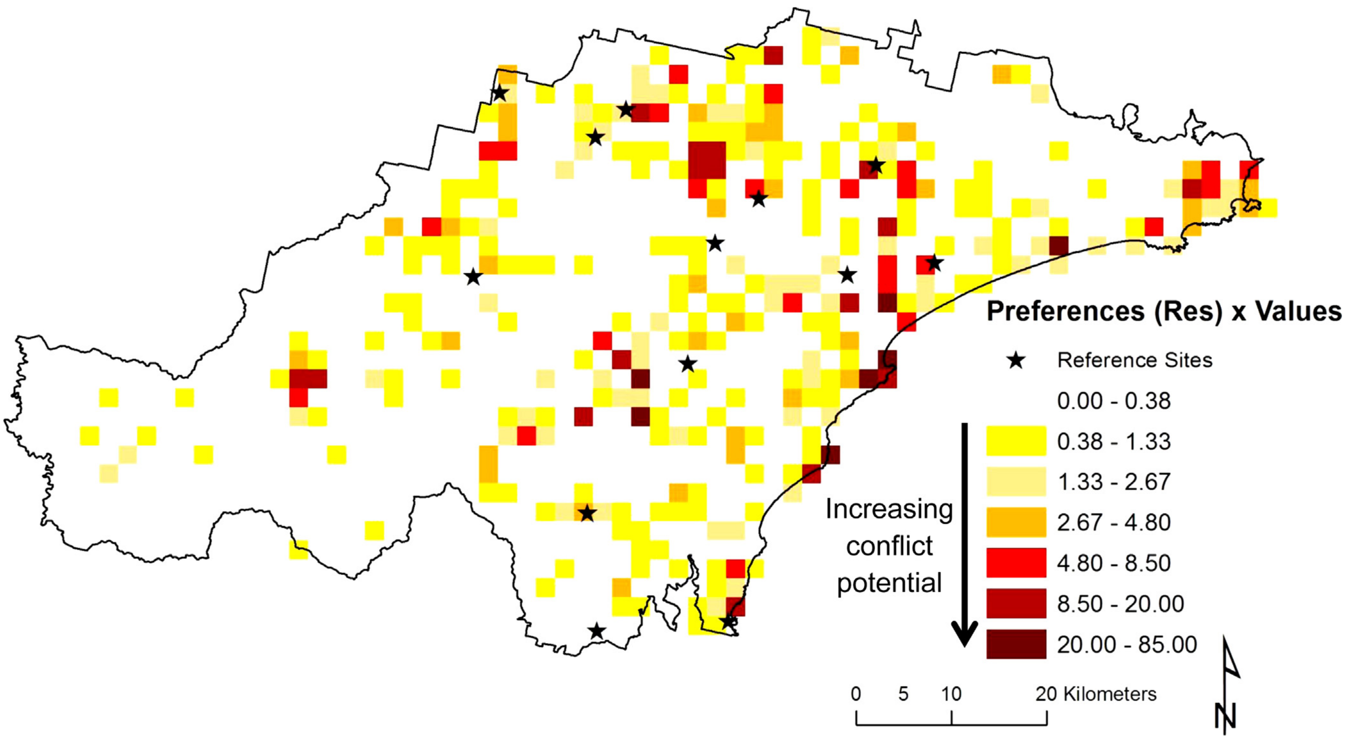


**Fig. 5.** Map of conflict potential for residential development derived from the difference in mapped residential development preferences (in each sampling grid cell) that are amplified (multiplied) by the number of landscape values mapped in each cell. Larger numbers on the index indicate increasing residential conflict potential.

are equal in magnitude, but different in the number of preferences expressed.

