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Mapping Perspectives for Environmental Planning

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Mapping Perspectives for Environmental Planning

A dissertation submitted in partial satisfaction of the
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by

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Curriculum Vitae

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December 2017

EDUCATION

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2004	Bachelor of Science in Biological Sciences (Minor in Archaeology), Conferred with Distinction, Stanford University, California

RESEARCH AND PROFESSIONAL EXPERIENCE

2011–2017	Research Associate, Center for Spatial Studies, University of California, Santa Barbara
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PUBLICATIONS

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Currier, K. (2015) Mapping with strings attached: Kite aerial photography of Durai Island, Anambas Islands, Indonesia. *Journal of Maps* 11(4): 589-597.

Randage, S.M., A. Alling, **K. Currier** & E. Heywood (2014) Review of the Sri Lanka Blue Whale, *Balaenoptera musculus*, with observations on its distribution in the shipping lane. *Journal of Cetacean Research and Management* 14:43–50.

Currier, K. & H. Couclelis (2014) Geodesigning 'from the inside out'. In H. Scholten, E. Dias & D. Lee, eds. *Geodesign by Integrating Design and Geospatial Sciences*, 287–298. Cham: Springer.

Walker, B.L.E., D. López-Carr, C. Chen & **K. Currier** (2014) Perceptions of environmental change in Moorea, French Polynesia: the importance of temporal, spatial, and scalar contexts. *GeoJournal* 79(6): 705-719.

Milner, C., **K. Currier**, B. Kopcho & A. Alling (2013) A status report on the coral reef at Pulau Durai, Anambas Islands, Indonesia. *Atoll Research Bulletin* 591: 1–17.

INVITED TALKS

Pendapat tentang Bahasa Indonesia dari seorang pelajar pemula [*Opinions on the Indonesian language from a beginning student*]. Academic seminar, Fakultas Bahasa & Seni, Universitas Pendidikan Ganesha, Singaraja, Bali, Indonesia, 23 Oct. 2016

Kite aerial photography for coastal environmental monitoring. Workshop organized by Balai Pengelolaan Sumberdaya Pesisir dan Laut [*Center for Coastal and Marine Resource Management*], Denpasar, Coral Triangle Center, Sanur, Bali, Indonesia, 6 Aug. 2016

Mapping with kite aerial photography. GIS Colloquium, University of Redlands, California, 21 May 2014

AWARDS

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Marine Conservation Graduate Fellowship Honorable Mention, Women Divers Hall of Fame, 2015

David S. Simonett Memorial Award, Department of Geography, University of California, Santa Barbara, 2015 & 2012

Affiliates Graduate Dissertation Award, University of California, Santa Barbara, 2014

Best Student Illustrated Paper for "Mapping with Strings Attached", Coastal and Marine Specialty Group, Annual Meeting of the Association of American Geographers, 2013

National Science Foundation Graduate Research Fellowship Program Honorable Mention, 2011

Regents Special Fellowship, University of California, Santa Barbara, 2009–2014

National Collegiate Athletic Association Pac-10 Women's Track and Field All-Academic First Team, Stanford University, 2002–2004

SERVICE

Visibility and Outreach Committee, Department of Geography, University of California, Santa Barbara, 2009–2015

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Geography and Geographic Information Science

Abstract

Mapping Perspectives for Environmental Planning

Katharine Elisabeth Currier

The idea that ordinary people should have a say in decisions affecting their surroundings is now well accepted, though how to achieve this in practical terms remains a challenge. Where focus groups and town hall meetings dominated in the past, Web-based surveys have become the tool of choice for engaging the public in environmental planning, or activities aimed at changing the way humans interact with the non-human, natural environment. Environmental planning is inherently spatial, well suited to map-based representations characteristic of geographic information systems (GIS). Yet, planning is conducted for purposes driven by values and interests—concepts that often lack direct spatial references, making their integration within a GIS framework difficult. This dissertation explores techniques for using maps to understand how people think about environmental issues, ultimately in service of planning. It begins with digital participatory mapping—Web-based crowdsourcing of geographic information—conducted in a country where less than 20% of households owned a desktop or laptop computer in 2015. Indonesia, which operates a national online participatory mapping portal, was the site of an ethnographic case study that examined implications of Web-based participatory mapping in a place where computers are uncommon. Using the online collaborative planning tool SeaSketch, two map-based surveys were administered to locals and visitors in rural Bali, one on non-biodegradable litter and the other on tourism development in the region. No correlation was found between prior computer experience and the locational accuracy with which participants mapped features, though experienced computer users tended to map more features. Their responses, including digital maps annotated with place descriptions, were analyzed through a combination of spatial density analysis and text mining techniques, namely word clouds and topic modeling. The resulting geovisualizations were used to interpret common themes invoked by participants, such as *marine resources* and *civic responsibility*, and relate those themes to the spatial pattern of features mapped across the land- and seascape. Based on these themes, two simple plans are proposed, one addressing waste management and the other the future of tourism in West Bali. Finally, an alternative planning methodology is proposed, one that expands upon the straightforward participatory mapping approach demonstrated here to systematically relate intangible aspects of participants' perspectives to geospatial data. Together, the work is intended to improve how digital participatory mapping is conducted in rural, non-Western settings; provide new ways of combining spatial and textual data analysis that help planners interpret annotated maps; and from a critique of this approach propose a more comprehensive methodology to incorporate notions of function, purpose and value into a geospatial design framework for environmental planning.

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Chapter 1
Introduction

Environmental issues arise when people disagree over how to appropriately interact with elements of the natural environment. Devising strategies for interaction—not always, but often prompted by conflict—is the purview of landscape planning, land use planning, landscape ecology, coastal and marine spatial planning and environmental resource management (see Randolph 2004; IALE Executive Committee 1998; Ehler and Douvere 2009; National Academies of Sciences 2016). To encompass the tasks of these diverse fields, the generalized term *environmental planning* here refers to activities aimed at changing the way humans interact with the non-human, natural environment. Under this definition environmental planning is inherently spatial, well suited to map-based representations characteristic of geographic information systems (GIS). Yet planning is conducted for purposes driven by values and interests—concepts that often lack direct spatial references, making their integration within a GIS framework difficult (Chan, Satterfield, and Goldstein 2012). Values, interests and purposes, in turn, vary by perspective, or, for this discussion, a conceptualization of an environment held by an individual or group. Is a plastic wrapper *marine litter* or just one of many *things that float in the water*?

This dissertation explores techniques for using maps to understand how people think about environmental issues, ultimately in service of planning. It begins with sampling people's opinions and perceptions, then mining the resulting cartographic and text data for common principles, and finally applying those principles to design a plan. The setting is rural Bali, Indonesia, where locals look to tourism to grow their economy while concern over solid waste management builds. The maps in question—at least, initially—are digital, 2-D representations of geographic space, annotated with points, lines, areas and text descriptions offered in response to questions that ask *Where*. For some circumstantial cartographers, these maps represent their first encounter with a laptop computer.

Maps and mapping constitute a broader theme throughout the discussion, not only as a means of illustrating geographic locations but identifying and representing components of a system and their relationships—geographic, ideological, functional and otherwise. A similarly broad definition of GIS is adopted here, as a digital container for quantitative and qualitative facts, theories, opinions and plans that are geographically referenced. Rather than reducing the concept to a collection of digital cartographic map layers, this definition enables a GIS to represent, for example, competing philosophies that fuel a contentious environmental debate, instantiated at a geographic location. The results of the dissertation are intended to improve how digital participatory mapping is conducted in rural, non-Western settings; provide new ways of combining spatial and textual data analysis that help planners interpret annotated maps; and from a critique of this approach propose a more comprehensive methodology to incorporate notions of function, purpose and value into a geospatial design framework for environmental planning.

