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Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research

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A B S T R A C T

Public participation GIS (PPGIS) methods have progressed over the last decade, but as a rapidly evolving practice and area of research, there are new challenges. To identify the key issues and research priorities in PPGIS, two researchers that have designed and implemented more than 40 empirical studies spanning both environmental and urban applications present their views about the present and future of PPGIS for land use planning and management. This paper is intended to be a synthesis, but not necessarily a consensus of the key issues and research priorities. We have organized the paper into six general key issues and four priority research topics. The key issues are: (1) conceptual and theoretical foundations, (2) the diversity of definitions and approaches to participatory mapping, (3) the spatial attributes measured in participatory mapping, (4) sampling, participation, and data quality, (5) relationships between participatory mapped attributes and physical places, and (6) the integration of PPGIS data into planning decision support. Our top research priorities include: (1) understanding and increasing participation rates, (2) identifying and controlling threats to spatial data quality, (3) improving the "PP" or public participation in PPGIS, and (4) evaluating the effectiveness of PPGIS. Our purpose for presenting a research agenda is to stimulate discourse among PPGIS researchers and practitioners about future research needs and to provide support for the mobilization of resources to undertake future empirical research.

Introduction

The drive to understand and describe the world using maps is central to the human condition. From sketches in the dirt to paintings on cave walls, humans have evolved and refined methods for transmitting experience, knowledge, and inspiration about the places that sustain them physically and spiritually. The modern geospatial revolution with technologies that map earth systems has greatly accelerated understanding of the physical world. But the knowledge of social and cultural landscapes, while enhanced by information technology, is more complex with understanding proceeding at a much slower pace. Technological advances have provided sophisticated devices and remote sensing equipment to record the physical world, but the measurement and mapping of subjective experience with place presently lacks such technology. And yet, there has been progress over the past two decades to develop methods for engaging non-experts to identify the spatial dimensions of social and cultural landscapes using public participation GIS (PPGIS) methods.

The purpose of this paper is to summarize the key issues in PPGIS from the perspective of two researchers that have completed more than 40 empirical studies in regional and environmental applications (Table 1) and urban-specific applications (Table 2). The global, geographic locations of the PPGIS studies that form the experience base for this paper appear in Fig. 1. This paper is not intended to provide a comprehensive literature review of the broad field of PPGIS, but rather is focused on synthesizing issues and priorities based on empirical PPGIS research. More comprehensive reviews of the PPGIS literature are provided by Craig, Harris, and Weiner (2002), Dunn (2007), McLain et al. (2013), Sawicki and Peterman (2002), Sieber (2006) while compiled bibliographies are available at www.ppgis.net/bibliography.htm.

To provide context for our synthesis, we first review PPGIS concepts and terminology to address the continuing ambiguity within the PPGIS field. We then summarize important issues for PPGIS research to provide a foundation for identifying research priorities based on current knowledge gaps in PPGIS practice and

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Table 1
Regional and environmental PPGIS studies (1998–2013).

Year	Implementation mode	Location	Planning purpose	Published references
2013	Internet (Google Maps)	Tongass National Forest (Alaska)	National forest planning	Study in progress. Website: http://www.landscapemap2.org/wrangell
2013	Internet (Google Maps)	New South Wales, Australia	Outdoor recreation planning (mountain bike and horse riding)	Study in progress. Website: http://www.landscapemap2.org/nswmtnbike
2013	Internet (Google Maps)	Adelaide, Australia	Urban park planning	Brown, G., Schebella, M, and D. Weber. Website: http://www.landscapemap2.org/adelaide
2012	Paper	South Suriname, South America	Conservation planning	Ramirez-Gomez, S.O.I., Brown, G., and Tjon Sie Fat. 2013.
2012	Internet (Google Maps)	Sierra, Sequoia, and Inyo National Forests (California)	National forest planning	Brown, G., Kelly, M., and D. Whitall. 2013. Website: http://www.landscapemap2.org/sierra
2012	Internet (Google Maps)	Chugach National Forest (Alaska)	National forest planning	Brown, G. and S. Donovan. 2013. Website: http://www.landscapemap2.org/chugach
2011	Internet (Google Maps)	Otago Region (New Zealand)	Regional conservation	Brown, G. and L. Brabyn. 2012a. Website: http://www.landscapemap2.org/otago
2011	Internet (Google Maps)	Southland Region (New Zealand)	Regional conservation	Brown and D. Weber, 2012a. Website: http://www.landscapemap2.org/nzdoc
2011	Internet (Google Maps & Google Earth)	South West Victoria (Australia)	Regional conservation and national park management	Brown, G., Weber, D., Zanon, D., and K. de Bie . 2012. Website: http://www.landscapemap2.org/swparks3
2010	Internet (Google Maps)	Kangaroo Island (South Australia)	Tourism and conservation	Brown, G., and D. Weber. 2012b. Brown, G., and D. Weber. 2012c. Website: http://www.landscapemap2.org/kangaroo
2010	Internet (Google Maps)	Grand County (Colorado, U.S.)	Ecosystem service mapping	Brown, G., J. Montag, and K. Lyon. 2012. Website: http://www.landscapemap2.org/ecoservices
2009	Internet (Flash)	Alpine Region (Victoria, Australia)	National park planning	Brown, G., and D. Weber. 2011.
2007	Internet (Flash)	Mt. Hood National Forest (Oregon, U.S.)	National forest planning	Brown, G. and P. Reed. 2009. Website: http://www.landscapemap2.org/mthood
2007	Internet (Flash)	Deschutes/Ochoco National Forest (Oregon, U.S.)	National forest planning	Brown, G. and P. Reed. 2009. Website: http://www.landscapemap2.org/deschutes
2006	Internet (Flash)	Coconino National Forest (Arizona, U.S.)	National forest planning	Brown, G. and P. Reed. 2009. Website: http://www.landscapemap2.org/coconino
2006	Paper	Murray River, Victoria (Australia)	River conservation	Pfueller, S., Zhu, X., Whitelaw, P., Winter, C. 2009.
2005	Paper	Otways Region, Victoria (Australia)	Tourism and conservation	Brown, G., and C. Raymond. 2006. Brown, G. and C. Raymond. 2007. Raymond, C., and G. Brown. 2007. Raymond, C., and G. Brown. 2006.
2004	Paper	Kangaroo Island (Australia)	Tourism and development planning	Brown, G. 2006.
2003	Paper	Anchorage Parks and Open Space (Alaska)	Urban park and open space planning	Brown, G. 2008.
2002	Paper	Kenai Peninsula (Alaska)	Coastal area management	Alessa, N., A. Kliskey, and G. Brown. 2008.
2001	Paper	Alaska Highways (Alaska)	Scenic byway nomination	Brown, G. 2003.
2000	Paper	Prince William Sound (Alaska)	Marine conservation	Brown, G., C. Smith, L. Alessa, and A. Kliskey. 2004.
1998	Paper	Chugach National Forest (Alaska)	National forest planning	Brown, G. and P. Reed. 2000. Reed, P. and G. Brown. 2003.

research. We conclude with some reflections on the barriers to advancing PPGIS in practice.

PPGIS, PGIS, and VGI

As defined by Tulloch (2008), public participation GIS (PPGIS) is a "field within geographic information science that focuses on ways the public uses various forms of geospatial technologies to participate in public processes, such as mapping and decision making." Participatory GIS (PGIS) and volunteered geographic information (VGI) are related terms that also describe processes for capturing and using non-expert spatial information. The term "public participation geographic information systems" (PPGIS) was conceived in 1996 at meetings of the National Center for Geographic Information and Analysis (NCGIA) in the U.S. to describe how GIS technology could support public participation for a variety of applications (NCGIA, 1996a, 1996b; Sieber, 2006). While use of the term "PPGIS" originated in the United States, the term "participatory GIS" or "PGIS" emerged from participatory approaches in rural areas of developing countries, the result of a spontaneous merger of Participatory

Table 2
Urban-based PPGIS studies (2007-2013).