### *3.4. Values and preferences combined as indictors of conflict potential*

This method assumes that landscape values and development preferences represent significantly independent indicators of conflict potential and by combining these two factors, the identification of potential land use conflict is enhanced. There are multiple mathematical ways to combine values and preferences. Fig. 5 shows the mapped result of one approach that multiplies residential development preference differences in each sampling grid cell by the number of landscape values in the cell. This has the effect of amplifying preference differences by the landscape values at stake. The resulting conflict index shows a strong spatial association with residential preferences only ($\varphi = .61$) and a moderate association with values only ($\varphi = .42$). For industrial development, the results are similar with the combined index showing a moderate association with industrial preferences only ($\varphi = .54$) and values only ($\varphi = .37$). The results indicate the combined preference and value conflict index is influenced by both the value and preference dimensions of conflict potential.

### *3.5. Evaluation of the methods using reference sites*

Land use conflict *potential*, by definition, describes the conditions that can lead to future events. As such, the predictive power of conflict mapping methods cannot be assessed until after the passage of time. However, it is possible to use ongoing or proposed development projects as a proxy for future land use conflict under the rationale that conflict maps should flag current as well as future projects that are controversial. We identified nine residential and four industrial developments as references sites for identifying land use conflict potential. We examined whether each of the conflict mapping methods flagged the 13 reference sites as potential high conflict areas. The results of the analysis appear in Table 4.

The mapping of development *preferences* (*PS*) identified most of the study reference sites as locations for potential land use conflict (11/13 sites for residential preferences, 12/13 sites for industrial preferences). The weighting of preference scores by the number of preferences (*WPS*) did not change this result. Conversely, the mapping of landscape *values* (by density) identified only 3/9 of residential developments and only one industrial reference site. The Getis-Ord method for mapping landscape value clusters identified even fewer reference sites (3/13). When the landscape values were assigned compatibility scores for the two types of development, there was little change in the value results (4/13 for residential sites, 5/13 for industrial sites). The combined index with both values and preferences (*PVS*) for residential development increased the number of reference sites identified (8/9 residential sites, 1/4 industrial sites) while the PVS for industrial development also identified more references sites (7/9 residential sites, 2/4 industrial sites). These results suggest that the preference scores amplified by values are most promising for use in the identification of potential land-use conflicts. However, we present some important caveats below.

To the extent that current or near future developments represent potential land use conflict, our results indicate that mapped preferences (*PS*) perform well in identifying conflict areas, while the mapping of values alone has less discriminatory power to detect conflict potential. The combined values and preferences (*PVS*) for residential and industrial development identified somewhat fewer reference sites that preferences alone (*PS*), but were somewhat better in their ability to differentiate between residential and industrial development. For example, the residential preferences index (*PS*) identified 3/4 industrial reference sites while the combined residential values and preference index (*VPS*) identified 1/4 industrial sites. Similarly, the industrial preferences index (*PS*) identified 8/9 residential reference sites while the combined industrial values and preferences index (*VPS*) identified 7/9 residential reference

**Table 4**
Evaluation of development reference sites within study region by different conflict mapping methods. The marks indicate reference sites that were flagged as an area of high land use conflict potential (top 10%) with the method in the column heading.

| Site/Project | Dev. Type | Conflict potential mapping method | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Value Density | Value Hotspot | Prefs (Res) *PS* | Prefs (Ind) *PS* | Weighted Prefs (Res) *WPS* | Weighted Prefs (Ind) *WPS* | Value Compat. (Res) *VCS* | Value Compat. (Ind) *VCS* | Prefs + Values (Res) *PVS* | Prefs + Values (Ind) *PVS* |
| Catherine Hill Bay | Residential | • | • | • | • | • | • | • | • | • | • |
| Branxton–Huntlee (up to 7200 dwellings) | Residential | | | • | • | • | • | | | • | • |
| Thornton North (up to 7000 dwellings) | Residential | • | • | • | • | • | • | | • | • | • |
| North Raymond Terrace (up to 5000 dwellings | Residential | | | • | • | • | • | • | • | • | |
| Bellbird (up to 4000 dwellings) | Residential | | | • | | • | • | | | • | |
| Cooranbong (up to 3000 dwellings) | Residential | | | • | • | • | • | | | • | • |
| Lochinvar (up to 5000 dwellings) | Residential | | | • | • | • | • | | | • | • |
| Anambah (up to 4000 dwellings) | Residential | • | | • | • | • | • | • | • | • | • |
| Wyee (up to 2000 dwellings) | Residential | | | | • | | • | | | | • |
| Hunter Econ. Dev. Zone (Kurri Kurri) | Industrial | | | • | • | • | • | | | | |
| Newcastle Airport Employment Zone | Industrial | | | • | • | • | • | | | • | |
| West Wallsend Employment Zone | Industrial | | | • | • | • | • | | | | |
| Tomago Employment Zone | Industrial | • | • | | • | | • | • | • | | • |

