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Key issues and priorities in participatory mapping: Toward integration or increased specialization?

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ABSTRACT

The theory and practice of participatory mapping (PM) has expanded significantly over the last two decades with proliferation of a wide range of methods and applications. The potential for synthesis and integration across four broad domains of PM (*indigenous/rural/community*, *urban/regional*, *environmental/natural resource*, and *mapping technology*) was examined at the Participatory Mapping/GIS 2017 conference held at California Polytechnic State University (San Luis Obispo, USA) Jul 31-Aug 3, 2017. At the conference, PM leaders in each of the four domains participated in working groups to: (1) identify the key issues, including "barriers" and "knowledge gaps" that limit effective PM outcomes, and (2) identify the most important research priorities. This paper summarizes the findings of the working groups for the purpose of identifying common and unique challenges across the four PM domains and to discuss the desirability of stronger integration of PM knowledge and practice. In the *indigenous/rural/community* domain, achieving clarity in PM purpose and building trust in the process were identified as the most critical issues; in the *environmental/natural resources* domain, wider use and adoption of PM to inform policy and management decisions through stakeholder engagement was considered most important; and in the *urban/regional* domain, developing urban indicators and adapting PM to complex and heterogeneous urban environments were identified as important needs. The key issue in the domain of *PM technology* was understanding how technology influences PM usability and user behavior for the development and implementation of appropriate PM technology. The most significant cross-cutting theme to emerge across all PM domains was the need to evaluate PM outcomes to provide evidence of success.

1. Introduction

Participatory mapping (PM) is a term that refers to multiple ways humans interact to create and communicate knowledge, experience, and aspirations about the world in maps. Participatory mapping has been defined as the creation of maps by local communities, often with the involvement of supporting organizations including governments, non-governmental organizations, universities, and other actors engaged in the development and land-related planning (Corbett, 2009). Participatory maps—whether crude or sophisticated—are created for a wide range of human/environment applications such as delineating territorial boundaries, identifying important places that sustain livelihoods and quality of life, and communicating preferences about future land use. Over the last two decades, the growth and interest in PM has evolved and progressed from diverse application domains (*indigenous/rural/community development*, *urban/regional planning*, and *environmental/natural resource management)* in recognition of the potential for PM to address complex social issues and problems. A consistent aspiration of PM has been to engage and empower marginalized groups in society through the use of spatial technologies. The proliferation of PM applications has co-evolved with (1) advances in geographic information systems (GIS) technology that provides for the capture, storage, analysis and management of spatial or geographic data, (2) increased demands from under-represented social groups that want greater influence in decisions that affect their lives and livelihoods, and (3) recognition that the use and integration of non-expert, place-based knowledge and experience can help address complex land use problems to become valued, legitimized, and sanctioned.

We use the term participatory mapping (PM) to cover a range of terminology and acronyms including public publication GIS (PPGIS), participatory GIS (PGIS), volunteered geographic information systems (VGI), and participatory three-dimensional modeling (P3DM). Each of these terms have different origins. 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

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public participation for a variety of applications (NCGIA, 1996a; 1996b; Obermeyer, 1998; Sieber, 2006). The term "participatory GIS" or "PGIS" emerged from participatory approaches in rural areas of the global south, the result of merging Participatory Learning and Action (PLA) methods with geographic information technologies (Rambaldi, Kyem Kwaku, Mbile, McCall, & Weiner, 2006; Rambaldi, Corbett et al., 2006). The term volunteered geographic information (VGI) was introduced by Goodchild (2007) to describe the development of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals. Participatory three-dimensional (3D) modeling (P3DM) was conceived as a method to bring GIS to rural communities to bridge the gap between GIS technology and social capacities in marginalized, isolated communities dependent on natural resources (Rambaldi, 2010).

Brown and Kyttä (2014) reviewed PPGIS, PGIS, and VGI concepts and described them on the variables of purpose, sponsors, global and place context, importance of mapped data quality, sampling approach, data collection, data ownership, and dominant mapping technology. They concluded that there was not a bright line between the terms in practice and attributed continuing ambiguity to methodological pluralism in design and implementation concerning what is mapped, who does the mapping, the reason for mapping, the technology used to map, and the location where the mapping is done. Further, participatory mapping can vary dramatically depending on whether the public participation component (the "PP" in PPGIS) or the geographic information system (the "GIS" in PPGIS) component is emphasized in the process (see Schlossberg & Shuford, 2005). This natural tension between the relative importance of technology versus the participatory process is likely to continue as PM represents an uneasy merger of contrasting knowledge paradigms.