Year	Implementation mode	Location	Research theme	Published references	Languages	Participants (approximate)
2013	Internet (Google Maps)	Pacific Beach, San Diego, USA	Community development together with NGO	Study in progress. Website: http://www.softgis.fi/sandiego	Finnish English	120
2012	Internet (Tailored address maps with layers)	Kainuu, Finland	Socio-ecological tools for ecotourism planning	Study in progress. Website: http://www.softgis.fi/vaaka	Finnish English	260
2012	Internet (Tailored address maps)	Tampere, Finland	Everyday mobility of urban tribes	Haybatollahi, M. & Kyttä, M. (2013). In review. Website: http://www.softgis.fi/tampere	Finnish English	3300
2012	Internet (Tailored address maps)	Kuninkaankolmio, Helsinki metropolitan area	Everyday mobility of urban tribes	Schmidt-Thomé, K. Haybatollahi, M. Kyttä, M. & Korpi, J. (2013); Salonen, M. Broberg, A. Kyttä, M. & Toivonen, T. (2013). In review. Website: http://www.softgis.fi/kuninkaankolmio	Finnish English	1100
2011	Internet (Tailored address maps)	Kirkkojärvi, Espoo, Finland	Perceived safety of a neighborhood	Ahmadi, E. Hirvonen, J. Kuoppa, J. Kyttä, M. & Tzoulas, T. (2013). In review. Website: http://www.softgis.fi/turvallisuus	Finnish	330
2011	Internet (Finland: Tailored address maps, Japan, Australia: Google maps)	Kauhajoki, Finland Tokyo, Japan Bendigo, Australia	Environmental child friendliness of various contexts	Study in progress. Website: http://www.softgis.fi/children	Finnish Japanese English	1200
2010	Internet (Tailored address maps)	Vaasa, Finland	Continuous softGIS service for participatory urban planning	Website: http://www.softgis.fi/vaasa	Finnish Swedish	
2010	Internet (Two map options: Tailored address maps and aerial photos)	Helsinki, Finland	Urban environment promoting active lifestyle of children	Broberg, A. Salminen, S. & Kyttä, M. (2013). Website: http://www.softgis.fi/helsinkilapset	Finnish	1100
2010	Internet (Tailored address maps)	Soukka, Espoo, Finland	Mapping local services	Kytö, H. Väliniemi-Larsson, J. & Tuorila, H. (2011). Website: http://www.softgis.fi/palvelu	Finnish	900
2010	Internet (Tailored address maps)	Billnäs, Finland	Participatory urban planning: Mapping local character	Broberg, A. (2011). Website: http://www.softgis.fi/billnas	Finnish Swedish	110
2009	Internet (Two map options: Tailored address maps and aerial photos)	Helsinki and Espoo	Urban densification & social sustainability	Kyttä, M. Broberg, A. Tzoulas, T. & Snabb, K. (2013); Kyttä, M. Broberg, A., Haybatollahi, M., and Schmidt-Thomé, K. (2013) In review. Websites: http://www.softgis.fi/helsinki http://www.softgis.fi/espoo	Finnish English Swedish	3100
2009	Internet (Tailored address maps and aerial photos)	Tammisalo, Helsinki, Finland	User feedback regarding an urban park	Broberg, A. (2011). Website: http://www.softgis.fi/tammisalo	Finnish	200
2008	Internet (Tailored address maps and aerial photos)	Muotiala, Tampere, Finland	Perceived safety of a CPTED neighborhood	Kyttä, M. Puustinen, S. Hirvonen, J. Broberg, A. & Lehtonen, H. (2008). Website: http://www.softgis.fi/muotiala	Finnish	180
2007	Internet (Aerial photos and axonometric drawings)	Turku, Finland	Child friendliness of urban environment	Kyttä, M. Broberg, A. & Kahila, M. (2012); Broberg, A. Kyttä, M. & Fagerholm, N. (2013) Website: http://www.softgis.fi/turku	Finnish	1600
2007	Internet (Address maps)	Mäntsälä, Kerava and Nurmijärvi, Finland	Perceived environmental quality	Kyttä, M. Kahila, M. & Broberg, A. (2011). Websites: http://www.softgis.fi/mantsala http://www.softgis.fi/kerava http://www.softgis.fi/nurmijarvi	Finnish	1600
2007	Internet (Aerial photos and axonometric drawings)	Järvenpää, Finland	Introducing softGIS methodology in the field of urban planning	Kahila, M. & Kyttä, M. (2009) Website: http://www.softgis.fi/jarvenpaa	Finnish	400

Learning and Action (PLA) methods with geographic information technologies (Rambaldi, Kyem Kwaku, Mbile, McCall, & Weiner, 2006). The term volunteered geographic information (VGI) was introduced by Goodchild (2007) to describe the harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals.

There has not been a bright line between PPGIS, PGIS, and VGI concepts, with continuing ambiguity over the appropriate use of the terminology in the academic literature and in real-world applications. As noted by Tulloch (2008), researchers and practitioners from different backgrounds and contexts have brought diverse vocabularies to the field of PPGIS. He argues that since it remains unclear how distinctions in PPGIS will emerge in practice, the terms (PPGIS and PGIS) should be treated in the most inclusive manner possible, a type of lexicon “big tent”. While there may be wisdom in terminology inclusiveness, as PPGIS researchers we

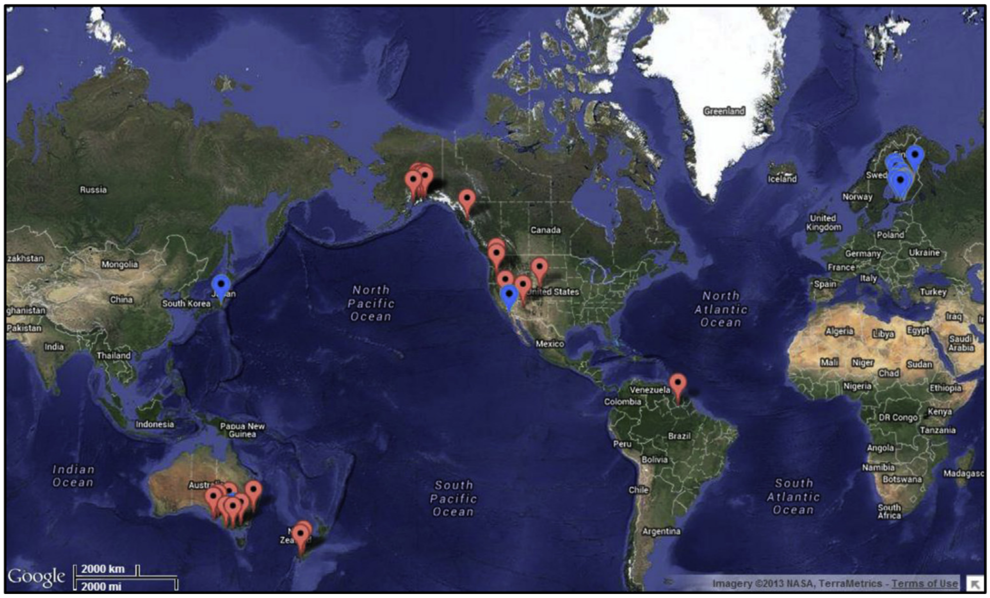


Fig. 1. Google® map showing global distribution of PPGIS studies completed by the authors in regional/environmental applications (red markers) and urban applications (blue markers). (For interpretation of the references to color in this figure legend, the reader referred to the web version of this article.)

spend considerable effort explaining the relationships between PPGIS, PGIS, and VGI to planners, stakeholders, and even other academics. The terms are not synonyms and enough points of distinction have emerged in practice over the last decade to warrant a more nuanced description of similarities and differences.

In Table 3, we characterize PPGIS, PGIS, and VGI on the dimensions of purpose, geographic context, importance of the mapped data quality, sampling approaches, data collection, data ownership, and dominant mapping technology. Both PPGIS and PGIS promote the inclusion and empowerment of marginalized or under-represented populations in the development and use of spatial information. The distinctions between PPGIS and PGIS largely reflect the situational context (developing vs. developed country) in which the practices have emerged. In developing countries, the focus of PGIS has been on social learning and community engagement, primarily in rural areas, with the resulting maps a potentially useful, but secondary outcome. PGIS is used as a development tool to encourage community identity, empowerment, and the creation of social capital. The promotion of social justice and equality is often an implicit goal of the process. In many cases, the participation component is more important than the resulting maps that are presumed to be the intellectual property of the people and communities that created them.

In contrast, PPGIS targets urban-centered populations in developed countries with an emphasis on the generated maps and how the spatial data can be used to inform future land use. The driver for PPGIS appears less about social and economic marginalization (although this may be present), but enhancing participation processes to improve the quality of land use decisions. The creation of social capital and enhanced community identity may result from the PPGIS process, but these are secondary to the quality and representativeness of the spatial data. The data collected through PPGIS may be subjected to scientific standards of data quality, especially if it is to be used to support and justify decisions that are purported to have broad public support.