sites. However, this apparent capacity of the combined indices (*VPS*) to better differentiate conflict between the two types of development may be a spurious result given the significant spatial association between residential and industrial development preferences.

## 4. Discussion

This paper evaluated three methods for identifying potential land use conflict using participatory mapping data from a regional study in New South Wales, Australia. The first method used landscape values as a proxy for potential land use conflict by capturing the relative importance of different values in specific locations. Conflict potential is determined by the perceived compatibility between proposed land uses and the landscape values. The second method identified potential land use conflict as differences in land use preferences in specific locations. Conflict potential is greatest when land use preferences in the region are divided. The third method combined both value and preference data. Preference differences are amplified by the values in the same location to determine the potential land use conflict. The three methods, and their respective strengths and weaknesses, are summarized in Table 5. An assessment of the strengths and weaknesses of each method reveals that the one with combined values and preferences was the most reliable predictor of specific land-use conflict potential. When interpreting the results specific to the Lower Hunter, the potential for residential and industrial development conflict occurs in high value areas such as those located along the coastal zone, which is consistent with previous studies (see Brown & Weber, 2013).

Our results provide support for a two dimensional model of conflict (Fig. 1) where spatial values and preferences measure two different social-psychological aspects of the potential for land use conflict. Landscape values identify the most important areas in the regional landscape, where respondents exhibit some degree of place attachment (Brown & Raymond, 2007). Because participants identify with, or may be dependent on these places, they are more likely to oppose changes in land use that interfere with these place attachments. And yet, values, as an indirect measure, are not reliable in predicting an individual's preference with respect to a specific, proposed land use (Brown & Reed, 2000). Values provide a general ranking of what landscape qualities people perceive as important in an area. For mapping participants, there does not appear to be an explicit connection made between specific land uses and how these might affect the place qualities that people consider important. Although the mapping of values and preferences is done within the same survey procedure to encourage cognitive linkage, participants are not specifically instructed to consider the relationships between landscape values and development preferences. The result is relatively weak spatial relationships between landscape values and land use preferences found in this study.

The mapping of land use preferences provides a more direct measure of the participants' predisposition towards prospective land uses in specific locations. When aggregated, preferences provide a directional measure (supporting or opposing) of the land use within the sampled population. But the directionality of the land use preference is distinct from the participant's ability or motivation to sustain the preference. Further, even with the ability and motivation to sustain a preference, there is not always a clear behavioural pathway to sustain the preference (e.g., how does one actually stop or modify a proposed development?). In short, land use preferences do not measure behavioural intentions that are linked to overt behaviours such as attending public hearings to express support or opposition to a proposed development.