Since 1996, there have been multiple book and journal reviews of PM including those by Craig, Harris, and Weiner (2002), McCall (2003), Rambaldi et al. (2006; Rambaldi, Corbett et al., 2006), Sieber (2006), Dunn (2007), McCall and Dunn (2012), Brown and Kyttä (2014), Brown and Fagerholm (2015), McCall, Martinez, and Verplanke (2015), Mukherjee (2015), and Pánek, J. (2016), as well as numerous conferences, workshops, symposiums, and conference special sessions with a thematic focus on participatory mapping: U.S. National Center for Geographic Information and Analysis Varenius Workshop 1998; Workshop on Access and Participatory Approaches in Using Geographic information in Spoleto, Italy 2001; International PPGIS Conferences 2002–5; Indigenous Mapping: Mapping for Indigenous Advocacy and Empowerment Conference, Vancouver, BC, 2004; Mapping for Change, Nairobi, Kenya 2005 (Rambaldi et al., 2006a; Rambaldi, Corbett et al., 2006); Workshop on Volunteered Geographic Information, Santa Barbara, CA 2007; Symposium on The Future of PGIS: Learning from Practice?, Enschede, Netherlands, 2013 (Verplanke, McCall, Uberhuaga, Rambaldi, & Haklay, 2016); AAG Special Session: Looking Backward and Forward in Participatory GIS, Chicago, IL 2015; Modern Methods and Tools for Public Participation in Urban Planning, Poznan, Poland 2017.

In 2014, Brown and Kyttä (2014) presented the quantitative results of bibliographic searches that showed an exponential increase in the number of academic publications related to PM, an indicator of the academic and social relevancy of the topic. In the last 4 years, the number of publications related to PM has continued to increase exponentially (see Table 1) as indicated by updated bibliographic search results from the Web of Science, Scopus, and Google Scholar. The largest increase in search hits was associated with the search term "VGI" which increased by more than 500 publications.

The focus of this paper is the Participatory Mapping/GIS Conference 2017 held at California Polytechnic State University in San Louis Obispo, CA Jul 31 – Aug 3, 2017. (http://landscapemapvalues.org/ppgis2017/). The goals of the conference were to bring together an international community of academics, agency planners/managers, non-governmental organizations (NGOs), and PM practitioners to: (1) describe state of knowledge in PM methods, (2) share new mapping applications and technology, and (3) identify best practices, standards, and future research needs. About 60 participants from 10 countries presented PM applications in land/marine management, urban and regional planning, community development and indigenous rights, biodiversity conservation, and participatory mapping technology. From the rainforests of the Amazon and Congo basins, to the European cities of Helsinki and Poznan, to public lands in the U.S. and marine areas in Indonesia, conference attendees shared diverse PM knowledge, experiences, and applications, as well as participating in special workshops on PM software and community mapping methods.

2. Methods

On the final day of conference, participants were requested to attend one of four possible working group thematic sessions covering the following four PM domains: *indigenous/community/rural mapping*; *urban/regional mapping*; *environmental/natural resource mapping*, and *mapping tools and technologies*. Each working session had a facilitator whose role was to conduct a nominal group process (Delbecq, Van de Ven, & Gustafson, 1975) for each of the following two questions:

1) What are the key issues, including "barriers" and/or "knowledge gaps" that limit effective outcomes for participatory mapping in your PM domain?
2) What are the most important research priorities for participatory mapping in your domain?

The nominal group process consisted of four phases: (1) *silent generation of ideas* where the facilitator requested that group participants identify and write down at least two possible answers on note cards; (2) *round-robin listing of ideas* where the facilitator sequentially asked each participant to provide an answer that was recorded on large poster paper; (3) *clarification and discussion* where the facilitator helped generate a final list that the group accepted as an accurate representation of the process; (4) *ranking* where the facilitator asked the group to examine the final list and to individually rank the top choices to generate the perceived most important answers. The ranked responses of the four thematic sessions was the final outcome of the nominal group process. In the final plenary session of the conference, each thematic group reported and discussed their results with all conference participants to identify similarities and differences.

To validate our interpretation and summary of the four working group sessions, a draft of this paper was distributed to conference attendees for review, comment, and refinement. The summary contained in this paper does not reflect a consensus by each and every participant, but rather identifies the broad issues and priorities as reported by the four PM working groups.