1.1 Maps and people in the context of planning

Maps, and geovisualization in general, facilitate environmental planning in numerous ways. Often accepted as symbols of authority, they can lend legitimacy to a group's claims (Everett and Towle 2005). As a tool they can be used to document and share information (Craig and Elwood 1998), to educate (McKinney and Johnson 2009) and to stimulate information recall and discovery (Montello 2002). A map can serve as a *boundary object*, or an artifact (e.g. map, photograph, concept) that fits into the perspectives of collaborating group members—though perhaps in different ways—and mediates between perspectives (Maceachren and Brewer 2004). Harvey and Chrisman (1998) draw an analogy between boundary objects and geographic boundaries in the function they serve: both distinguish differences between groups yet provide a reference held in common. While a common reference does not guarantee consensus, it can help groups communicate by acting as an anchor for explaining each group's own ideas and concepts.

The idea that ordinary people's input could enhance planning was pioneered in the mid-1900s by urban planner Kevin Lynch, who conducted interviews to learn how residents perceived and understood their city (Steinitz 2008). The idea has since become widely accepted, as has emphasis on collaborative planning, an approach that fosters communication among people with different stakes in the outcome (Healey 1997). Related to the collaborative planning approach are the fields and methods of participatory mapping, participatory GIS and public participation GIS, which emphasize the value of local geographic knowledge to a range of applications that continues to grow. Bibliographies maintained by McCall (2008, 2015, 2017) list around 2,000 references to publications, websites and projects since the 1960s that invoke these practices all over the world for urban and rural planning, community risk assessment and reduction, education and other applications.

Whereas pencil and paper dominated efforts to collect geographic knowledge from the public in the past, Web-based tools for participatory mapping have become ubiquitous. Sponsored by governments from the municipal to national levels and by community interest groups, citizen science initiatives and private companies, these tools are used to collect geospatial information about many things—public amenities, plant and animal species, noise levels, etc.—either as they currently exist or as people would like them to exist in the future. Web-based tools are lauded by some over town hall meetings, focus groups and other traditional ways of including the public in planning because they allow people to participate remotely, without incurring financial and time costs associated with travel to meeting places (Scholz et al. 2004). Consequently, they are regarded as a way to increase citizen participation in planning (Warren-Kretzschmar and Haaren 2004; Seeger 2008; Jankowski 2009; Kahila and Kyttä 2009a; Kahila-Tani et al. 2016). The growing panoply of Web-based participatory mapping tools reflects a change in attitudes towards the Internet's function in planning. From a technology for transmitting information to one that supports creating, sharing, remixing and repurposing of content, Web 2.0 allows planners to consult the public and the public to collaboratively create plans and co-decide on them (van den Brink et al. 2007).

With the potential to increase engagement through novel technologies come other questions. As participation in planning increases, facilitated by Web-based mapping tools, how will planners efficiently analyze the growing volume of data to understand the perspectives represented, and how will those perspectives be manifested in planning decisions? Are the benefits of these tools limited to developed Western countries, where Internet access and computer literacy are generally widespread?

1.2 Research objectives and chapter outline

This dissertation begins to explore these questions, focusing on the geographic and cultural context in which Web-based participatory mapping tools are used; the challenge of jointly analyzing cartographic and text-based data; and the task of incorporating non-geospatial elements of participants' perspectives into environmental planning decisions. Specifically, it begins with the research questions, *What opportunities and challenges do Web-based tools for participatory mapping present in a place where laptop and desktop computers are uncommon?* and *What methodological, technological and analytical modifications are necessary to produce results that are useful in a non-Western planning context?*

Through an ethnographic case study in West Bali, Indonesia chapters 2 and 3 describe a participatory mapping exercise conducted to address these questions. Bali, as an internationally renowned travel destination, is well served by telecommunications and widely available Internet access. Most local families own at least one mobile phone, whether smartphone or other, and it is common for a single individual to own more than one to take advantage of benefits offered by competing mobile carriers. The widespread popularity of social media has ensured that the Internet, digital files and routine operations such as logging in to an online account need no explanation for most Balinese, even in rural areas where traditional ways of life predominate. However, many Balinese access the Internet exclusively through a smartphone, as few rural families own a desktop or laptop computer. While Internet cafés exist in a few rural villages, and some high schools have computer labs for training students on basic software, regular desktop and laptop computer use is generally restricted to those who work in white-collar jobs. In rural Bali, these jobs constitute a minority of employment opportunities.

Chapter 2 begins with a brief description of the history and practice of participatory mapping and the related fields of participatory GIS, public participation GIS and volunteered geographic information. Participatory mapping in the context of Indonesia is outlined, from its grassroots beginnings to present-day implementation by the country's national geospatial agency. Zeroing in on West Bali, field data collection methods are described that culminate in two surveys, administered to select residents and visitors via an online, map-based platform: one on the issue of non-biodegradable garbage and the other on the future of tourism in West Bali. The surveys were part of an ethnographic case study, accompanied by participant observation, to generate hypotheses regarding the methods, technology and analysis of data produced through Web-based participatory mapping in a non-Western context as described above. Sampling, therefore, was guided by key informants and the snowball method, rather than a protocol that would have produced a random sample representative of West Bali's population, necessary for rigorous hypothesis testing.

Chapter 3 presents results from these surveys, focusing on participants' cartographic choices, locational error in the features they mapped and how these relate to demographic variables such as language (Indonesian vs. English), age class, frequency of computer use and frequency of Google Maps use. A discussion draws on the survey results and insights gained from a year and a half of participant observation to address the research questions posed above.

The chapter concludes with a summary of lessons learned, critiques of the study design and suggestions for improved participatory mapping-based studies in the future.

To address the challenge of analyzing cartographic and text-based data within the same framework, **Chapter 4** demonstrates a combination of spatial analysis and text mining methods for visualizing and interpreting participatory mapping data in a planning context. Kernel density mapping, a popular technique for identifying hot spots in participant-generated maps, is combined with two text mining techniques—word clouds and topic modeling—to visualize participants' responses. From the resulting map- and word-based visualizations a set of principles is interpreted, representing common themes among participants' responses. The goal of Chapter 4 is to evaluate this combination of techniques for its ability to generalize common themes from freeform text and relate those themes to the spatial pattern of features mapped by participants.

Chapter 5 begins with the principles interpreted in Chapter 4 and incorporates them into two simple plan proposals, one regarding waste management and the other regarding tourism policies for West Bali. Then, this approach is critiqued and a modified approach to planning is proposed, one that attempts to systematically incorporate purposes, values and interests of stakeholders into a plan design process facilitated by GIS-based tools. The proposed methodology, called *perspectives mapping*, is described as it relates to the classic environmental design disciplines, geographic information science and other sciences.

Finally, **Chapter 6** summarizes major insights from each step of the study and discusses how they are theoretically and practically relevant to participatory mapping and analysis methods and to environmental planning, in general. Factors that limit the generalizability of this study's conclusions are examined before concluding with a summary of ideas for future research that would both improve and build upon this work.

Chapter 2
Tourism and Trash I: An Ethnographic Case Study in Digital Participatory Mapping from Bali, Indonesia

In 1999, education researcher Sugata Mitra mounted a computer monitor and touchpad in the wall of a slum in New Delhi. He left no explanation nor instructions with the slum's residents, who had probably never seen a computer, didn't know what it was for or how to use it, and did not speak English—the language of the machine's Windows NT operating system. Within eight hours, however, children of the neighborhood were browsing the Internet.