The preferred method for assessing the potential for land use conflict is one that can capture both land use preference directionality as well as the importance of the landscape values that can motivate behaviour resulting in explicit land use conflict. The preference and value scores (*PVS*) method described herein represents the first approach to date that operationalizes social-psychological constructs from conflict theory using participatory mapping methods. And yet, we acknowledge this is an imperfect measure as the constructs of place importance and land use preferences are mapped as separate constructs by participants and then mathematically combined after the data is collected. An alternative approach

**Table 5**
Spatial approaches for assessing land use conflict potential using participatory GIS data.

| Method | Assumption | Spatial operationalization | Strengths | Weaknesses |
|---|---|---|---|---|
| 1.Values/importance approach<br>a. Aggregate values are a proxy for land use conflict potential<br>b. Assign compatibility scores for specific land uses with specific values and aggregate by place location (Brown &Reed, 2012) | Conflict results from incompatible values held for land use in specific places | • Total mapped values per land unit of analysis (more values = higher potential conflict)<br>• Create numeric index based on consistency of value with land use and link to land unit of analysis | • Generalized values can be applied to variety of potential land uses<br>• Significant participatory GIS research experience in mapping values | • Values are indirect measure of specific land use conflict potential.<br>• Subjective judgments required for value/land use compatibility ratings. |
| 2. Preferences approach<br>a. Difference in land use preferences<br>b. Weighted differences in land use preferences | Conflict results from different preferences for land use in specific places | • For each land unit of analysis, subtract preferences opposing land use from preferences supporting land use and map result (Brown & Donovan, 2013). Differences can be weighted by total mapped preferences per land unit. | Most direct measure of landscape land use conflict potential. Shows directionality of preference (supporting or opposing) and level of agreement/disagreement with prospective land use | Preferences must be mapped for each specific land use which requires significant participant effort for mapping multiple land uses. |
| 3. Values/preferences hybrid approach | Conflict results from different preferences for land use that are amplified by the values at stake in specific places | • Multiply land use preferences (+/−) for each land unit by the total number of values in the land unit | Conceptually stronger because considers two dimensions of land use conflict—level of agreement and place importance | • Requires collection of both value and land use preference data.<br>• Requires subjective judgement on how much to weight values in amplification |

would integrate these constructs in the same mapping activity. For example, "Please indicate on the map any land use changes that you would be willing to take action to support or oppose those land use changes." Such an approach could be used to validate the indirect, post hoc approach to mapping conflict potential described herein.

The preferred method assesses conflict potential from the two theoretical perspectives of interpersonal and social values conflict. High social values conflict occurs in areas where there is development preference ambivalence while high interpersonal conflict is likely to occur in areas of high place importance (high landscape value intensities). This conceptualisation and operationalization of conflict potential appears consistent with current land-use conflicts in places in the Lower Hunter. For example, in Catherine Hill Bay, interpersonal conflict exists between wildlife viewers and developers seeking to develop the area for residential housing. There is also social values conflict, particularly around the clearance of natural areas to allow for residential allotments.

Previous studies have noted that participatory mapping ought to be an iterative process whereby local stakeholders can review and refine the mapped results (Brown, 2012). However, Brown notes there are few examples of this iterative process in land use planning as a result of institutional barriers to local stakeholder engagement. Ideally, planners at local or state government would identify potential conflict areas as a type of early warning system before land use issues become polarized during the wider consultation phase. The approach described herein could be applied around the world because regional planners in Australia and elsewhere are required to consult with local communities about prospective industrial and residential developments prior to approval. After identifying conflict areas, planners could facilitate early conflict management strategies such as engaging local opinion leaders using focus groups, semi-structured interviews, or more formal mediation techniques. The conflict maps would provide a substantive basis for constructive discourse around future land use.

PPGIS data can, and should be included in spatial decision support systems (SDSS) and multi-criteria evaluation (*MCE*). Indeed, the conflict mapping approach described herein is a form of MCE because it attempts to integrate multiple attributes (i.e., values and preferences) in a given geographic locale. PPGIS data can also feed into a more formal spatial decision support system such as *values compatibility analysis* (Brown &Reed, 2012) that can assess the compatibility of specific land uses and management activities on public lands.