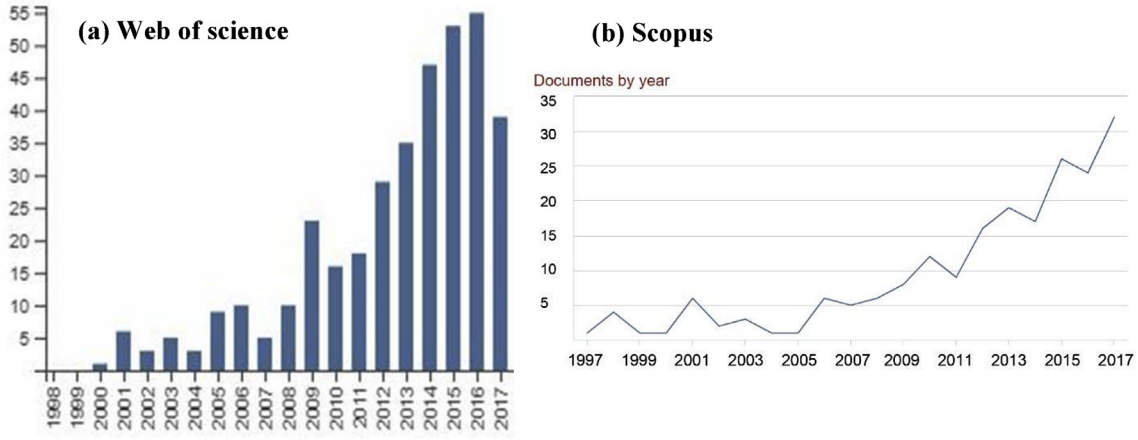
3. Results

3.1. Indigenous/rural/community development

An aspiration for participatory mapping has been the empowerment of indigenous, rural, or otherwise disadvantaged communities to overcome historical legacies associated with colonialism, class exploitation, and/or the inequitable distribution of economic, social, and political power; frequently associated with (re-)claiming territory and natural resources. In this context, PM may be viewed as a type of "counter-mapping" (Peluso, 1995) to contest dominant governance structures while advancing progressive social goals. As identified in the "Mapping for Change International Conference" held in 2006, participatory mapping is believed to have the capacity to: (1) enhance capacity in generating, managing, and communicating spatial information; (2) stimulate innovation; and if effective, (3) encourage positive social change. But the use of PM and spatial technology as a counter-measure

Table 1
Bibliographic search results by terminology and number of publications by year (as of November 1, 2017). Graphs show the increase in: (a) Web of Science publications by year (1998–2017) and (b) Scopus publications, using the combined search terms of PGIS or PPGIS.

	PPGIS	PGIS	VGI	P3DM	Participatory Mapping
Search terms	"public participation GIS" OR "public participatory GIS"	"participatory GIS"	"volunteered geographic information"	"P3DM"	"participatory mapping"
Web of Science[a]	162	180	518	6	293
Scopus (2017)[b]	199	234	713	8	376
Google Scholar[c]	3780	4710	7810	315	8770
Scopus (2013)[d]	129	105	177	N/A	N/A
Most published journal	*Applied Geography (n = 24)*	*Applied Geography (n = 13)*	*International Journal of Geographic Information (n = 144)*	*Applied Geography (n = 2)*	*Applied Geography (n = 29)*



[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.
[d] Search results reported by Brown and Kyttä (2014) as of Oct. 31, 2013.

to assist marginalized peoples has been subject to a sustained discourse and critique about the potential positive and negative effects of PM (see e.g., Bryan & Wood, 2015; Dunn, 2007; Elwood, 2006; Rundstrom, 1995; Sletto, 2009; Sletto, Muñoz, Strange, Donoso, & Thomen, 2010; Turnbull, 1993; Wood, 2010).