With its origin in countries having stable property rights and legal requirements for public consultation, PPGIS may be sponsored or sanctioned by a government planning authority as a means to complement other participation methods. For example, in the first act of its kind, the government of Finland (Ministry of Finance and Ministry of Environment) commissioned the development of national PPGIS software for use by local governments throughout the country (see http://portal.eharava.fi). And yet, it remains to be seen whether local governments in Finland embrace this opportunity to use PPGIS and how it actually informs land use decisions. The legal requirement in many democratic countries

Table 3
Characteristics of PPGIS, PGIS, and VGI.

	PPGIS	PGIS	VGI
Process emphasis	Enhance public involvement to inform land use planning and management	Community empowerment Foster social identity Build social capital	Expand spatial information using citizens as sensors
Sponsors	Government planning agencies	NGOs	NGOs, ad hoc groups, individuals
Global context	*Developed* countries	*Developing* countries	Variable
Place context	Urban and regional	Rural	Variable
Importance of mapped data quality	Primary	Secondary	Primary
Sampling approach	Active: probability	Active: purposive	Passive: voluntary
Data collection	Individual (e.g., household sampling)	Collective (e.g., community workshops)	Individual
Data ownership	Sponsors of the process	People and communities that created data	Shared (e.g., data commons license)
Dominant mapping technology	Digital	Non-digital	Digital

that allows ordinary citizens to nominally participate in land use planning (e.g., through written or oral comment) does not equate to substantive or meaningful participation. Traditional public participation processes may still favor interest groups and active minorities, especially development interests, while under-representing the "silent majority" of public stakeholders. At the very least, PPGIS adds to the existing toolbox of participatory planning methods and offers a means to potentially reach larger numbers of participants or groups that are hard to reach with more traditional methods.

In contrast to PPGIS, PGIS seeks to promote the goals of nongovernmental organizations, grassroots groups and community-based organizations that may oppose official government policy, especially as pertaining to land tenure, the rights of indigenous peoples, and the current distribution of wealth and political power. The term "countermapping" (Peluso, 1995) is most closely associated with PGIS wherein spatial information becomes a means to oppose dominant power structures through the promotion of progressive social goals.

In PPGIS, the dominant form of spatial data collection involves *probability* sampling of individuals, often through household surveys or interviews, to ensure population representativeness. In contrast, the dominant sampling approach in PGIS is *purposive* sampling to ensure that key stakeholders such as community leaders are included in the mapping process. PGIS mapping is often done in groups with the resulting maps reflecting a *collective*, rather than *individual* outcome. VGI typically uses citizen-initiated, *convenience* sampling methods that generate individual mapping contributions.

These descriptions of PPGIS, PGIS, and VGI are generalizations, and as such, are subject to exceptions. For example, PPGIS and PGIS may contain unsolicited, voluntary participation while VGI methods may involve active solicitation for participation. PPGIS might involve a group mapping process while PGIS may generate individual maps. Thus, the sampling methods (active vs. passive, probability vs. non-probability, purposive vs. convenience) and the mapping methods (individual vs. collective) represent potential, but not definitive points of distinction between PPGIS/PGIS and VGI systems.

PPGIS methods in developed countries are increasingly dominated by digital, web-based mapping techniques, as are VGI applications. In contrast, PGIS has historically used simpler, non-digital mapping technology that may be more culturally suitable or pragmatic for mapping in rural locations. However, any technological distinction between PPGIS and PGIS is less obvious today with advances in internet and mobile mapping technologies (i.e., the "Geoweb"). The availability of high quality digital basemaps and imagery through Google®, Bing®, and open source products such as Openstreetmap, and the development of application programming interfaces (APIs) that provide for customized mapping applications, has revolutionized the field, providing high technology options in remote environments. PPGIS "mashups" are relatively quick and inexpensive to develop and have resulted in the proliferation of "cloud" or internet-based mapping applications, with increased access to spatial information even in remote, rural areas.

For VGI, technology has been a dominant force giving rise to a multitude of web-based mapping applications. The ubiquity of user-generated spatial information and mapping applications has contributed to the "crowdsourcing" (Howe, 2006) of spatial information where content is solicited from a large group of people, especially from an online community (see Sui, Elwood, & Goodchild, 2013). Surowiecki (2005), in the book *The Wisdom of Crowds*, describes the potential for superior decisions through crowdsourcing by providing examples of how a group of people may converge on a solution to a problem that an individual, even an expert, may be unable to solve. And yet, VGI systems have yet to play a significant role in land use decisions because land use planning is not a single problem to be solved, but rather an ongoing set of social trade-offs.

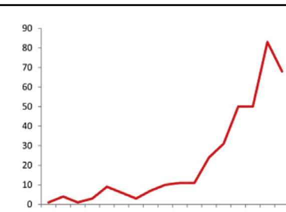
The social and academic interest in PPGIS has increased since its emergence as a focal area of research and application. For example, a query of the Institute for Scientific Information's (ISI) Web of Science database (as of October 31, 2013) for peer-reviewed journal articles for topics containing the search terms "public participation GIS", "participatory GIS", or "volunteered geographic information" located over 200 published articles (see Table 4). The Scopus database, with broader coverage in the social sciences, contained over 300 articles, while a similar Google Scholar search yielded more than 3000 search results indicating the presence of considerable informally published material (i.e., grey literature) related to PPGIS. Within the academic community, the journal *Applied Geography* has been the leading publisher of PPGIS/PGIS research while *Transactions in GIS* has been the leading journal publisher for VGI research.

As a multidisciplinary concept, PPGIS is subjected to an intellectual tug-of-war between its two dominant components—geographic information systems (GIS) and public participation (PP). Whereas the former emphasizes spatial technology and information, the latter emphasizes the human and social processes used to engage broader audiences in planning, design and management. This contest between technology and social processes is likely to continue as this multidisciplinary partnership represents an uneasy merger of contrasting knowledge paradigms.

The issues presented below synthesize some of the more important issues in PPGIS based on our experience. While the list is not exhaustive, it provides a foundation for identifying and describing some of the key research priorities that follow.

Table 4
Search results from selected bibliographic databases (as of October 31, 2013) including a trend line showing the number published documents from the Scopus database in a combined search for PPGIS, PGIS, and VGI.

Database	PPGIS	PGIS	VGI
Search term	"Public participation GIS"	"Participatory GIS"	"Volunteered geographic information"
ISI Web of Science[a]	82	87	84
Scopus[b]	129	105	177
Google Scholar[c]	1770	2410	2060
Most published journal	*Applied Geography*		*Transactions in GIS*



[a] Search for articles, books, book chapters, and published proceedings in "topic" which includes title, abstract, and keywords.
[b] Search for articles or conference papers in title, abstract, keywords.
[c] Search results are estimates.

Important issues in PPGIS

Conceptual and theoretical foundations

PPGIS, as a relatively new field of study, has yet to develop a distinctive conceptual and theoretical foundation, but rather draws upon concepts and theories from a number of fields of study. Participatory mapping assumes a transactional approach to person-environmental relationships exemplified by Gibson's (1979) ecological approach to perception or Zube's (1987) transactional model of landscape perception. In a transactional model, humans are active participants in their environment—thinking, feeling, and acting—leading to the attribution of meaning and valuing of specific places. Gibson used the term "affordances" to describe the latent possibilities of the material and cultural environment that human agents perceive, use or shape. Participatory mapping relies on the ability of individuals to recall their transactional experiences in a place or landscape i.e., the actualized affordances, or in the absence of previous experience, the ability to locate the potential affordances of places on a map.

Some spatial theories have been applied to help explain the mapped results. The theory of geographic or spatial discounting suggests that people wish to be close to what they like or consider "good" and distance themselves from what they dislike or consider to be "bad" (Hannon, 1994; Norton & Hannon, 1997). Some evidence of geographic discounting has been observed with PPGIS data. For example, mapped environmental values appear to cluster around communities, with values associated with direct uses located closer to communities than values associated with indirect uses (Brown et al., 2002). Pocewicz and Nielsen-Pincus (2013) and de Vries et al. (2013) also found significant evidence of spatial discounting in their PPGIS studies of development preferences and scenic attributes respectively. Positive experiences in urban environments have been shown to locate closer to homes than negative ones in some studies (Kyttä, Kahila, & Broberg, 2011), while other studies have found opposite results (Kyttä, Broberg, Tzoulas, & Snabb, 2013). Brown (2008) posited a theory of urban park geography suggesting that the diversity of mapped urban park values are a function of park size and distance from concentrated human settlement.