Dr. Mitra's TED talk (2007) about this and similar experiments emphasized the point that lack of computer *experience* is not the same as lack of computer *ability*, the premise underlying the study presented in this and the next chapter. Computer-based participatory mapping is now common in Western countries, where computer literacy is generally high compared to non-Western developing countries. There are plenty of valid reasons why computers have been avoided for participatory mapping in developing countries—lack of resources to acquire, operate and maintain hardware and software, spotty or nonexistent Internet access and concerns regarding social marginalization enforced by a technocratic elite (Weiner, Harris, and Craig 2002; Elwood 2006). But lack of computer experience should not be one of them. To evaluate this claim, two computer-based surveys with substantial mapping components were conducted with participants in rural Bali, Indonesia, where laptop or desktop computer use ranges from frequent to never. The surveys were designed to collect information that could be used to inform policy decisions regarding waste management and tourism development, though they were not part of an official planning process. A Web-based mapping platform was used to survey visitors to and residents of West Bali, and their responses were analyzed to explore how culture, age, prior computer experience and other factors may have influenced the participants' cartographic choices and the distribution, scale and locational accuracy of features they mapped. The main research questions of the study were:

1. What opportunities and challenges do Web-based tools for participatory mapping present in a place where laptop and desktop computers are uncommon?
2. What methodological, technological and analytical modifications are necessary to produce results that are useful in a non-Western planning context?

This study is presented over two chapters, beginning with background information relevant to participatory mapping including application areas, available technologies and a brief history of its use in Indonesia. The chapter continues with an explanation of the study's methods, including a description of the location, participant observation activities prior to survey data collection, design of the online map-based surveys, how participants were recruited and how the surveys were implemented. The results are reported and discussed in the following chapter, which concludes by summarizing answers to the research questions posed above.

Acknowledging that smartphones, tablets and many other digital devices can be considered computers, here the term refers to computers of the personal laptop or desktop kind unless otherwise noted.

2.1 Background

Participatory mapping engages local people, usually who lack cartographic training, to provide spatially referenced information about the place where they live. Fundamental to this and other participatory methods is the philosophy that local people can and should be empowered to investigate and analyze their own condition (Chambers 1994). In developing countries, participatory mapping has usually been facilitated by anthropologists, human geographers and sociologists on behalf of non-governmental organizations (NGOs) with humanitarian or environmental goals or academic institutions with basic research interests. These efforts have sought to assist communication between indigenous communities and regional or national governments in order to establish legal claims to territory, resolve conflicts over natural resources and land ownership, catalyze infrastructure improvements and obtain federal funding (Baohua 2005; Everett and Towle 2005; Meta and Ironside 2005). They have also pursued goals internal to communities like improving knowledge of local natural resources, raising awareness to environmental degradation, preserving intangible cultural heritage and avoiding reliance on proprietary geographic information in places where it is controlled by the government (Baohua 2005; Bujang 2005; Rambaldi et al. 2006). As planners and academics trained in Western scientific methods have come to realize the value of traditional environmental knowledge (TEK) (Aswani 2016), developed through generations of inhabiting an area, participatory mapping has been used to document and integrate TEK with Western scientific information to support environmental planning (Brodnig and Mayer-Schönberger 2000).

In Western countries, goals for participatory mapping have tended towards decision support in urban and rural environmental planning. It has been used to collect spatially explicit information regarding uses of public land and marine areas (St. Martin and Hall-Arber 2008; Wang et al. 2008; Whale and D'Iorio 2010; Levine and Feinholz 2015), land- and seascape values (Alessa, Kliskey, and Brown 2008; Beverly et al. 2008; Brown and Reed 2009; Ruiz-Frau, Edwards-Jones, and Kaiser 2011; Brown and Donovan 2014; Mahboubi et al. 2015; Gee et al. 2017; Moore et al. 2017), ecosystem services (Brown, Montag, and Lyon 2012; Busch et al. 2012; Klain and Chan 2012), tourism and national park planning (Hasse and Milne 2005; Brown and Weber 2011, 2013), marine protected area planning (Scholz et al. 2004; Klein et al. 2008; Gleason et al. 2010; Merrifield et al. 2013), climate change risk identification and adaptive planning (Stocker et al. 2012) and regional and urban development preferences (Kahila and Kyttä 2009b; Pocewicz and Nielsen-Pincus 2013; Jankowski et al. 2016a; Kahila-Tani et al. 2016).

Analogue and digital methods have been used to collect information in both developed and developing countries, alike, though typically with different technologies and processes. Analogue media include plain paper with pens for drawing sketch maps (Vajjhala and Walker 2010), printed topographic or thematic paper maps with colored stickers to mark locations (Brown 2004; Hasse and Milne 2005; Alessa, Kliskey, and Brown 2008), large-format prints of aerial imagery or nautical charts, often laminated to facilitate re-use and annotation with markers (Pomeroy and Rivera-Guieb 2006; Klain and Chan 2012; Baldwin, Mahon, and McConney 2013; Ramirez-Gomez, Brown, and Tjon Sie Fat 2013; Aswani, Diedrich, and Currier 2015), three-dimensional physical models (Rambaldi and Manila 2005) and sand or dirt, sticks, leaves, rocks and other natural materials arranged on the ground (Paul et al. 2016). Digital technologies include global navigation satellite systems such as GPS (Aswani and Lauer 2006; Vajjhala and Walker 2010), tablets or smartphones running mapping software (Aditya 2010; Whale and D'Iorio 2010; Mahboubi et al. 2015; Goldberg, D'Iorio, and McClintock 2016; Paul et al. 2016), interactive whiteboards with projected maps (Whale and D'Iorio 2010; Levine and Feinholz 2015; Goldberg, D'Iorio, and McClintock 2016), touch tables running mapping software (Arciniegas and Janssen 2012) and personal computers running desktop- or Internet-based mapping software (Kahila and Kyttä 2009b; Gleason et al. 2010; Brown, Montag, and Lyon 2012; Stocker et al. 2012; Brown and Donovan 2014; Cravens 2016). These media may be deployed individually, with each participant directly adding features to a map (Alessa, Kliskey, and Brown 2008; Gleason et al. 2010; Mahboubi et al. 2015) or within a group, where a designated recorder or technology operator is directed by the group (Pomeroy and Rivera-Guieb 2006; Levine and Feinholz 2015). In non-Western developing countries, printed maps are the predominant media for participatory mapping described in the literature, though GPS-based data collection—either with a dedicated receiver or a smartphone running a location-aware app—is becoming more common. Laptop- or desktop-based mapping applications have been used in this context, though typically in a group setting, where a technician operates the software and captures information according to the group members' direction (Corbett and Keller 2004). This study appears to be one of the first instances where participants in a rural area of a developing country used a computer-based mapping application individually, as other examples are absent from the literature.

Geographic context, technology and the data collection process along with purpose, sampling approach and importance of data quality are dimensions that Brown and Kyttä (2014) use to distinguish between different participatory mapping pursuits (Table 1). The labels *participatory GIS* (PGIS), *public participation GIS* (PPGIS) and *volunteered geographic information* (VGI) all describe activities that use participatory mapping as a means for capturing non-expert spatial information, but the terms have come to describe different realizations of it. Efforts in developing countries that promote social learning and community engagement over data quality are generally labeled as PGIS, while PPGIS is deployed by urban populations in developed countries, where the maps are often intended to inform land- and sea-use decisions. Both PGIS and PPGIS emphasize inclusion and empowerment of under-represented populations in the production and use of spatial information, but PPGIS typically prioritizes data quality and representativeness over participation by marginalized social

	PPGIS	**PGIS**	**VGI**
Global context	Developed countries, urban & regional	Developing countries, rural	Variable
Mapping technology	Digital	Non-digital	Digital
Data collection process	Individual (e.g., household sampling)	Collective (e.g., community workshops)	Individual
Purpose	Enhance public involvement in planning	Empower community; Build social capital	Use citizens as sensors to expand spatial information
Sampling approach	Active: probability	Active: purposive	Passive: voluntary
Importance of data quality	Primary	Secondary	Primary

Table 1. Generalized characteristics of PPGIS, PGIS and VGI (adapted from Brown and Kyttä 2014)

groups, the reverse of PGIS. VGI, in contrast, is less clearly defined by geographic context (i.e., developing vs. developed country), but data quality is typically prioritized over empowerment and other social goals.