Participants in this thematic working session were challenged to identify common barriers and knowledge gaps across the broad range and variability in PM applications that include diverse geographic and social contexts located in the global south in Africa, the Americas, and Asia, as well as rural areas in developed countries. Understanding the unique historic, geographic, and social context for a PM process appears to be a necessary, but insufficient condition, for achieving positive social change, especially when the purpose for the PM process may be unclear or ambiguous. Thus, participants identified the most frequent barriers to improving PM for indigenous/rural/community development as having *clarity of purpose for the PM process*, *building trust with participants* in the process, and *understanding the power dynamics* of the PM process – a basic contestation being `who participates?', and `who selects the participants?` (Table 3a). When facilitated by outsiders such as non-governmental organizations (NGOs), PM is rightfully viewed with skepticism by the target communities, some of which have likely been exploited in the past, and who regularly complain that there are no follow-ups to the PM projects. Thus, participants also identified potential PM barriers such as participants' views toward outsiders, ethical concerns about ownership and intellectual property of PM data, selecting culturally appropriate incentives for participation, the possibility for local corruption, and awareness of the potential for unintended consequences such as insecurity and exposure to dangers given the dynamic relationships between different stakeholders and actors in the PM process. Practical barriers to more effective PM included language and communication, distances to rural locations, and time/funding limitations.

Key research priorities were logically related to reducing the knowledge gaps and included better understanding how trust and clarity in PM purpose influence outcomes, identifying the effects/influence of technology on empowerment, and assessing PM impact on building community capacity and social capital (Table 3a). Fundamental to these research priorities is defining measures to assess the impact and effectiveness of PM, especially across different geographic case studies, a type of evaluation research. Evaluating PM impact is challenging—and rare—because there are normally many other factors and drivers in play (not a simple cause-effect), and the potential impact may be delayed into the future, long after the PM process has concluded. Further, if the PM process was intended to be used in a larger policy development and implementation process, e.g., to establish or adjudicate indigenous rights and territory, the political process can be long with an indeterminate timeline.

An increasing opportunity and use of PM with indigenous communities involves storytelling and sharing of cultural heritage. Emerging technologies such as smartphone data collection now make it possible to add media content to digital maps. This mapping and sharing of cultural heritage and knowledge can benefit the communities engaged in the process, for example, by passing on knowledge to the youth about cultural traditions, as well external audiences that obtain greater appreciation for the richness and complexity of indigenous ways of life.

3.2. Environmental/natural resource planning and management

Most PM applications explicitly or implicitly involve environmental/natural resources in the planning and management of the geographic areas of interest. A potentially distinctive characteristic of PM for environmental/natural resource management is the relative

Table 2
Workshop participants in the 2017 Participatory Mapping/GIS Conference held at California Polytechnic State University, San Luis Obispo, California, USA, Jul. 31-Aug. 3, 2017.

Alvarez, Alina	Universidad Nacional Autonoma de Mexico
Aran, El	USDA Forest Service
Broburg, Anna	Mapita, Ltd.
Brown, Greg	California Polytechnic State University
Brunelle, Adam	Portland State University
Carter, Mitch	Auburn University
Carvalho, Carolina Monteiro de	Universidade de São Paulo
Cook, Jessica	National University of Singapore
Currier, Kitty	University of California, Santa Barbara
Czepkiewicz, Michal	Adam Mickiewicz University
Dunning, Kelly	Rainforest Foundation United Kingdom (RFUK)
Evans, Peter	Trailmark Systems
Fisher, Rohan	Charles Darwin University
Goldberg, Grace	University of California, Santa Barbara
Goldhor-Wilcock, Ashley	USDA Forest Service
Harkness, Pia	Charles Darwin University
Hausner, Vera	University of the Arctic
Hitchins, Tim	Portland State University
Hoyte, Simon	University College London
Jankowski, Piotr	San Diego State University
Jenkins, Jeff	University of California, Merced
Jimenez, Malin	Verde Community Group, Portland
Kahila-Tani, Maarit	Aalto University
Kantola, Sini	University of Oulu
Kemper, Rudo	Amazon Conservation Team
Kne, Len	University of Minnesota
Kotus, Jacek	Adam Mickiewicz University
Kytta, Marketta	Aalto University
La Port, Todd	George Mason University
Lauria, Mickey	Clemson University
León, José	Universidad Nacional Autonoma de Mexico
MacFadyen, Josh	Arizona State University
MacLennan, Gregor	Digital Democracy
McCall, Michael	Universidad Nacional Autonoma de Mexico
McClintock, Will	University of California, Santa Barbara
McLain, Rebecca	Portland State University
Milley, Brad	USFWS
Morris, Randy	Portland State University
Muise, Allison	ESRI
Neumann, Zachary	USDA Forest Service
Perkl, Ryan	ESRI
Ratajczyk, Elicia	Arizona State University
Reed, Pat	USDA Forest Service
Robinson, Jonnell	Syracuse University
Rout, Angela	University of Calgary
Roxas, Efrim	University of the Philippines Los Baños
Ruff, Bess	Florida State University
Rzeszewski, Michal	Adam Mickiewicz University
Sanders, Sara	San Luis Obispo County
Shaw, Ashley	University of Saskatchewan
Smith, Charlynne	North Carolina State University
Stortz, Sasha Driscoll	Northern Arizona University
Valenzuela, Jorge	CECPAN
Walden-Schreiner, Chelsey	North Carolina State University
Whillas, Erika	Institute for Sustainable Futures