Prior to employing the PPGIS approach presented here, we recommend that planning practitioners describe and document the multiple issues and concerns of local actors with respect to land-use plans in a given region to account for the broad range of land-use issues. We acknowledge that the conflict mapping methods presented here are empirical and heuristic, and specifically focus on conflicts that are value and preference-based rather than issue-based. It is also important to obtain responses from a random and representative set of households that are located throughout the region of interest. Raymond and Curtis (2013) found that values and preferences in the Lower Hunter tend to be assigned by respondents within a mean range of 25 km from their domicile. This geographic or spatial discounting phenomenon in participatory mapping where spatial attributes are mapped closer to one's domicile, is supported in multiple other studies (Brown, Reed, & Harris, 2002; Pocewicz & Nielsen-Pincus, 2013; de Vries et al., 2013).

Practitioners should consider whether sub-group analyses (e.g., urban versus rural landholders) is important in their assessment of conflict potential. Sub-group analyses require more intensive sampling in specific geographic areas to yield sufficient spatial data to model land-use conflict. Further, practitioners must be aware of the participation bias that is common to most social data collection methods. In this study, we targeted all sociodemographic groups but it was challenging to engage young adults in the 18–30 age bracket as well as renters in the region. We recommend the use of multiple mapping methods (e.g., mail-based surveys, community workshops, and online PPGIS) to maximize response by different sociodemographic groups (see Raymond & Brown, 2011; Brown, 2012).

### 4.1. Study limitations

The number of study participants, the quantity of participatory mapping data, and the relatively high response rate in this study provided a good case study for examining different approaches for identifying the potential for land use conflict. However, there are also limitations with the results. First, the landscape values used in the Hunter Valley case study did not contain an explicit "economic" value in the typology. Other participatory mapping studies indicate that economic values and environmental values tend to geographically avoid each other (Nielsen-Pincus, 2011). Thus, it would appear important to include an explicit economic value in the typology to provide for the greatest spatial contrast in the mapped values. Although economic value is implicit in other values in the typology, the direct mapping of economic value most accurately captures perceived land use trade-offs, particularly with respect to ecological and amenity values. The greater the contrast in landscape values, the more likely value conflict will be captured in the mapping process and indices that are derived from values. The lack of sufficient contrast in the values typology may also help explain why the values compatibility approach, even if hypothetical, did not identify many of the development reference sites.

A second limitation is that our analysis focused on residential and industrial land uses to evaluate the conflict mapping methods. These are but two of many potential land uses for which conflict potential could be evaluated. It seems reasonable to conclude that the same methods could be applied to variety of potential land uses from longer-term development to shorter-term land uses related to natural resource management. For example, Brown and Donovan (2013) used participatory mapped values and preferences to evaluate the potential for conflict related to public land uses such as siting recreation facilities, motorized recreation, mining, tourism development, and hunting/fishing activity. We acknowledge that the scope of potential land uses was limited in our analysis, a limitation that is compounded by the similarity of mapped results between residential and industrial development preferences indicating there may not be a bright line between the two types of development. Future research would benefit from assessing the methods across a broader range of potential land uses.

A third limitation is that the methods described herein rely on point data from participatory mapping, but the use of polygons is also common in participatory mapping. Landscape values and preferences mapped as polygons can be used to identify the potential for land use conflict, but the derivation of the conflict indices would require a different set of equations because the spatial analysis in GIS would likely be raster, rather than vector-based.

A fourth limitation is that the conflict indices presented here do not consider the influence of proximity to residence on conflict intensity. Work in the broader geography literature indicates that land-use conflicts are often promoted by the 'not-in-my-backyard' phenomena, in addition to place attachment factors, whereby people living closest to a new type of land-use are more opposed than people living further away (Devine-Wright, 2005; van der Horst, 2007). Future work could consider including a proximity variable into the conflict indices presented here with the aim of understanding the interactions between distance from place of residence, development preferences and landscape values. Calculating the mean distance from a landscape value point to one's place of residence could be a fruitful way of measuring proximity in this context.

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