The participatory mapping exercise presented here shares characteristics of both PPGIS and PGIS as described above. It was conducted in a rural part of a developing country using purposive sampling—typical of PGIS—but it employed digital mapping tools with an emphasis on locationally accurate data—typical of PPGIS. Data were collected both individually, through remote Internet participation, and collectively, through community workshops, and equal emphasis was placed on public involvement in planning and empowering community members as the exercise's purpose.

In Indonesia, the geographic setting of this study, participatory mapping has been documented since at least the early 1980s, though a straightforward process for incorporating such information at the national government level has not yet been established. In one of the earliest examples, a US-based NGO used sketch mapping with small farmers in Sumba and Flores to assist planning for tree-planting and soil conservation (Hardiono et al. 2005). In 1992 the management plan of the Kayan Mentarang National Park in East Kalimantan was developed with input from participatory mapping (Shahab 2016; http://jkpp.org/profil-jkpp/). Several years later, in 1996, a group of activists and NGOs founded the Participatory Mapping Network (*Jaringan Kerja Pemetaan Partisipatif*; JKPP) to assist rural communities in mapping their land. As the quantity of maps produced by this and other groups grew, the Ancestral Domain Registration Agency (*Badan Registrasi Wilayah Adat*; BRWA) was established by the JKPP and other organizations in 2010 to consolidate the results of disparate customary land mapping projects into a single database (Shahab 2016; http://brwa.or.id/pages/about). BRWA regularly submits maps to different Indonesian ministries as well as the Geospatial Information Agency (*Badan Informasi Spasial*; BIG), which holds sole responsibility for producing thematic basemaps recognized as authoritative by the government. BIG is overseeing implementation of the country's One Map Policy (*Kebijakan Satu Peta*), an attempt to standardize the geospatial information used across government ministries that was launched in 2011 and is still in progress (Indonesia NSDI: One Map for the Nation 2012; Hanafi 2015).

One notable feature of BIG's online cartographic resources is a participatory mapping application that allows any registered user to submit spatially referenced features for consideration (http://petakita.ina-sdi.or.id/pempar/). A set of standard operating procedures (http://petakita.ina-sdi.or.id/pempar/dokumen/SOP_Pemetaan_Partisipatif.zip) illustrates the process of toponym validation, and a user guide (http://petakita.ina-sdi.or.id/pempar/dokumen/Panduan_Penggunaan_PMAP.pdf) describes the process of creating features, though little direction is provided regarding the type of features the system is intended to document. Despite BIG's apparent espousal of participatory mapping, the agency has been criticized for failing to establish a standard mechanism for verifying and incorporating community-generated maps submitted by organizations like BRWA into the country's authoritative spatial data infrastructure (Hanafi 2015; Shahab 2016).

The existence of BIG's *Aplikasi Pemetaan Partisipatif* (Participatory Mapping Application) would be unremarkable in a North American or European country, where OpenStreetMap is cool, every pocket carries a Google map and humanitarian map-a-thons are now common on college campuses. Yet in Indonesia, a country where less than 20% of households owned a computer in 2015 (Badan Pusat Statistik 2017), the application raises more questions: How will it be used? Who will contribute, and who will not?

These are the same types of questions raised in the GIS and Society conversations of the 1990s (Harris and Weiner 1996; Weiner, Harris, and Craig 2002). The concerns discussed—unequal access to technology and information, privileging certain forms of knowledge over others, the potential for public participation to legitimize conventional top-down decision-making and others (Harris and Weiner 1996; Elwood 2006)—deserve careful consideration today before initiating any participatory mapping venture. Fox et al. (2005) caution that deploying spatial information technologies will have ethical consequences, and that there are no "exit rights" from a technology once it has become embedded within a society. In the case of Indonesia, spatial information technologies certainly already have—from the sophisticated GIS procedures required to implement the country's One Map Policy to the GPS-enabled smartphone in the rice farmer's pocket. Rather than lamenting this fact, however, a more productive perspective is one that acknowledges the potential negative consequences of these technologies and their use (or misuse) while weighing them against the benefits that stand to be gained, including the democratic ideals of community empowerment underlying the practice of participatory mapping. Legitimate barriers to participation exist in Indonesia, particularly where digital technology is involved. However, by avoiding computer-based tools over fears of digitally incompetent or disinclined participants, well-meaning facilitators may, in fact, perpetuate causes of unequal access and opportunity that participatory mapping seeks to address. Digital participatory mapping undoubtedly requires a modified approach in places where computers are uncommon; understanding *how* motivates this study.

2.2 Methods

2.2.1 Study site

The study was conducted in West Bali with survey questions referencing an area of interest of approximately 350 km^2 in Bali's Buleleng and Jembrana regencies (Figure 1). These regencies are sparsely populated, with the Bali's third-lowest and lowest population densities, respectively (Badan Pusat Statistik Provinsi Bali 2017c). Within this area are six villages where the predominant occupation is farming, though other sectors include artisanal and commercial fisheries—both for consumption and the aquarium trade—aquaculture and tourism (Gustave

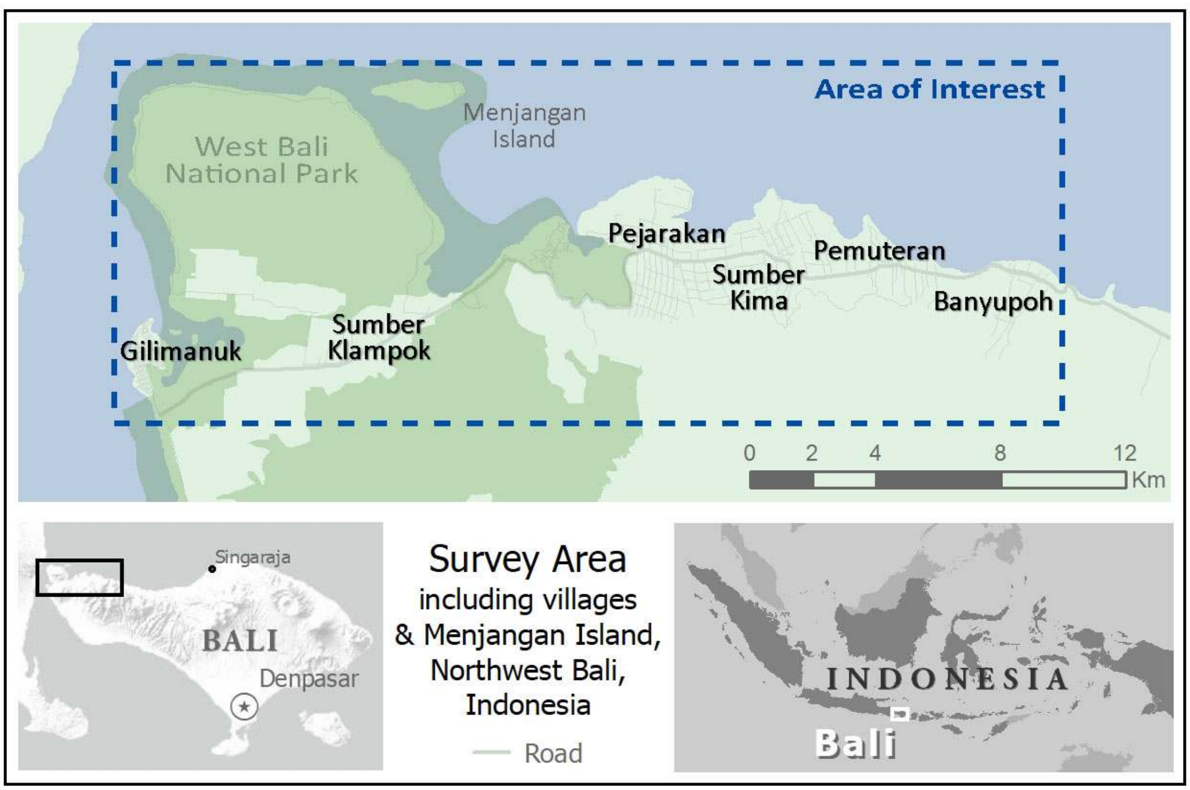


Figure 1. Survey area of interest in Bali Province, Indonesia (data: Esri, openstreetmap.org, gadm.org, CEES|CU 2017)