focus of the natural environment compared to the human built environment in the mapping process. The scope and spatial scale of these types of applications are highly variable and can range from large urban parks and open space systems to relatively natural landscapes in regions and states. The most frequent PM case studies in this domain involve the planning and management for public lands such as national parks and forests that are guided by mandates to use some type of public participation process. However, environmental/resource management applications can involve multiple land tenure and property rights systems within the geographic mapping area that add complexity to the PM process with implications for future management.

Participants in this working session reflected a predominantly Western perspective with significant experience in public lands management from a U.S. context where land tenure typically has stable

Table 3
Summary of frequently identified issues for more effective PM in four thematic domains with key research priorities.

(a) Indigenous/community/rural mapping	(b) Environmental/natural resource planning and management	(c) Urban/regional planning	(d) Mapping tools and technology
Barriers/knowledge gaps			
Trust	Establishing value of PM as mode of planning/management discourse	Challenges of complex urban systems	Technology to guide users to select appropriate PM methodology
Clarity of goals/impacts/purpose	Conflicting values and achieving stakeholder consensus	Resources: money, time, experts, motivation	Software should be adapted to different situations/user groups
Power dynamics in PM process	Trust, stakeholder buy-in, and motivation	Co-creation and design of the process and outcomes by participants	Keeping public interact/engaged in the apps
Who participates? Who leads? Who owns the outputs?			
Key research priorities			
Understanding effects/influence of technology on empowerment	Building a community of PM practice	More examples and evaluations for translating PM data collection to implementation	Methods for analyzing data from PM, e.g., aggregating the spatial data
Assessing and measuring PM impact (e.g., capacity building)	Assess the outcomes and publish the results in multiple outlets	Development of urban indicators	Usability: assessing expected usability, i.e., do people use the app as design intended
Understanding issues of trust and clarity in PM purpose	Developing stronger links between PM and policy and decision-making	Classify existing analysis techniques.	Understanding user behavior and response to different user experience
i) Prioritizing the need to clarify *purpose* in a PM; ii) Assessing and reinforcing *trust* between all parties.			

legal standing within a political jurisdiction (e.g., municipality, state, or country), but potential allocation and use of these lands for conservation or development activities may be contested by individuals and groups that hold conflicting values and interests for these lands. In this context, PM serves to identify spatial values and preferences from "stakeholders" seeking to influence public land management. Thus, the key barriers for more effective PM in this domain were establishing the value of PM as a mode of planning/discourse in the management agency, managing conflicting interests to achieve stakeholder consensus, and building stakeholder trust in the PM process (Table 3b). Unlike many indigenous and rural PM applications that are facilitated by NGOs, government agencies seeking expanded public engagement are often the sponsors of a PM process as they trial alternative and expanded public participation methods. Participants noted, however, that agency governance and management structures (especially organizational hierarchy) can serve to enable or limit access to power and decision-making resulting from PM processes undertaken by the agency. Given that agencies have final decision-making authority for land use decisions, the potential influence of PM will largely depend on how specific individuals with decision authority in the agency view the value of PM relative to other factors such as external political pressures. The lack of clarity or commitment on how stakeholder's input will be integrated into final decision-making therefore also presents a barrier to widespread use of PM.

There are fewer global examples of environmental/natural resource agencies that have adopted PM as a standard operating procedure (SOP) for resource planning and management and thus PM knowledge and experience has accumulated slowly on an ad hoc, case-by-case basis. An exception being the Canadian policy of `Land Use and Occupancy mapping' (e.g., Tobias, 2008). Consistent with this observation, session participants identified key research priorities as building a community of PM practice for environmental/natural resource planning and management, assessing PM outcomes and communicating the results in multiple outlets, and developing stronger links between PM and policy and decision-making (Table 3b). Land management agencies in the U.S., Finland, Australia, and New Zealand have experimented with PM methods and these countries appear the most likely places for advancing PM practice in this domain.