A few PPGIS studies have utilized a quasi-experimental design to test different research hypotheses related to participatory mapping methods. One study evaluated the spatial concurrence of point versus polygon mapped features while another study evaluated the similarity in mapped results between using printed maps and internet/digital maps. The results indicate the mapping of spatial attributes by participants with point rather than polygon features appears simpler and more effective but requires significantly greater sampling effort (Brown & Pullar, 2012) while PPGIS methods that use simple mapping technology such as paper maps and markers result in higher response rates, reduced participant bias, and greater mapping participation (Pocewicz, Nielsen-Pincus, Brown, & Schnitzer, 2012).

A stronger conceptual and theoretical foundation is likely to emerge through induction based on more PPGIS studies. For example, in urban applications, PPGIS studies can evaluate various safety planning approaches, like the "broken windows hypothesis" (Wilson & Kelling, 1982), can relate social, psychological and health outcomes to the effects of urban densification (Kyttä, Broberg, Haybatollahi, & Schmidt-Thomé, 2013), can identify the child friendliness of various urban environments (Broberg, Kyttä, & Fagerholm, 2013; Broberg, Salminen, & Kyttä, 2013), and describe how urban parks and greenspaces contribute to physical activity and community health (Brown, Weber, & Schebella, 2014). PPGIS research may also be used to better understand travel behavior in urban environments (Haybatollahi & Kyttä, 2013; Salonen, Broberg, Kyttä, & Toivonen, 2013)

To date, PPGIS research has been driven more by the need to identify spatial information potentially useful for planning and decision support (i.e., applied research) than conceptual and theoretical development (basic research). In the absence of a distinctive conceptual and theoretical tradition, there has been relatively little guidance for the design and implementation of empirical PPGIS systems. As a consequence, a diversity of approaches to participatory mapping has emerged in practice.

Diversity of approaches to participatory mapping

The choice of map attributes (what is mapped?), sampling (who does the mapping?), purpose (reason for mapping?), technology (how is mapping done?), and location (where is mapping done?), provide a large number of participatory mapping design options. Mapping technology can involve the use of materials *in situ*, printed media, or digital media. The most common data collection approach is to have individuals map spatial attributes using self-administered surveys, key informant interviews, or mapping in a group setting such as community workshops. Group techniques such as focus groups that generate collective maps have also been used (Lowery & Morse, 2013) as well as participatory 3D modeling (P3DM), a specialized mapping technique where community members collectively construct a 3-dimensional map and then annotate with features (Rambaldi & Callosa-Tarr, 2001). Early PPGIS data collection used simple technology such as paper maps and markers (e.g., pencil, pen, stickers) while digital mapping, especially through the internet, has been common in more recent applications. The location of mapping activity can be done in the field or in a built environment (e.g., home, office, or community center). Common to all types of participatory mapping is the need to represent spatial attributes of importance on a map.

The general categories of what is mapped (described further below) include landscape values, development preferences, place qualities, and participant experiences. Mapping participants include stakeholders, broadly defined, such as residents or visitors to an area, experts or non-experts, and decision-makers or decision-takers. As Schlossberg and Shuford (2005) note, the "public" in PPGIS depends on the definition and may include "decision makers", "affected individuals", or the "random public", among other groups. Some key objectives for participatory mapping may include (1) describing current or historical connection to place, (2) identifying place qualities, values, or conditions, (3) identifying current behavior patterns or everyday practices in particular settings, and (4) identifying preferences for future land use and management.

The development of the "softGIS" method emerged in Finland as a distinctive, urban-focused internet tool for participatory mapping with the goal of identifying the relationship between environmental factors, and local experiences and everyday behavior (Kahila & Kyttä, 2009; Rantanen & Kahila, 2009). The qualifying term "soft" refers to the subjective and qualitative nature of the mapped attributes as a contrast to the "hard" spatial data layers usually associated with GIS. Although the participatory mapping method appears similar to other PPGIS internet applications, an important point of distinction is that "softGIS" methods have been used to map children's experiences and behavior (Kyttä, Broberg, & Kahila, 2012). The latest versions of softGIS tools include administrative pages that allow the creation of a new PPGIS survey easily and include online data visualization tools.

In the absence of large-scale, systematic research, the variety of PPGIS methods and practices ensures that participatory mapping knowledge and experience will accumulate slowly through a successive string of case studies where specific outcomes are not easily transferrable across physical and social conditions. This situation is compounded by the lack of systematic evaluation research in PPGIS methods. Longitudinal and meta-studies can increase the generalizability of research findings, but to date, there have been only two longitudinal PPGIS studies (Brown & Donovan, 2013b; Brown & Weber, 2011) and one meta-study using PPGIS data (Brown, 2013a).

Spatial attributes mapped in PPGIS

Common to all types of PPGIS is the need to symbolically represent spatial attributes of interest on a map. The types of spatial variables that have been asked of participants have varied significantly across applications. Table 5 provides a partial list of operationalized PPGIS attributes with definitions from various applications. For example, in environmental planning applications, the list of spatial attributes include *landscape values* and *special places* (Alessa, Kliskey, & Brown, 2008; Beverly, Uto, Wilkes, & Bothwell, 2008; Brown, 2005; Brown & Alessa, 2005; Brown & Raymond 2007; Brown & Reed, 2009; Brown & Reed 2000; Brown et al., 2004; Brown & Weber, 2012b; Clement & Cheng,

Table 5
A composite of selected spatial attribute definitions used in different PPGIS studies. The number and type of spatial attributes varied depending on the purpose and location of the PPGIS process. Other PPGIS spatial attributes not shown here include activities, highway qualities, urban park values, and ecosystem services.

Landscape values	Development preferences	Experiences
Aesthetic/scenic—these areas are valuable because they contain attractive scenery including sights, smells, and sounds.	*Tourism accommodation* —this area is acceptable for building tourism accommodation such as hotels, motels, or lodges.	*Aesthetic/scenic*—I experienced pleasing sights, sounds, and/or smells.
Economic—these areas are valuable because they provide timber, fisheries, minerals, or tourism opportunities such as outfitting and guiding	*Tourism services* —this area is acceptable for building tourism services such as restaurants, petrol stations, or retail establishments.	*Crowding/congestion*—I experienced crowding with other visitors (e.g., the car park was full, I didn't find the right spot).
Recreation—these areas are valuable because they provide a place for my favorite outdoor recreation activities.	*Urban development* —this area is acceptable for new urban development (residential and commercial)	*Solitude/escape*—I experienced solitude, tranquillity, and escape from social pressures.
Life sustaining—these areas are valuable because they help produce, preserve, clean, and renew air, soil, and water.	*Rural residential development* —this area is acceptable for rural residences with acreage.	*Social interaction*—I experienced positive social interaction with family, friends, or other visitors.
Learning/scientific —these areas are valuable because they provide places where we can learn about the environment through observation or study.	*Industrial development*— this area is acceptable for industrial development including manufacturing, processing, or mining (e.g., gravel).	*Trail-based activity*– I experienced trail-based, physical and/or adventure activity (e.g., bushwalking, mountain biking, cycling, jogging/running, cross country skiing).
Biological—these areas are valuable because they provide a variety of fish, wildlife, plants, or other living organisms.	*Wind energy development* —this area is acceptable for installing commercial wind turbines.	*Other physical activity/adventure*—I experienced other physical and/or adventure activity (e.g., canoeing, caving, swimming, exercising/fitness, fishing).
Spiritual—these areas are valuable because they are sacred, religious, or spiritually special places or because I feel reverence and respect for nature here.	*Natural resource development*— this area is acceptable for natural resource development such as gravel extraction, grazing, or forestry	*Overnight stay/camping*—I experienced an overnight stay or camping.
Intrinsic—these areas are valuable in their own right, no matter what I or others think about them.	*Energy development*— this area is acceptable for energy development such as hydro-electric dams or wind turbines	*Learning/discovery*—I experienced learning about nature, culture, or heritage.
Historic—these areas are valuable because they represent natural and human history that matters to me, others, or the nation.	*Tourism development*— this area is acceptable for building tourism accommodation and services	*Positive wildlife/vegetation experience*– I had a positive experience with wildlife or vegetation
Future—these areas are valuable because they allow future generations to know and experience the area as it is now.	*Other development*— this area is suitable for future development. Please click on the marker and write the type of development.	*Noise*—I experienced excessive noise (e.g., other people, aircraft, boats) here
Subsistence—these areas are valuable because they provide necessary food and supplies to sustain my life	*No development*–this area is perfect as is and should not have any new development of any kind	
Therapeutic—these places are valuable because they make me feel better, physically and/or mentally.		
Cultural—these places are valuable because they allow me or others to continue and pass down the wisdom and knowledge, traditions, and way of life of ancestors.		
Wilderness—these places are valuable because they are wild, uninhabited, or relatively untouched by human activity		
Marine—these areas are valuable because they support marine life		
Social—these areas are valuable because they provide opportunities for social interaction		
Special places—these places are special or valuable because…indicate your reason.		