and Hidayat 2008; Doherty et al. 2013; Januarsa and Luthfi 2017). The population of Pejarakan Village, where the majority of the surveys were conducted, was approximately 11,000 in 2016 (Januarsa and Luthfi 2017). Ethnically, most of West Bali's inhabitants are a mix of Balinese, Javanese and Madurese, with Hinduism the predominant religious affiliation, followed by Islam and Christianity. Literacy in Buleleng Regency, which encompasses all but one of these villages, was reported to be 90% in 2015, slightly lower than the value of 93% for all of Bali Province and 95% nationally (UNESCO Institute for Statistics 2017). Household computer ownership in Bali's rural areas averaged about 14% in 2015 (Badan Pusat Statistik 2017).

While tourism is Bali's predominant industry, tourism to the North, including the study area, lags far behind that of the South. Eighty-five percent of Bali's hotel rooms were located in the southern regencies of Bandung and Gianyar and capital city Denpasar as of 2015 (Badan Pusat Statistik Provinsi Bali 2017a, 2017b). A few villages and points of interest in the North, however, attract significantly more visitors than the surrounding areas. One such example inside the study area is Pemuteran Village, where tourism began growing in the early 1990s and in 2016 was named one of Asia's top ten travel destinations by Lonely Planet (Heber Dunning 2015; Yu 2016). Many of the region's tourists are drawn by West Bali National Park (WBNP), one of Indonesia's oldest national parks. Originally proposed as one of 11 candidates in 1982, WBNP was definitively established in 1995, covering approximately 190 km^2 of land and coastal marine area (Mahmud, Satria, and Kinseng 2015a). Many who visit the park come to snorkel or dive on the reefs surrounding Menjangan, a small (<2 km^2) island located approximately 600 m off the Bali mainland. In addition to marine recreation, religious activities draw Balinese and Javanese Hindus, who come to worship at the island's several temples. The island has no permanent inhabitants, though park officials occasionally overnight at an outpost there.

Bali's tourism-driven development has increased demand for imported products while creating a new middle class with new consumption habits, exacerbating the problem of solid waste management (MacRae 2012). Before the widespread use of petroleum products, especially plastic packaging, forest resources such as banana palms, coconut trees and bamboo served daily needs of food handling, building construction and other necessities. Materials that were no longer needed were either left in place to decompose, burned, or swept into rivers, regarded as purifying forces. Non-biodegradable consumer products have taken much less time to infiltrate Bali than the time necessary to change generations of behavior. Consequently, like many Southeast Asian destinations, Bali now faces a serious solid waste management dilemma. Various solutions have been proposed and tried, from large commercial waste-to-energy plants to community-based composting and so-called *trash banks* (*bank sampah*)—facilities that pay members for their recyclable materials. Most of the facilities currently in operation are in the South, near the population centers of Denpasar, Ubud and Nusa Dua (http://2cdenpasar.com/). In West Bali, most villages have a designated landfill area where residents may bring their refuse to be sorted informally by garbage-pickers and eventually burned. However, most households deal with their waste by burning it themselves or depositing it into rivers, ditches, or other convenient locations. Pemuteran Village is unique in West Bali for its garbage collection service, organized and paid for by local resort and hotel operators. Gilimanuk, too, has the region's only trash bank.

West Bali is an ideal region for studying factors such as prior computer experience and culture on digital participatory mapping because of its population, Internet access and status as a tourism destination. Laptop and desktop computer use varies among residents from none to frequent, enabling comparison among a range of experience levels. Mobile telecommunications network coverage provides Internet access to most villages in this area at speeds sufficient to operate imagery-intensive online mapping software. Bali, as a world-class tourism destination, attracts more Western visitors and expats than other parts of Indonesia, so recruiting Western participants for the surveys was not difficult. Prior to the surveys, municipalities of West Bali were already contemplating their own environmental planning challenges—managing waste and steering the future of tourism—so many residents were amenable to participating in surveys that they believed might benefit their discussions already underway. Finally, the possibility of advancing practical initiatives regarding waste management and tourism planning through an academic study strongly motivated the selection of this site.

Rather than divide the available time and budget between two or more sites to provide a comparison across locations and cultures, the effort focused on a single site. The researcher's connections to West Bali, dating back almost a decade, provided experiential background and contacts that made a focus on depth, rather than breadth, more attractive for this case study.

2.2.2 Participant observation

The topics of this study's surveys—waste management and tourism development—were developed largely through participant observation (Atkinson and Hammersley 1994). The researcher spent approximately 18 months living in Pejarakan Village, spread over two visits—in December 2014 and from July 2015–November 2016. This time was critical for the people of Pejarakan to get to know the researcher and for the researcher to gain a basic understanding of local customs and politics, identify key informants, learn local place names and achieve basic proficiency in the Indonesian language. This happened through participation in local celebrations for holidays, such as *Galungan* and *Nyepi* on the Hindu calendar and *Idul Fitri* on the Muslim calendar; attending birthday, wedding and cremation ceremonies and prayers in Hindu temples; participating in community service and conservation projects; studying Indonesian through several months' of intensive lessons; and teaching classes to local high school students on both English and mapping skills such as making maps with Google Earth, submitting corrections to Google Maps and editing OpenStreetMap.

The survey topics emerged out of these experiences, motivated by factors both external and internal to the Balinese communities surveyed. The government of Buleleng Regency had initiated a planning process to explore how tourism to North Bali might be expanded. Local excitement surrounding the prospect of further developing regional tourism, which is generally perceived as a positive force that brings economic prosperity, motivated the survey on tourism. The survey on waste management was motivated by the researcher's desire to foster critical thinking about the connection between tourism and non-biodegradable litter in the participants' communities. While this connection was never made explicitly to participants, it was implied by presenting the two surveys sequentially.

A primary motivation for conducting the mapping classes, aside from teaching basic cartographic skills, was to recruit and train local assistants to help administer the surveys. The classes took place over a four-month period, where the concept and utility of digital participatory mapping were first introduced to students through learning activities based around kite aerial photography (Currier 2015). Kites are integral to Balinese Hindu culture, believed to have been introduced by the earthly representative of Lord Shiva (Anggaraditya 2017). Children grow up constructing and flying their own kites in competitions well into adulthood, and every year the Bali Kite Festival attracts local and international participants. In the mapping classes, students flew a kite and attached camera along a local beach, the camera automatically snapping photographs of the coastline below. Later, students created a photomosaic of the beach by aligning overlapping photographs, first with hardcopy prints and then with digital files in Google Earth (Figure 2). The students were further familiarized with computer-based mapping operations and concepts through lessons with Google Earth, Google Maps and OpenStreetMap. By the time they were introduced to this study's map-based survey

Figure 2. Students assemble aerial photographs into mosaics, first in hard copy with photographic prints and then digitally in Google Earth

software, the students had experience using several different digital mapping platforms and had figured out strategies for approaching mapping tasks, like locating familiar buildings in aerial imagery to help orient themselves to the map. The students who assisted in conducting the surveys could explain and teach these strategies to participants in their own local language, rather than relying solely on the researcher's instructions.