3.3. Urban and regional planning

The human built environment has been an early and important focus for PM, especially in developed countries such as Finland where researchers pioneered urban PM software and applications called "softGIS" that produce localized experiential knowledge about the everyday lives of the residents (Kahila & Kyttä, 2009; Kyttä, 2011; Rantanen & Kahila, 2009) that can be used as a public participation method in various geographical scales and in different phases and types of planning processes (Kahila-Tani, 2015). Given the rapid pace of urbanization globally, the potential contributions of PM to enhancing the quality of life of urban residents and more sustainable urban environments are large. However, urban areas are diverse and complex, from both a geographic and demographic perspective. Further, urban areas often contain legal and regulatory restrictions on land use through zoning that constrain planning options. And yet, urban areas have demonstrated resilience through innovation and regeneration and thus provide important geographic areas for applying and evaluating PM methods.

The key barriers identified by participants in this PM domain were the challenges of applying PM to complex urban systems, limited resources including money, time, expertise, and motivation; and the co-creation and design of the PM process by participants (Table 3c). Cities are complex adaptive systems that combine spatial, temporal, social, and cultural processes and structures in unique ways. This complexity is difficult to manage with any single PM methodology or approach. Although PM is able to combine 'soft' (i.e., behavioral and experiential knowledge, values and preferences) and 'hard' (urban structural) place-based information, the opportunity to integrate urban behavior and the lived experience with planning, design, and urban structure has not been exploited. Limited resources were identified by participants as an important barrier. Even if PM technology was free or low-cost, time, expertise, and motivation are needed. Without investments, high quality participation mapping projects cannot be realized. Further, existing urban PM projects can also be criticized as a continuation of top-down participation. Grassroots actors can potentially use PM tools without outside support, create PM tools, collect and analyze data, and develop urban and regional planning solutions. However, few examples exist thus far of this kind of bottom-up PM activism. Exceptions include some projects of YIMBY groups in Helsinki and Stockholm who have used PPGIS to query the wider support of inhabitants for an alternative plan.

The key research priorities included more examples and evaluations for translating PM data collection to implementation of urban plans, the development of urban indicators to be used in PM data analysis, and the classification and standardization of existing analysis techniques for PM data (Table 3c). Like other types of knowledge created in public participation processes, there is a danger that PM data are not used in actual planning or implementation. Too often, public participation remains "shallow" or simply `box-ticking`(c.f. Arnstein, 1969) without deeper involvement, collaboration, and the possibility to produce knowledge that will influence planning outcomes. Although some cities, like the city of Lahti in Finland, have developed ways to translate PM knowledge to the implementation of plans, more examples are needed. Sophisticated urban indicators should also be developed to analyze soft and hard place-based knowledge where PM serves as a diagnostic tool for revealing critical characteristics of urban structure. Finally, according to the participants of this working session, a synthesis of various data analyses techniques used in PM mapping project is urgently needed. These include spatial, visual, statistical techniques that are both place-based and person-based.

3.4. Mapping tools and technology

The rapid pace of software and technology innovation has greatly expanded the range of options available for PM. But matching the appropriate PM tools and technology to the social and geographic context is necessary to achieve effective outcomes. In this sense, the use of digital technology in PM is not intrinsically better or more effective than "low-tech" PM options. PM methods may involve primitive sketch mapping, hardcopy maps with markers/stickers, three-dimensional models, and computers and mobile devices. The use of digital cartography (e.g., Google Maps), in combination with internet technology, has greatly expanded PM applications given the efficiency in spatial data collection, storage, and analyses.

The key issues and knowledge gaps to more effective PM outcomes were identified as the use of technology to guide users to select appropriate PM methods, the adaptation/customization of software for different PM mapping contexts and user groups, and keeping the public engaged and interacting with the PM process (Table 3d). An online support tool could be developed to assist users in selecting suitable PM methods (see e.g., Pánek, 2015) similar to those for selecting general participation methods (https://www.participedia.net/) and action research methods (http://actioncatalogue.eu/). There is also the potential to dynamically adapt and customize PM software according to the special needs of various user groups. At present, there are few examples where PM software was customized for a specific user group, an exception being Gottwald, Laatikainen, and Kyttä (2016) who did a usability study among older adults to improve the PM software interface. Similarly, a knowledge gap exists about how to motivate people to participate in PM projects. Especially challenging are longer-term projects where the same participants are requested to provide information over an extended period of time.