Table 6
A composite of selected spatial attribute definitions used in various urban-based, softGIS applications.

Experiences (adults)		Experiences (children)		Everyday behavior patterns (adults)	Development preferences
Positive	Negative	Positive	Negative	Work, study, day-care	
Functional		Functional			
I can live according to my lifestyle well	I can live according to my lifestyle poorly	Doing recreational sports: Skateboarding, Playing ball games, swimming etc.	My parents don't like me to come here	Workplace	Object to be preserved
Walking or cycling is smooth	Walking or cycling is complicated	Enjoying nature	There's nothing to do here	Day-care	Place to be improved
The cultural life is vivid	The cultural life is quiet	Other activities: music, dance, scouting, clubs etc.	The place is not in good enough condition (lighting, equipment)	School	Area to be improved
The services are good	The services are poor	Hanging out	I need someone to take me here (lack of public transport, too far away, difficult to find my way)	Study place	Object to be removed
Opportunities for hobbies are many	Opportunities for hobbies are few	Doing competitive sports: Playing ball games, swimming etc.	I can't afford to come here	Work-related place	New building
Use of private car is smooth	Use of private car is complicated	Exploring, discovering, wandering	The place is closed when I'd want to go there	**Shopping place**	New route
Using public transportation is smooth	Using public transportation is complicated	Moving around: Walking, running, biking, bushwalking	The traffic on the way here is dangerous	Neighborhood grocery store	
The traffic is safe	The traffic is dangerous	Chores: Doing groceries, walking the dog, feeding animals, picking up little brother/sister from school	Physical barriers prevent coming here	Supermarket	
Social		City life: Going to movies, cafes, shopping, library, karaoke	Weather conditions are too extreme	Mall/shopping center or department store	
The residents take care of the surroundings well	The residents take care of the surroundings badly	Games (electronic, board, card, figure)	I'm forced to come here	Specialized shop	
The people significant to me are nearby	The people significant to me are far away	**Social**		Farmers' Market	
Neighbor relations here are harmonious	Neighbor relations here are quarrelsome	I make new friends	Strict social control	Swap Meet/Market Place	
The social life is vivid	Social life is dull	I enjoy privacy	Place of arguing	**Running errands**	
The diversity of residents is adequate	The residents are too diverse or similar	I meet my friends	I feel like an outsider	Bank, post office or bureau	
I feel socially secure	I feel socially insecure	Nobody watches over me (no control)	I'm lonely	Health services	
Reputation of this place is good	Reputation of this place is bad	I spend time with pets or animals	Scary adults (drunks, addicts)	Other service, e.g. hair salon or barber	
The residents care for each other	The residents do not care for each other	I can be myself	Kids/youth my age are not tolerated here	**Sports and outdoor activities**	
Atmosphere		Possibility to meet girls or boys	Hectic, crowded	Recreational outdoor location	
Silent	Noisy	Lively place	Unpleasant/unpredictable girls and boys/gangs	Designated sports location	
Lively	Dull	I spend time with adults	Place of bullying	Playground	
Relaxing	Stressful	I impress others	There is no-one around, the place is empty	**Leisure time**	
Unpredictable	Too predictable	**Emotional**	Visiting place (friends, relatives)		
Inviting	Unwelcoming	Exciting/Fun	Boring	Restaurant, bar, café	
Child-friendly	Unfriendly towards children	Beautiful	Dangerous	Library	
Nature is present	Nature is absent	Good memories	Dirty, lots of rubbish	Church, parish activities	
Calmness	Hectic	Cheerful/Happy	Polluted, bad air to breathe	Summer house, holiday house	
Appearance		Fresh air to breathe	Feel bad place	Adult education center	

(*continued on next page*)

Table 6 (*continued*)

Experiences (adults)		Experiences (children)		Everyday behavior patterns (adults)	Development preferences
Positive	Negative	Positive	Negative	Work, study, day-care	
Functional		Functional			
Density of development is fine	The buildings are too sparsely built	Safe	Sad, down	Other leisure time location	
The price-quality ratio of living is appropriate	The price-quality ratio of living is inappropriate	Clean and tidy	Ugly		
Personalizing this place is possible	Personalizing this place is impossible	Relaxing	Stressful		
The surroundings are attractive	The surroundings are unattractive	Feel good place	Bad memories		
The sparse development is fine	The buildings are too densely built	Calm and quiet	Noisy or rowdy in a bad way		
The surroundings are tidy	The surroundings are untidy				
The history is present	The history is absent				
The surroundings are finished	The surroundings are unfinished				

2011; Nielsen-Pincus, 2007; Sherrouse, Clement, & Semmens, 2011; van Riper, Kyle, Sutton, Barnes, & Sherrouse, 2013; de Vries et al., 2013; Zhu, Pfueller, & Whitelaw, 2010), *development preferences* (Brown, 2006; Brown & Weber, 2012c; Pocewicz & Nielsen-Pincus, 2013; Raymond & Brown, 2007), *national park experiences and perceived environmental impacts* (Brown & Weber, 2011), *climate change risks* (Raymond & Brown, 2010), *transportation corridor qualities* (Brown, 2003), *urban park and open space values* (Brown, 2008; Brown, Schebella, & Weber, 2014; Tyrväinnen, Mäkinen, & Schipperijn, 2007), *knowledge of landscape conditions* (Pocewicz, Schnitzer, & Nielsen-Pincus, 2010), *recreation resources* (McIntyre, Moore, & Yuan, 2008), and *ecosystem services* (Brown, Montag, & Lyon, 2012; Fagerholm, Käyhkö, Ndumbaro, & Khamis, 2012).

The diversity of spatial attributes in Table 5 reflects the diversity of land use planning applications the data was intended to inform. The general categories of place *values*, *preferences*, *qualities*, and *experiences* were operationalized as spatial variables and applied to different geographic settings at multiple scales. For example, landscape *values* were first developed to assist national forest planning in the U.S., but were subsequently adapted to other public lands such as national parks and conservation reserves. Transportation corridor *qualities* were developed to inform national scenic byway planning while development *preferences* were applied to tourism planning. Visitors to national parks were asked to describe their park *experiences* to identify the potential need for new facilities or infrastructure.

In urban-specific applications, the list of spatial attributes have included *environmental experiences* of inhabitants conceptualized as "quality factors" (Kyttä et al., 2011, Kyttä, Broberg, Haybatollahi, et al., 2013; Kyttä, Broberg, Tzoulas, et al., 2013; Kyttä, Kuoppa, et al., 2013) or *environmental affordances* (Kyttä et al., 2012; Broberg, Kyttä, et al., 2013; Broberg, Salminen, et al., 2013), *everyday mobility and behavior patterns* (Broberg, Kyttä, et al., 2013; Broberg, Salminen, et al., 2013; Haybatollahi & Kyttä, 2013; Salonen et al., 2013; Schmidt-Thomé, Haybatollahi, Kyttä, & Korpi, 2013), attributes related to the *perceived safety* of traffic and accident danger or criminal and social threats (Kyttä, Kuoppa, Hirvonen, Ahmadi, & Tzoulas, 2013), and urban *development preferences* (Kyttä, Broberg, Tzoulas, et al., 2013). Table 6 provides a list of spatial attributes used in urban-specific applications. Mapping the qualities of place has been common in both urban and regional PPGIS applications, while the mapping of human behavior has been more common in urban applications.

The range of spatial attributes in a PPGIS process may be viewed on a continuum ranging from *objective* locations based on participant knowledge or experience in the study area (e.g., activities, uses, behaviors) to *subjective* perceptions of place based on participant knowledge, experience, or symbolic meanings (e.g., aesthetics, place safety). Brown (2012a) conceptualized the mapping of potential spatial attributes in PPGIS on two dimensions that describe the degree of cognitive challenge for the participant and the level of expert knowledge required to spatially locate the attribute in the study area.

The fundamental questions about which spatial attributes are to be collected in PPGIS center on the type of place-based information that participants are presumed to possess and the purpose that this information is thought to serve. The optimal spatial attributes include variables that participants have the capacity and willingness to provide with the potential to inform decisions about place, broadly defined. In some cases, these attributes will be more tangible (e.g., location of participant uses/activities), and in others, more intangible (e.g., location of participant values).