2.2.3 Survey design

The first survey was intended to (a) capture participants' perceptions of non-biodegradable litter in West Bali; and (b) familiarize participants with the interface and operations of SeaSketch, the online software used to deliver the surveys. The survey included two main questions: (1) *To your knowledge, which places in West Bali have a lot of non-biodegradable trash in the environment?* and (2) *Which places in West Bali have little or no trash that is non-biodegradable in the environment?* The term "place" (*tempat* in Indonesian) was selected over "location" (*lokasi*), "spatial location" (*lokasi spasial*) or other geographic expressions for two reasons: in everyday Indonesian speech, *tempat* is the most common noun associated with the question *Where?*; and it is more general than alternative terms in English (and perhaps Indonesian), having the dual interpretation of *location in space* and "a center of meaning constructed by experience" (Tuan 1975, 152). *Place* therefore accommodates responses that name an entity with a specific location, e.g. "Mimpi Resort", or a concept with an unspecified location, e.g. "resorts and hotels". Leaving such broad latitude in interpreting *place* was done on purpose, with few guidelines as to the scale or nature of place that was sought, to determine if culture or other demographic characteristics influenced how participants responded to the question. Likewise, the term “a lot” was purposely left open to interpretation, as a standardized measure of garbage was not important to the survey.

Answers were constrained, however, to a geographic interpretation of *place* by requiring that they be represented on a map. To reduce cartographic complexity for the participants’ first mapping task, participants were limited to adding points only—no lines or areas—to a map, along with a name and description attribute to represent each place. Participants were instructed to add as many points as they wished. Several subsequent questions asked participants about their knowledge of landfills and trash banks in the area and required them to add lines and areas to the map, giving them practice with SeaSketch’s feature drawing tools. The full text of both surveys, in English and Indonesian, appears in Appendix A.

The second survey, on tourism to West Bali, was intended to collect (a) basic demographic information about participants, including age class, home location, work location, occupation, amount of computer experience, amount of Google Maps experience and frequency of visits to West Bali, for those living outside the area; and (b) opinions regarding tourism development in West Bali. The two map-based questions of this survey included (1) *In West Bali, which places should be PROMOTED as tourist attractions?* and (2) *In West Bali, at which places should tourism be RESTRICTED or PROHIBITED?* Participants were given the choice to use points, lines or areas to represent places, of which they could add an unlimited number. Each geometric feature was also associated with a name and description attribute.

The two surveys, intended for a single sitting, were administered via SeaSketch, an online, map-based platform for collaborative spatial planning and spatially explicit surveys (http://www.seasketch.org). The SeaSketch interface consists of an interactive map on the left and a pane with tabs on the right that allow the user to toggle spatial data layers on or off, change the basemap, view a map legend and participate in surveys (Figure 3; Appendix B). The interface and surveys were available in both English and Indonesian. To keep the interface as simple as possible, only five spatial data layers were made available—Area of Interest; Place Names, including villages, Menjangan Island and a harbor; Streets from OpenStreetMap; Pejarakan Village Neighborhoods; and Conservation Areas. Three basemap choices—Esri's Imagery and Light Gray, and OpenStreetMap—were available.

2.2.4 Participant recruitment

Both Indonesian and foreign participants were recruited for the study. The decision to include foreigners, aside from the study's investigation into the differences in participatory mapping between Westerners and Indonesians, was justified by the fact that foreigners are a

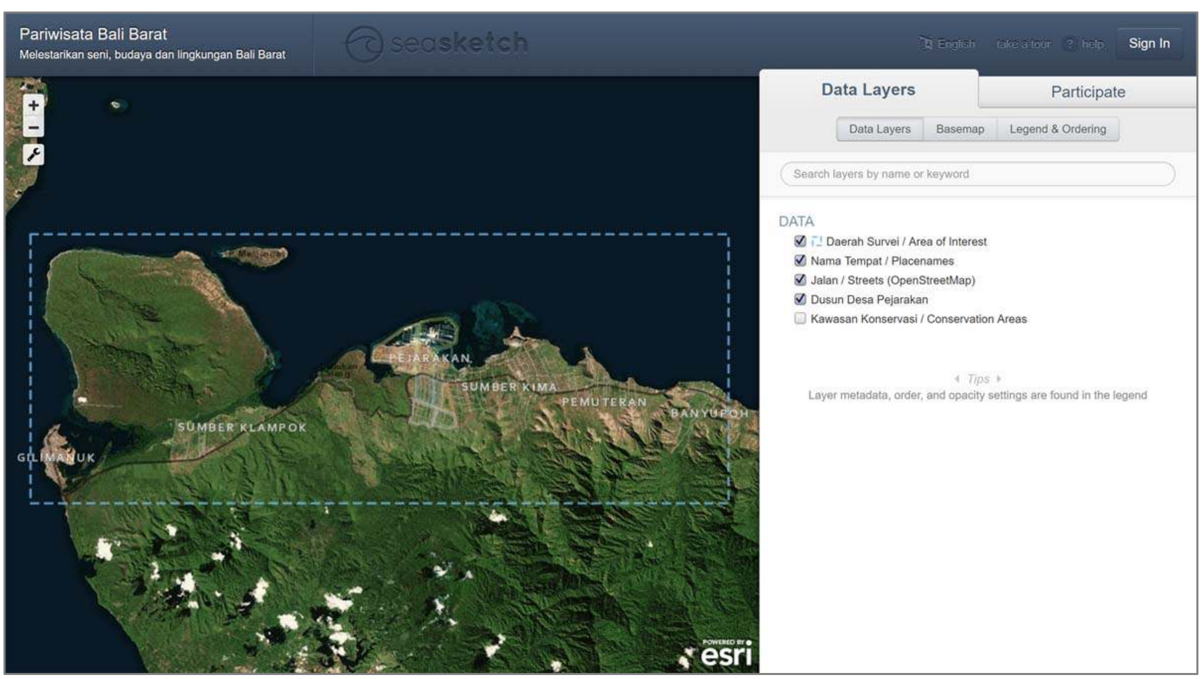


Figure 3. SeaSketch survey platform interface

significant target market for Bali's tourism, so their perspective is relevant in tourism planning. Indonesian participants were recruited through snowball sampling (Atkinson and Flint 2001), beginning with the head of Pejarakan Village, a teacher at Pejarakan's tourism vocational high school, and key informants with the national park and grassroots community organizations in Gilimanuk, Sumber Klampok, Pejarakan and Pemuteran. Foreign (all Western) participants were recruited in the same way, mainly from the small population of expats who reside in West Bali and from the NGO Biosphere Foundation, which has maintained a presence in Pejarakan since 2009.

2.2.5 Survey implementation

The surveys were conducted from September–November of 2016. Participants took part in the surveys in one of two ways, either remotely—using their own computer and Internet connection—or in person during a small workshop of five to eight people. For remote participants, a PDF document with illustrated step-by-step instructions was provided, along with an explanation of the surveys' purpose. The in-person workshops were arranged at times that were convenient for participants' schedules, in public spaces or private residences in Pejarkan and Sumber Klampok villages. Five laptops, connected to the Internet via a cellular network hotspot, were made available to participants, with one laptop per participant. After a brief introduction, including the purpose of the surveys and illustrated step-by-step instructions, participants were given an unlimited amount of time to complete the two surveys. The workshops, which were exclusively attended by Indonesian participants, were presented in English and translated by a bilingual Balinese translator. Local Balinese assistants, recruited from among the mapping class attendees, were available to provide help, either by answering questions, showing participants how to use the software, or fully operating the computer if a participant preferred not to input their own answers. No financial incentive to participate was provided, but people who participated through in-person workshops were offered refreshments. The surveys were approved under protocol number 22-16-0692 by the Human Subjects Committee of the University of California, Santa Barbara and research permit number 442/SIP/FRP/E5/Dit.KI/I/2015 by the Ministry of Research, Technology and Higher Education of the Republic of Indonesia (*Kementerian Riset Teknologi Dan Pendidikan Tinggi Republik Indonesia*).