The key research priorities identified were the development of more effective methods for analyzing data from PM, especially the meaningful aggregation of spatial data, usability of PM applications, and better understanding of user behavior and responses based on the user experience with the PM technology (Table 3d). Although some examples exist where PM software provides for easy-to-use, interactive data collection and analysis of PM data (cf. https://maptionnaire.com/ and https://www.cybertracker.org/), more advanced tools are needed. The development of accessible PM tools for both data collection and data analyses has lagged from the perspective of both participants and organizers of participatory processes, although there is a recent surge in the development of PM software from private companies, NGOs, and government agencies. Critical research is needed concerning the quantity and quality of knowledge produced with PM tools. This includes research on the ability of PM projects to achieve representative samples of participants and on the accuracy of location-based information that participants provide.

4. Discussion

The convening of the conference was premised on the important question about whether there is benefit in pursuing greater integration of PM knowledge and practice (the PM "big tent") across PM application domains or whether PM specialization would continue given the wide range of social and geographic contexts for PM implementation. At the extremes, there are truly significant differences in PM applications involving, for example, indigenous peoples in the global south versus PM mapping with urban residents in Western, developed countries. The development of specialized knowledge in PM has been the norm in the four domains described in this paper, and in absence of special effort toward integration, specialization would likely continue into the future. In short, greater PM integration is unlikely without collective recognition of the benefit in developing a broader PM community.

The identification of key issues and priorities for PM across the four domains suggests the possibility for greater integration and synthesis of PM knowledge and application (see Fig. 1), but key differences remain on the purpose for implementing PM. The challenge of building and maintaining trust with participants is important across all PM domains, but especially important in *indigenous/rural/community* mapping because the process is typically sponsored by individuals outside the community of interest. The nature of the interests represented by outside facilitators should, and will be rightfully, questioned by PM participants. Even if the primary goal of PM is community capacity building rather than obtaining evidence to leverage social and environmental justice claims, trust is needed for the sharing of collective community knowledge, especially when this knowledge concerns deep cultural or sacred places, and/or the re-claiming of customary territory. PM is ultimately about the sharing of knowledge and experience about *place*; history reveals this sharing has not often ended well for indigenous and rural peoples globally.

Linking PM outcomes to land (marine) planning and management decisions is central to the *environmental/natural resource* domain, but also appears important in *urban/regional* applications, depending on the scope and scale of the geographic area. Some public land management agencies have trialed PM through the spatial data collection phase of the process, but most do not yet trust PM to yield information leading to better decisions. Agency decision support systems have been developed for spatial data (see e.g., Brown & Reed, 2012) but have not been adopted to inform planning and management decisions. Even with internal acknowledgment that broader public engagement through PM could lead to improved management decisions, agencies are reluctant to cede or reduce what could be interpreted as their legal authority to manage public lands. The ambiguity about how PM data should be used, *if at all*, for planning and management decisions is shared with PM in the *urban/regional* domain. This question about how to use PM data to inform decision making can be easily avoided by agencies simply choosing not to implement PM as part of the public participation process. Building capacity by finding or cultivating internal, bureaucratic champions who see the value in PM methods and are willing to publicly articulate how participatory contributions will be used, is a pre-condition of more widespread agency use of PM and adoption by the public.

Within the *urban/regional* domain, PM often confronts an entrenched system of local politicians, planning professionals, and development interests that may be viewed as a type of "iron triangle" for urban zoning and land use decisions. The perceived technical complexity of urban land use and zoning systems contributes to an expert/lay divide in planning knowledge wherein those with power and decision authority can be dismissive of lay knowledge and experience obtained from PM. Resident concerns over future urban land use may be discounted as self-interested "Not in my backyard" (NIMBY) attitudes that are antithetical to the broader public interest. And yet, it is the lived experience of urban residents who understand the nuances of