Although the mapping of place-based values and preferences has achieved some level of standardization through replication, the development of a singular, definitive typology of spatial attributes appears unlikely given the variability in landscapes, spatial scales, participants, and application needs. Some degree of PPGIS customization appears inevitable for each application.

Sampling, participation, and data quality

The quality of PPGIS data is inextricably linked with sampling design and participation rates. Two important metrics for data quality include sufficiency of spatial data for meaningful analysis, and the inclusion of the participants that are affected by land use decisions. At their core, PPGIS processes seek to inform and influence land planning and management decisions. Some PPGIS processes may be less ambitious and seek only to generate spatial information as part of a social assessment that will only indirectly inform a decision process. Relatively few participants willingly accept a participatory role in which their time and effort have absolutely no prospect of influencing future land use decisions. PPGIS researchers and practitioners have an ethical obligation to be forthright with prospective participants about the realistic prospects of the collected spatial data being used to inform land use decisions. With the increased challenges of participant recruitment in reluctant populations, sponsors of PPGIS must guard against exaggerating the potential influence of PPGIS results on land use decisions as a means of recruitment when such claims cannot be supported.

In democratic societies, land use decisions are made by political representatives wherein the public participation process often serves as a proxy for gauging public sentiment. The logic of collection action (Olson, 1971) ensures that vested interests in land use will participate to advocate their preferred outcomes. Interest groups have become quite adept at using public participation to present self-interested outcomes as the public interest. But who is the "public" and who determines what is in the "public interest" regarding land use and management?

Schlossberg and Shuford (2005) argue that the meaning of "public" and "participation" are essential to understanding public participation in PPGIS. In their typology of PPGIS, the term "public" may include decision makers, implementers, affected individuals, interested observers, or the random public. The latter classification—random public—appears most consistent with common dictionary definitions of public that include "all the people" or "people in general". But some PPGIS processes do not include a random sample of the general public leading to the critical question as to which "public" is actually represented in the PPGIS process.

Recent research on sampling effects indicates that special interests can mobilize in a PPGIS process and that their spatial preferences for land use will differ from those of a random household sample (Brown, Kelly, & Whitall, 2012). Thus, there is early evidence and a caveat, that convenience sampling as represented by VGI systems or voluntary components of PPGIS, can bias participatory spatial data with the potential to preference minority perspectives in land use decisions. The paradox here is that without careful attention to sampling design and participation, PPGIS, a process that seeks to enfranchise marginal or under-represented segments of society, could reinforce existing power relationships within society. Thus, sampling design emerges as one of the most important issues for the quality of a PPGIS application.

Participation by the most appropriate population segments must be accompanied by sufficient spatial data. The quantity of PPGIS data determines the power of inference and thus is a measure of data quality. Even if the most appropriate segments of the "public" are represented in a PPGIS process, sufficient spatial data are required to identify spatial patterns with confidence. The data sufficiency problem becomes more acute the larger the study area. For example, in a large study area, it is possible that only 10 out of 300 participants actually map spatial preferences for a given subregion of the study area. How much weight or deference should be given to the views of those 10 individuals for land use in that area?

Because PPGIS often engages lay or non-expert segments of society, there may be concerns about the spatial accuracy of the data (Brown, 2012b). This concern about data quality has also been articulated for VGI systems where there is a general lack of quality assurance (Goodchild & Li, 2012). There is an assumption that PPGIS should be evaluated with the same standards of spatial accuracy as obtainable in expert GIS systems that map physical landscapes. In the evaluation of PPGIS data quality, the concepts of spatial accuracy and spatial precision may become conflated adding to potential mistrust of the data. But there is an important distinction between spatial precision in mapping and accuracy in PPGIS-mapped attributes. Precision is a measure of the exactness in placing a PPGIS marker or attribute on the map, either paper or digital. Precision is influenced by map scale and the ability to mark locations. Internet and digital mapping methods, in general, provide greater precision in PPGIS mapping of attributes than static-scale, paper maps. Accuracy reflects how well a PPGIS marker approaches the true spatial dimensions of the attribute being mapped. The more refined the spatial attribute classification, the greater the likelihood of error. For some PPGIS attributes, especially subjective judgments about place qualities, the level of accuracy may be indeterminate and a judgment must be rendered about whether to accept or reject the data as valid. Arguably, if both high spatial accuracy and precision are required for a given spatial attribute, it may not be an appropriate attribute for mapping in PPGIS. And yet, the PPGIS studies that have been conducted to assess the spatial accuracy of certain mapped attributes suggest that a lay public can achieve reasonable accuracy, even in the mapping of physical landscape features. For example, New Zealand residents were able to accurately map the location of native vegetation (Brown, 2012b) while a general public sample was able to reasonably identify the locations of different wildlife habitats in a region in the U.S. (Cox, Morse, Anderson, & Marzen, 2013).

The debate over the spatial accuracy and quality of PPGIS data, although important, may be a proxy for the deeper question about whether land use decisions should be driven by expert judgment (i.e., top down) that often reflects the dominant power structures within society, or broader social preferences (i.e., bottom up) that can fundamentally alter existing power relations, property institutions, and the distribution of wealth.

Relationships between participatory mapped attributes and physical attributes of places

PPGIS methods can provide spatial data layers that identify the distribution of a wide range of spatial attributes such as activities, values, and preferences. These data can be overlayed with physical GIS data layers to examine potential spatial relationships between the mapped locations and the physical attributes of place. The general research question seeks to understand why different PPGIS attributes are mapped in various geographic locations. For some attributes, the answer may be obvious such as a fishing activity marker being placed on a body of water or a shopping activity marker in a commercial area. For other attributes, such as perceived aesthetics, the rationale for placement may be less obvious.

For participatory mapping in natural landscapes, these mapped attribute/physical place relationships can help inform research on social-ecological systems and the social values of ecosystem services. The concept of social-ecological systems (SES) emphasizes the integrated concept of humans in nature wherein the delineation between social systems and ecological systems appears artificial and arbitrary (Berkes, Colding, & Folke, 2001). While the GIS mapping of ecological features and processes as important components of ecological systems has proceeded at an accelerated pace with remote sensing technology, the GIS mapping of social systems has been limited owing to the complexity of translating social variables into spatial data. PPGIS has contributed to SES knowledge by providing an operational means to identify the location of social-ecological "hotspots" (Alessa et al., 2008).

PPGIS has also been used to spatially locate cultural ecosystem services (a.k.a. social values for ecosystem services), a task that is operationally difficult to accomplish through other means (see Brown, Montag, et al., 2012; Sherrouse et al., 2011). On a more basic level, the complex relationships between perceived landscape values, obtained through PPGIS methods, and physical landscapes have been described in detail by Brown and Brabyn (2012a) for regions in New Zealand. These empirical perception-physical relationships can be used to extrapolate to other landscapes where PPGIS data is not available (Brown & Brabyn, 2012b) and to identify the importance of different land uses/land covers for providing various ecosystem services (Brown, 2013a).

In urban settings, place experiences have been analyzed in relation to home locations and to urban structural variables such as urban density, green infrastructure, and land-use patterns (Kyttä, Broberg, Tzoulas, et al., 2013). In separate studies of children, the urban physical features of general land use, traffic environment, and distance to recreation facilities have been analyzed in relation to children's mobility and transport use (Broberg, Salminen, et al., 2013), while residential density, building density, and quantity of green structures have been analyzed in relation to child friendly environments (Broberg, Kyttä, et al., 2013).

Integration of PPGIS data into land use planning

The appropriate role of PPGIS in land use planning may be related to the planning cycle. Horelli (2002) describes the cycle of participatory planning as consisting of different phases, namely initiation, planning and design, implementation, evaluation, and maintenance phases. Various types of tools and methods support these phases. Typically, diagnostic tools like surveys and mapping techniques dominate in the initiation and evaluation phases whereas the planning phase uses expressive and organizational tools. Information communication technology tools such as PPGIS are seen as a means to enhance transactions and knowledge creation with stakeholders in the planning process. From this perspective, the effective integration of PPGIS would be judged by the purpose it is intended to serve within the planning cycle. PPGIS appears to be well-suited to the initiation (i.e., diagnostic and scoping) phase of a planning process. For example, Brown et al. (in press) describe how PPGIS was used in community meetings as part of an early engagement process for national forest planning in the U.S. But while the use of PPGIS might be viewed by planners as a useful diagnostic method in the planning process, bounding the expectations of participants regarding the role and purpose of PPGIS may prove challenging. The natural expectation for participants that willingly engage in PPGIS is that their knowledge, experience, and attachments to place will have some influence on planning or management decisions. Participants are less likely to engage with the planning process if their role is limited to simply providing information rather than contributing in a more consultative or collaborative planning role.