2.2.6 Analysis

Calculations, statistical analyses and visualizations were performed using the R base package (R Core Team 2013) in R Studio (RStudio Team 2015) and extensions (Wickham 2007, 2009, 2016, 2017a, 2017b; Fox and Weisberg 2011; Neuwirth 2014; Engels 2015; Revelle 2017; Wickham et al. 2017). Maps were created in ArcGIS Desktop version 10.4.1 (Esri 2016). Inferential statistics test hypotheses about the population from which a sample is drawn, under the assumption of random sampling. Therefore, the results presented here apply to a specific population of West Bali residents and visitors with connections to the researcher and do not represent a random sample of all people who reside in or visit West Bali. Acknowledging this limitation, both descriptive and inferential statistics are presented for readers who require inferential statistics to consider an analysis rigorous. Descriptive statistics are illustrated with box plots, where the band inside the box represents the median; the upper and lower hinges represent the first and third quartiles; the upper and lower whiskers represent the highest and lowest values no greater than 1.5 times the interquartile range (distance between first and third quartiles); and outlying points are plotted individually.

Where inferential statistics were performed, non-parametric tests were chosen, as none of the data were found to be normally distributed. In most cases, Indonesian and English-language responses were analyzed separately to avoid potential confounding effects of culture, i.e. Indonesian vs. Western. The small sample size and in some cases homogeneous nature of English-language participants made certain inferential statistical comparisons impractical—for example, all English-language participants reported frequent computer use, precluding the possibility of comparing English-language participants based on level of computer experience. Therefore, some comparisons among English-language participants were omitted.

Participant demographics

Plots of the participants' (a) frequency of computer use and (b) frequency of Google Maps use by language and age class were visually inspected for relationships. A Spearman's rank correlation test with 95% confidence interval was used to detect a possible monotonic association between these factors within each language group.

Count of features mapped per participant

To investigate the possible influence of (a) survey topic and question, (b) culture, (c) frequency of computer use, (d) frequency of Google Maps use and (e) age class on the number of features mapped per participant, features of each type—i.e., place with/without garbage, place for promoting/restricting tourism—were counted for each participant. Two-group comparisons were made between (a) surveys, and within each survey between (b) languages and (c) feature types. Wilcoxon signed-rank (paired) tests were used to test the difference in the median number of features mapped by participants in the garbage vs. the tourism survey, split by language group. The same test was used to evaluate the difference between the median number of features of each type mapped by participants within each survey. Mann-Whitney-Wilcoxon tests were used to test the difference in the median number of features mapped between language groups. Post-hoc Levene's tests (for samples from a non-normally distributed population) (Levene 1960) were performed on data yielding significant Mann-Whitney-Wilcoxon test results to check for heteroscedasticity, as this condition can raise chances of incorrectly rejecting the null hypothesis (Type I error) (Nachar 2008).

Four- and three-group comparisons were made among groups defined by (a) frequency of computer use, (b) frequency of Google Maps use and (c) age class. The non-parametric Kruskal-Wallis test was selected for this comparison, as the data under evaluation were non-normally distributed and not necessarily homoscedastic, neither of which are assumptions of this test (Burt, Barber, and Rigby 2009). Frequency of computer and Google Maps use and age class were considered as ordinal variables in this case, while the count of features became the ranked variable. Significant results were examined further with a Spearman's rank correlation test to determine if a monotonic association existed between variables.

Scale class and geometry of features

Features from both surveys were assigned a scale class based on the size of the feature indicated in its name or description attribute, either the length (for roads) or footprint area (for all other features) (Table 2). Features that lacked a sufficient name or description were excluded from this analysis. Scale class boundaries were defined to approximate several types of places that were frequently mapped, from resorts—the smallest place type—to entire villages—the largest type. The final class, 5, was defined for places whose size could not be readily determined, usually because the name or description referred to a generalized characteristic, such as “forested areas”, or because it referenced multiple places, like “private property, resorts, homestays”.

A Kruskal-Wallis test was used to investigate whether Indonesian and English-language responses differed in their mean ranks of features across scale classes. Considering Indonesian participants only, the same test was used to suggest whether differences related to frequency of computer use, frequency of Google Maps use and age class as independent variables.

Scale Class	Footprint Area	Length (roads only)	Archetypal Feature	Common Examples
1	< 50,000 m^2	< 300 m	resort	Mimpi Resort
2	50,000 m^2–1 km^2	300 m–2.5 km	local conservation area	Putri Menjangan, Salak Road
3	1.01 km^2–3 km^2	2.51 km–4 km	neighborhood	Menjangan Island
4	> 3 km^2	> 4 km	village/region	Pejarakan Village, West Bali National Park
5	Indeterminate	Indeterminate	N/A	“mountainous areas”, “forested areas”

Table 2. Scale class definitions for characterizing features according to size

Significant differences were investigated further with a two-tailed Fisher's exact test of independence by aggregating classes within the independent variables to arrive at a nominal variable with two possible values as required by this test. This test was selected as one appropriate for small ($n<1{,}000$) sample sizes, preferred over the Chi-square test or G-test of independence (McDonald 2014).

While participants were limited to mapping with points only in the garbage survey, they had the choice of using points, lines or areas to represent places in the tourism survey. To investigate whether participants selected geometry type randomly to represent features in the tourism survey, the proportions of points, lines and areas used by participants were compared to those that would be expected under random choice—⅓ points, ⅓ lines and ⅓ areas—using an exact test of goodness-of-fit, appropriate for small ($n<1{,}000$) sample sizes (McDonald 2014). Whether a difference in proportions existed between Indonesian and English-language groups was investigated using a Fisher's exact test of independence.

The distribution of features by scale class and geometry type was compared between Indonesian and English-language participants, both graphically and using a Fisher's exact test of independence.

Locational accuracy

A reference map of place footprints was constructed to validate the location of places named or described in point features' attributes. This type of *validity-as-accuracy* assessment (Spielman 2014) has been used to evaluate participants' spatial knowledge of native vegetation (Brown 2012) and OpenStreetMap content (Haklay 2010). Point features, only, were evaluated to simplify validation. Validation was attempted for point features from both surveys that included an official or colloquial place name, such as “Menjangan Island” or “the three-way intersection on the way to Mimpi Resort”. Features with missing or ambiguous location references, such as “a good place for surfing”, were excluded, as were features with place names or descriptions that were unfamiliar to the researcher and researcher’s Balinese colleagues. Points that fell within their corresponding reference feature footprint were considered to have no measurable error. If a point fell outside of the reference feature, the distance between the point and the closest edge of the reference feature was measured with a precision of ten meters, and this value was reported as the point feature’s locational error. Validation was performed in ArcMap 10.4.1 using the same imagery basemap that was available to survey participants.

The proportion of features mapped with and without measurable error as explained above was compared between language groups using Fisher’s exact test of independence. A per-participant error score was calculated as the average error per feature mapped, a metric standardized to account for differences in the number of features mapped by each participant. These error scores were used to identify differences among classes defined by frequency of computer use, frequency of Google Maps use and age class within the Indonesian group using Kruskal-Wallis tests. The English-language group was not tested, as there were too few participants spread across these classes to produce a reasonable comparison.

This chapter has introduced the participatory mapping study conducted in West Bali, Indonesia, which invited locals and visitors to take two online map-based surveys about their perceptions of litter and opinions regarding tourism in the region. The purpose of the study was to investigate how cultural and demographic differences may have influenced their cartographic choices, information that may suggest changes to the way digital participatory mapping projects in non-Western developing countries are conducted and interpreted. A summary and discussion of results are presented in the next chapter.