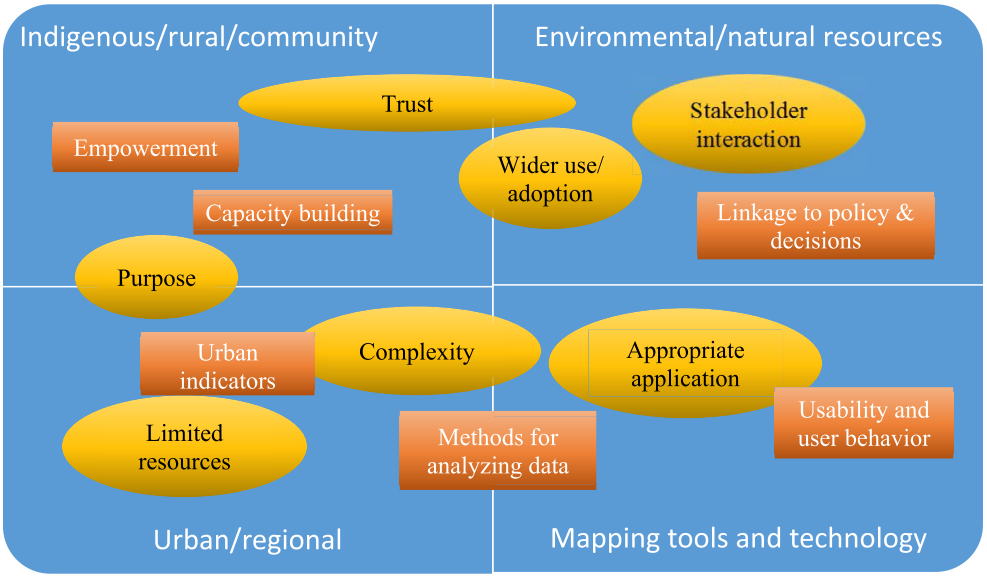


Fig. 1. Key issues (oval) and research priorities (rectangular) or for more effective PM by domain.

urban environments that arguably have the most to contribute to more functional and livable cities. Translating the lived experience identified through PM into the technical planning and zoning rules that guide urban/regional land use is an important aspiration for PM, but will be challenging given the limited resources and planning capacities found in many municipalities.

Mapping tools and technologies for PM have followed a path of specialization with multiple software companies now providing both turnkey and custom development environments for PM applications. Although the technical knowledge needed to develop and implement digital PM applications has been significantly reduced, with few exceptions, this knowledge has not been accompanied by greater understanding of how PM software and digital design influence PM spatial data. A potential limitation of digital PM is the geographic and spatial literacy required of participants for generating quality spatial information. But progress has been made in the use of digital technology to assist participants in their navigation and understanding of geographic space. And with the proliferation of online mapping applications such as Google Maps and OpenStreetMap, and mobile technologies such as smart phones, the spatial digital divide has closed significantly from early PM digital applications. The greater concern for digital PM going forward is the potential dominant focus on technology at the expense of the participatory processes which remain the core foundation of PM. The use of spatial technology, in the absence of knowledge of its limitations, may pose the same or greater risk as the lack of spatial information. In the uneasy relationship between the public participation (PP) component and the technology component (GIS), technology must ultimately yield to participatory component if there is to be meaningful social change. A closely associated issue is that of informational precision, or rather, the need for precision, in the PM processes and products (McCall, 2006). There is the spatial precision of the location, and there is the ontological precision of the contents of the map – which is the more existential in PM activities? The new technologies help with the first, but not much with the second.

After several decades of PM applications, evaluation research on PM social impact has been rare with little tangible evidence of significant social change (Brown, 2012). Conference attendees were keenly aware of the need to demonstrate measurable outcomes from PM across all domains and not to rely on simplistic evaluation of the process. A positive PM process, in the absence of PM decisions supported by participants, is a recipe for participant cynicism and disengagement with participation in the future. If one were to identify a single cross-cutting theme for PM, it would be the need to more effectively evaluate PM outcomes as well as the PM process itself.

The sharing of diverse perspectives by conference participants was an important outcome and represented the first intentional effort to bring together PM researchers and practitioners across the four PM domains. The summary contained in this paper does not reflect a consensus by each and every participant, but rather presents a broad overview of the issues and research priorities needed to advance PM as a more effective means for research, community development, and environmental sustainability. The conference ended with a discussion of potential next steps that included another Participatory Mapping/GIS conference to be convened in 2019 (Helsinki, Finland) and the creation of a new professional international society dedicated to advancing PM knowledge, methods, and practice (see http://pmappingsociety.org). In evaluating the conference, one attendee expressed this future aspiration, “I would like to see integration of more community mapping partners, as well as tangible working results for each conference to make it a place to build the future of P/PGIS and its networks”. An acknowledged deficiency of the conference was under-representation of individuals from the global south, especially PM participants rather than facilitators of PM processes.

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