Arguably, one of the important goals of PPGIS is to engage people in planning processes leading to decisions that will directly affect their lives. Beierle (1999) describes five goals to evaluate the quality of public participation. Does the process educate and inform the public? Incorporate public values into decision making? Increase trust in institutions? Reduce conflict? Improve the substantive quality of decisions? These are worthy aspirational goals for PPGIS as well, but difficult to measure without systematic evaluation based on some criteria. Public participation evaluation criteria, in general, can be placed into two primary categories: *process* and *outcome* criteria (Brown & Chin, 2013). Influencing land use decisions is an *outcome* criterion that requires tracking the PPGIS process from inception to decisions that become codified in a land use/management plan.

Academics excel in developing methods and models to show how spatial data can *hypothetically* be used to inform decisions, and the field of PPGIS is no exception. For example, Reed and Brown (2003) describe a method called *values suitability (or compatibility) analysis* that uses PPGIS data to assess the suitability of lands for different management activities. The premise of the method is that decisions for public lands should be consistent with public values collected through PPGIS. This method is further elaborated by providing a specific example showing how PPGIS data can be used to determine areas suitable for off-road vehicle use in public national forests (Brown & Reed, 2012a). More generally, PPGIS data can inform the allocation of public land through spatial zoning in long-range plans (Brown & Donovan, 2013a) and describe where land use conflicts are most likely to occur within a regional plan (Brown & Raymond, 2013).

The spatial attributes of landscapes identified with PPGIS can be quantified into landscape metrics that assist with decision support through integration with other biophysical or administrative GIS data layers (Brown & Reed, 2012b). PPGIS landscape metrics quantify the spatial distribution of mapped PPGIS attributes within a given area or region to compare the distribution to other areas. These landscape metrics may be useful in the planning and management of public lands such as national forests, parks, and resource management areas because statutory requirements often dictate that these lands be managed for a range of public values and uses. In urban applications, PPGIS may help identify the best potential areas for new development where the existing structure would allow densification but where inhabitants' experiences do not show strong need for preservation (Kyttä, Broberg, Haybatollahi, et al., 2013; Kyttä, Broberg, Tzoulas, et al., 2013; Kyttä, Kuoppa, et al., 2013).

Despite an increasing number of PPGIS studies, there is still little evidence that PPGIS has influenced specific land use decisions. For example, although public collaboration in Finland is supported by European Union (EU) directives and the Finnish Building and Land Use Act (1999), effective participation has lagged owing to inadequate resources (Kahila & Kyttä, 2009), resistance from planners (Puustinen, 2006), inefficiency in practice (Faehnle & Tyrväinen, 2013), or a lack of understanding about the actual purpose of citizens' participation in relation to planning and decision-making (Bäcklund & Mäntysalo, 2010). There are a number of other possible additional explanations including fear of engaging the public, lack of agency experience with meaningful public participation, and regulatory barriers (Brown, 2012a). To be fair, these reasons are associated with public participation in general, regardless of whether the process includes PPGIS. The use of PPGIS data to *inform* and importantly, *influence* land use decisions would represent a radical departure from current top-down land use planning methods used by most public agencies and municipal governments. For PPGIS to be effective, it would require that existing power structures accept that lay segments of society have valuable knowledge and experiences, beyond mass opinion, that can substantively contribute to land planning and management decisions. Public sponsors of participatory processes are likely aware that even with a public participation process that is effective on some important process goals such as providing information and allowing public expression of opinion, dissatisfaction may still result if the planning decisions do not reflect the desires of local populations (Brown & Chin, 2013). In other words, an effective PPGIS must do more than engage the public in learning, building social capacity, and providing for the expression of preferences—it must also demonstrate that local, public judgments regarding land use are actually reflected in decision outcomes. This deference to local values and preferences is difficult for many political jurisdictions to accept in practice.

PPGIS research priorities

Understanding and increasing participation rates

Engaging stakeholders and lay audiences in PPGIS is challenging in a fast-paced society where people confront increasing demands on their time. Internet-based PPGIS response rates with random household sampling have averaged 13% across five studies (Beverly et al., 2008; Brown, Montag, et al., 2012; Brown & Reed 2009; Brown, Weber, Zanon, & de Bie, 2012) while paper-based PPGIS response rates have ranged from 15 to 47%, with an average of 30% across 11 surveys (Alessa et al., 2008; Brown, 2005; Brown et al., 2004; Clement & Cheng, 2011; Nielsen-Pincus, 2011; Raymond & Brown, 2010; Zhu et al., 2010). The engagement of the general public in PPGIS shares the same challenges as general survey response rates. All modes of survey data collection show declining response rates (Couper & Miller, 2008) and internet-based surveys show 11% lower response rates (on average) than other survey modes (Manfreda, Bosnjak, Berzelak, Haas, & Vehovar, 2008). In the only study to compare PPGIS response rates between paper-map (postal delivery) and internet PPGIS methods, the response rate was 2.5 times higher for the paper-based method (Pocewicz et al., 2012). In Finland, the response rates from studies using the SoftGIS software have varied considerably depending on the mode of contact. Response rates from recruitment of children for participation through schools has been as high as 75%, while random sampling of the general public for participation has averaged about 15%.

For participation through the postal service (i.e., paper-map PPGIS), there are strategies to increase response rates such as monetary incentives, personalizing the invitation, recording the delivery, using postage-paid returns, contacting individuals before sending the map/questionnaire, using multiple follow-up contacts including a second questionnaire, and having the request originate from a university (Edwards et al., 2002). Paradoxically, offering an internet option to postal participants may actually decrease the response rate of intended postal participants (Medway & Fulton, 2012).

The challenges for internet-based PPGIS (e.g., using Google Maps) are similar to web-based, non-spatial surveys. Individuals are contacted, usually by post (for random household) or email (stakeholder group lists), and encouraged to participate in the online mapping activity. Some of the same strategies to increase response in postal surveys also apply to web-based PPGIS such as personalized contact, multiple contacts, and university origination. A monetary incentive ($10 electronic gift voucher for completion) was found to increase participation in a recent PPGIS study (Brown & Donovan, 2013b), but the increase in response was modest. The use of an internet panel for PPGIS was trialled in Australia and achieved significantly higher participation rates (77% of eligible panellists after screening), but the cost per completion was high with the spatial data quality lower than other PPGIS methods (Brown, Montag, et al., 2012; Brown, Weber, Zanon, & de Bie, 2012). de Vries et al. (2013) also used an internet panel for a national PPGIS study of scenic values in the Netherlands and reported similar data quality issues (e.g., participants mapping outside requested boundaries) and difficulty reaching the target response rate of 60% (the actual participation rate was 53%).

The research agenda for increasing PPGIS participation is similar to the research agenda to increase survey response in general. Initially, it was thought that the novelty of spatial mapping could increase participation rates, but there is little evidence to support this conclusion, and with the passage to time, the proliferation of maps and spatial information on the internet has reduced any potential novelty effect, if there ever was one. Our view is that theories for survey participation which include social exchange theory (Dillman, 1978), social psychological theories involving persuasion (Groves, Cialdini, & Couper, 1992), and leverage-saliency theory (Groves, Singer, & Corning, 2001) are applicable to PPGIS participation, but these have not been specifically examined in a PPGIS context. The role of salience for specific land use issues and its effect on response rates would appear to warrant special research attention in PPGIS.

Identifying and controlling threats to spatial data quality

The threats to spatial data quality are many, with several of the more important ones including the overabundance of information from new technologies, sampling and participation bias, quality associated with mapping effort, and sampling and participation coverage. The volume of spatial data generated from different sources, but especially through the internet, will continue to increase. Unlike scientific data that is filtered through peer review, there are few available tools to filter user-generated spatial content for quality. There is a critical need to ascertain the quality of spatial data from different sources and collected using different methods.

All PPGIS data contain potential bias from different sources such as the geographic location of participants, socio-demographic classes, participant beliefs, values, and ideology, and knowledge/experience in the study area. Many of these potential sources of sampling and participant bias are not well-understood for spatial data. What is known is that respondent characteristics such as gender, age, level of education, and knowledge of the landscape can influence the types of spatial attributes mapped (Brown & Reed, 2009); the domicile of the participant will influence the mapped locations of some spatial attributes due to spatial discounting (Brown, Reed, & Harris, 2002; Pocewicz & Nielsen-Pincus, 2013; de Vries et al., 2013), the participants' knowledge of the study area will influence the type and amount of spatial data provided (Brown, Montag, et al., 2012; Brown & Reed, 2009), general participant values influence spatial preferences for land use (Brown, 2013b), and volunteered spatial data may differ from randomly sampled household data (Brown, Kelly, et al., 2012). The available evidence suggests that under- or overrepresentation of some groups in PPGIS may not be systematic. For example, in a series of four PPGIS studies by Kyttä et al. (2011), middle-income households and middle-aged women were overrepresented while in a large PPGIS study by Kyttä, Broberg, Tzoulas, et al. (2013), the only groups that were slightly over-represented were the oldest age group and single households.

Evaluating participatory data for bias may be even more challenging in VGI systems where spatial data is collected but may not be accompanied by information describing the attributes of the participants. The control over sampling and participation, and the collection of participant variables that is usually present in PPGIS or PGIS, may not be present in VGI systems. More research is needed on the effects of sampling and participant bias on spatial data. This research will require the use of research designs such as differential research (Graziano & Raulin, 2012) that compares two or more groups that differ *a priori* on important variables of interest. Alternatively, the PPGIS process must obtain a sufficient number of participants that provide for meaningful *post hoc* comparison of responses from different groups.

High quality PPGIS data is grounded in participant experience and knowledge of place. Unlike traditional survey research, communicating knowledge and experience through participatory mapping requires significant participant time and effort. The type of information sought in PPGIS often requires deeper cognitive reflection on place to inform future land use. Modern internet technologies found in social media (e.g., Facebook®, Twitter®) encourage communication in short, simple messages; this type of communication may condition people to participate in similar ways with internet-based PPGIS mapping. Poor quality spatial information results when participants do not put the time and effort required for the mapping activity (Weber, Zanon, & de Bie, 2012). There is a need to better understand how the quality and usability of spatial information is influenced by participant time and effort, especially given these are likely to be more scarce than abundant in the future.

With social research participation rates showing declines across all traditional modalities, PPGIS sponsors will seek participation from organized groups and associations with interests in the study area. These groups and associations maintain a membership database and can provide access to a contact list. The engagement of these groups in PPGIS is beneficial provided there is not over reliance on these organized interests in the process and that the responses can be benchmarked against other participants (i.e., random household sampling) that may be less biased. In traditional survey research, significant effort has been focused on the sampling effects. PPGIS would benefit from similar research effort to better understand sampling effects on spatial data.

Improving the "PP" in PPGIS

The growing community of PPGIS researchers and practitioners have developed a variety of technology tools and mapping approaches over the last decade. Innovation in PPGIS tools and methods will remain vitally important to the future of PPGIS, but technology should be viewed as a means, not an end for PPGIS. There is a natural inclination to view the development of new PPGIS technology as a solution to otherwise, ineffective public participation methods. A focus on PPGIS technology, rather than the engagement process, will not achieve the broad, idealistic purposes that inspired early advocates of PPGIS. There is a danger that preoccupation with technology will distract from the effort required to meaningfully engage under-represented people in land use planning and management. Effective public participation requires more than innovative technology.

Maps possess a powerful force for stimulating discourse about the past and future of place. In the transference of human knowledge and experience to a map through PPGIS, humans are reminded of their identity and dependence on place, if not explicitly, then subliminally. If a PPGIS process provides for the exchange of individual perspectives, during or after the mapping process, people learn about shared connections to place. For advocates of bottom-up planning, the most desirable future land uses emerge from the participatory mapping process through discourse. But the scale of the PPGIS process can inhibit or enhance the opportunities for participant discourse. The future challenge for the development of PPGIS tools and methods will be to provide opportunities to achieve discourse and collaboration, rather than simple collection of spatial data. For example, if web-based PPGIS tools collect spatial data from a regional population, that spatial data can provide the foundation for smaller-scale, interpersonal engagement and discourse in the planning process.

To date, there have been few published studies wherein PPGIS data has been used as a means to engage stakeholders in an iterative process that provides for the review and refinement of the mapped results as part of the larger planning cycle. Among the rare examples is the case of the city of Vaasa, Finland, where PPGIS data produced by inhabitants were used as valuable information for an architectural competition where the viewpoints of inhabitants were visible in the final idea competition proposals, and hopefully, in the final plan that will be produced (Eräranta, Kahila, & Nurmi, 2013). The potential of PPGIS as a foundation for iterative public participation, rather than a singular by-product of a public participation process, appears large. Future research could explore the use of PPGIS throughout a complete planning cycle, from scoping to alternative development to decision to monitoring. This would require an expanded public participation process.

Evaluating the effectiveness of PPGIS

The formal evaluation of public participation without a GIS component is historically scarce, as governments are reluctant to spend funds on evaluation (Sewell & Phillips, 1979). Further, government agencies are reluctant to evaluate their own participatory performance unless required by the prevailing political system. Where evaluation has been performed, there are few cases where "the effectiveness of participation exercises have been studied in a structured (as opposed to highly subjective) manner (Rowe & Frewer, 2004, p. 512). Even with a resolve to engage in evaluation, there is no universal format in use for evaluating public participation that can be applied widely (Chess, 2010; Halvorsen, 2001; Rowe & Frewer, 2004) although there have been attempts to create such a format (Faehnle & Tyrväinen, 2013). Academic sponsors of PPGIS have focused their energies on spatial data collection and analysis because these results can be published relatively quickly. To the extent that academics have evaluated PPGIS, the focus has been on the PPGIS tools and technology, rather than outcomes of the participation process. NGO sponsors of PPGIS processes are guided by short-term, project outcomes that meet organizational needs and appeal to sponsors; evaluation research is difficult to pitch to organization supporters. Similar to NGO's, industry stakeholders would prefer to keep the number of actors in a planning process small and manageable and don't trust a process that could result in outcomes unfavourable to their interests (Brown, 2012a). Collectively, there is little incentive among potential sponsors of PPGIS processes to evaluate the outcomes. Without incentives for evaluation research, knowledge about PPGIS effectiveness will accumulate slowly.

For the putative benefits of PPGIS to be realized, there will need to be success stories based on empirical evidence that reveal its impact from inception to decision. This type of evaluation research will require patience and a relatively long-term commitment of resources, conditions that conspire against it. And yet, rigorous evaluation of PPGIS outcomes, in contrast with PPGIS tools, is arguably one of the most critically important research needs.

Conclusion

Over a decade and a half have passed following formal recognition of the public participation GIS (PPGIS) concept. PPGIS was enthusiastically received by early advocates who saw the potential of the method to bridge the expert-driven, technical world of land use planning with bottom-up, lay knowledge from the lived experience. What Friedmann (1973) envisioned nearly four decades ago with non-spatial transactive planning—bringing expert and lay knowledge together through mutual learning—now had a methodological counterpart in PPGIS. The systemic knowledge of planners and the direct personal experience of the lay public would come together through mutual learning and interpersonal dialog about the features and future of place. And yet, this idealistic vision for PPGIS has not substantively materialized.

Understanding the barriers to the adoption of PPGIS in the public sector is the basis for our final research priority. Early advocates of PPGIS believed that the democratization of public sector planning and decision making could be achieved through greater public access to spatial information and processes. But this view appears rather naïve without grounding in the factors that constrain public sector innovation. Mulgan and Albury (2003) provide a relatively comprehensive list of barriers in the public sector including delivery pressures and burdens, a culture of risk aversion, lack of incentives or rewards to adopt innovation, short-term budgets and planning horizons, poor skills in active risk management, over-reliance on high performers as sources of innovation, and constraining cultural or organizational arrangements.

PPGIS would benefit from future research that describes success stories of PPGIS adoption and integration in public sector planning, accompanied by a critical analysis of the enabling factors. What resources were made available to use PPGIS? What was done to encourage informed risk taking within the planning organization? What incentives, rewards, or support were offered to individuals or organizational units to adopt PPGIS methods? As a cautionary tale, providing freedom and space for innovation is unlikely to be sufficient for a planning professional conditioned to operating in a culture of constraints and risk-aversion until the surrounding organizational culture and social context facilitates it (Mulgan & Albury, 2003). Are public officials and planning professionals prepared to engage in substantive discourse with the public about future land use in a time-consuming process that will lead to trust, mutual learning, and accommodation? Is society ready to embrace the devolution of substantive land use policy to lay audiences through PPGIS methods?

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