Chapter 3
Tourism and Trash II: Results and Lessons Learned

Following the introduction, rationale, background and methods described in the previous chapter, this chapter presents the results of the two online map-based surveys on litter and tourism conducted in West Bali, Indonesia, from September–November 2016. The results are presented in the same order as they were described in the Methods section of the previous chapter, beginning with a description of participant demographics and continuing with metrics that characterize aspects of the participants' cartographic choices including the number of features mapped, the distribution of features among scale classes, the geometry types selected to represent features and the locational accuracy of features. The summary is followed by a discussion of these results and how they address the research questions posed early in the previous chapter, namely *What opportunities and challenges do Web-based tools for participatory mapping present in a place where laptop and desktop computers are uncommon?* and *What methodological, technological and analytical modifications are necessary to produce results that are useful in a non-Western planning context?* Limitations of the study, reflections on how it could be improved and suggestions for future research are included in the discussion, and the chapter concludes with a summary of lessons learned that directly addresses the research questions.

3.1 Experimental results

3.1.1 Participant demographics

A total of 54 people participated in the surveys with 42 who completed both, 8 who completed only the garbage survey and 4 who completed only the tourism survey. Participants ranged in age from 15 to over 40 and included 17 females, 29 males and 7 of unknown gender (Table 3). Of the participants, 44 completed the Indonesian-language version and 10 the English version. All who completed the Indonesian-language version were Indonesian nationals, while all who took the English version were currently or originally from Western countries (Australia, Belgium, UK or US), though some reported living full-time in Bali as expats. Of the Indonesian-language respondents, about 80% (n=35) reported living or working

	Garbage Survey		**Tourism Survey**	
	Indonesian language	English language	Indonesian language	English language
Total	41	9	37	9
Female	12	4	12	4
15–25	12	0	13	0
26–40	0	0	0	0
> 40	0	4	0	4
Male	22	4	24	5
15–25	7	0	8	0
26–40	9	2	10	2
> 40	6	2	6	3
Unknown	7	1	0	0

Table 3. Participants by gender and age, garbage and tourism surveys

in West Bali, while the remainder either live and work elsewhere in Bali (n=2) or did not report (n=7). Of the English-language respondents, half (n=5) reported living or working in West Bali, one elsewhere in Bali, three outside of Bali and one unknown.

Participants reported using a laptop or desktop computer with a frequency ranging from never to more than once per week (Figure 4). All English-language participants (n=8) except one unknown reported using a computer *often*, i.e. more than once per week, while Indonesian participants were fairly evenly split across computer use classes, with 13 reporting *often*, 11 reporting *sometimes* (about once per week), 7 reporting *rarely* (once per month or less), 5 reporting *never* and 8 unknowns.

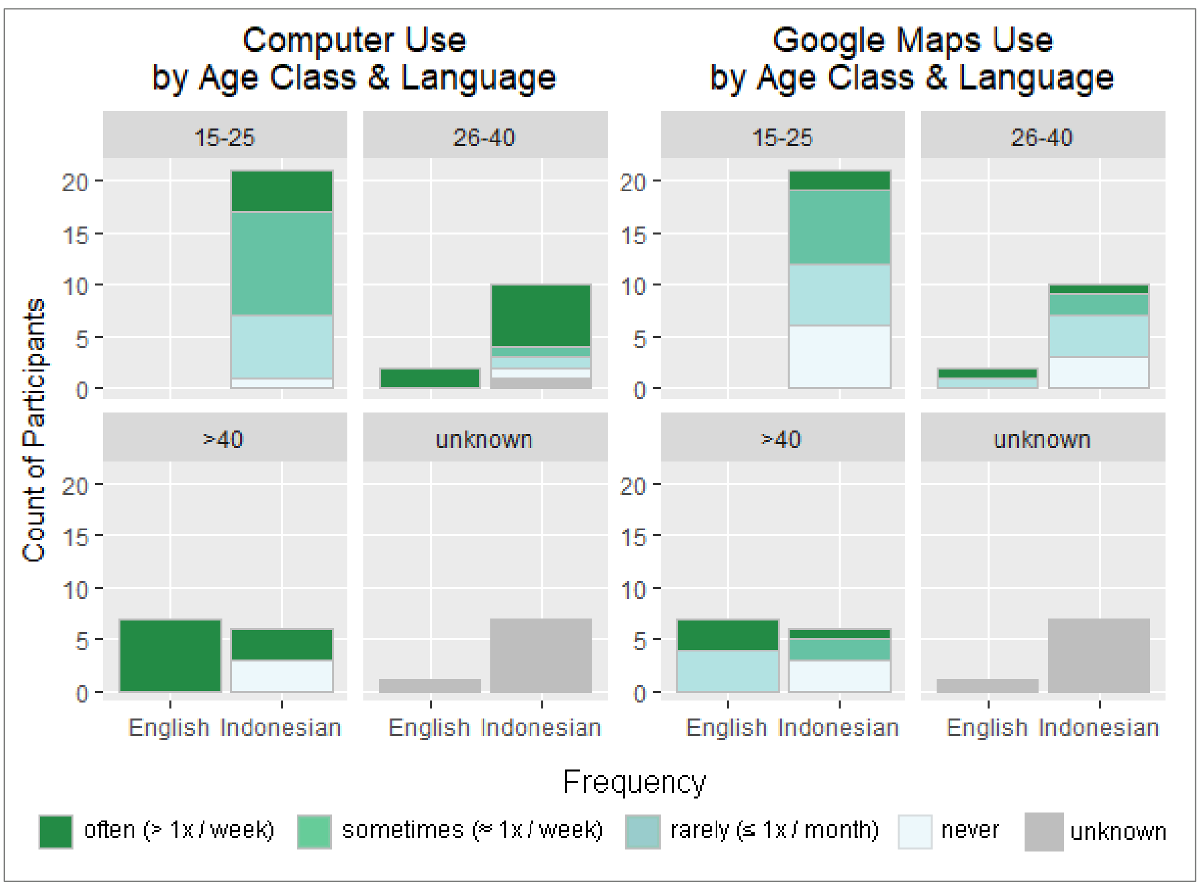


Figure 4. Participants' frequency of computer and Google Maps use by age class and language

Participants reported using Google Maps (on any device) with a frequency ranging from never to more than once per week (Figure 4). English-language respondents were split between *often* (n=4) and *rarely* (n=5) with one unknown. Indonesian-language participants were split across use classes, with 4 reporting *often*, 11 reporting *sometimes*, 10 reporting *rarely*, 12 reporting *never* and 7 unknowns. A significant positive association was found between frequency of computer and Google Maps use among Indonesian participants ($\rho=0.41$, $p<0.05$; Spearman's rank correlation test). No significant association was found between age and either (a) frequency of computer use ($\rho=0.12$, $p=0.50$) or (b) frequency of Google Maps use ($\rho=-0.06$, $p=0.73$) among Indonesian participants.

3.1.2 Count of features mapped per participant

Participants mapped a total of 300 features including 161 in the garbage survey and 139 in the tourism survey (Figure 5). All but four features were mapped within the area of interest. The number of features mapped per participant varied from 1–10 with a median of 2 in the garbage survey, and from 0–7 with a median of 3 in the tourism survey (Figure 6). The difference in medians between surveys was not significant ($p=0.84$; Wilcoxon signed-rank test). When considered by language group, there was still no significant difference in the median number of features mapped by Indonesian ($p=0.90$) nor English ($p=0.62$) language participants between the two surveys. Both Indonesian and English-language participants mapped significantly more places with garbage than places without ($p<0.001$ and $p<0.02$, respectively) (Figure 7). Indonesian-language participants mapped significantly more places to promote than restrict tourism ($p<0.0001$), but the difference was not significant for English-language participants ($p=0.14$).

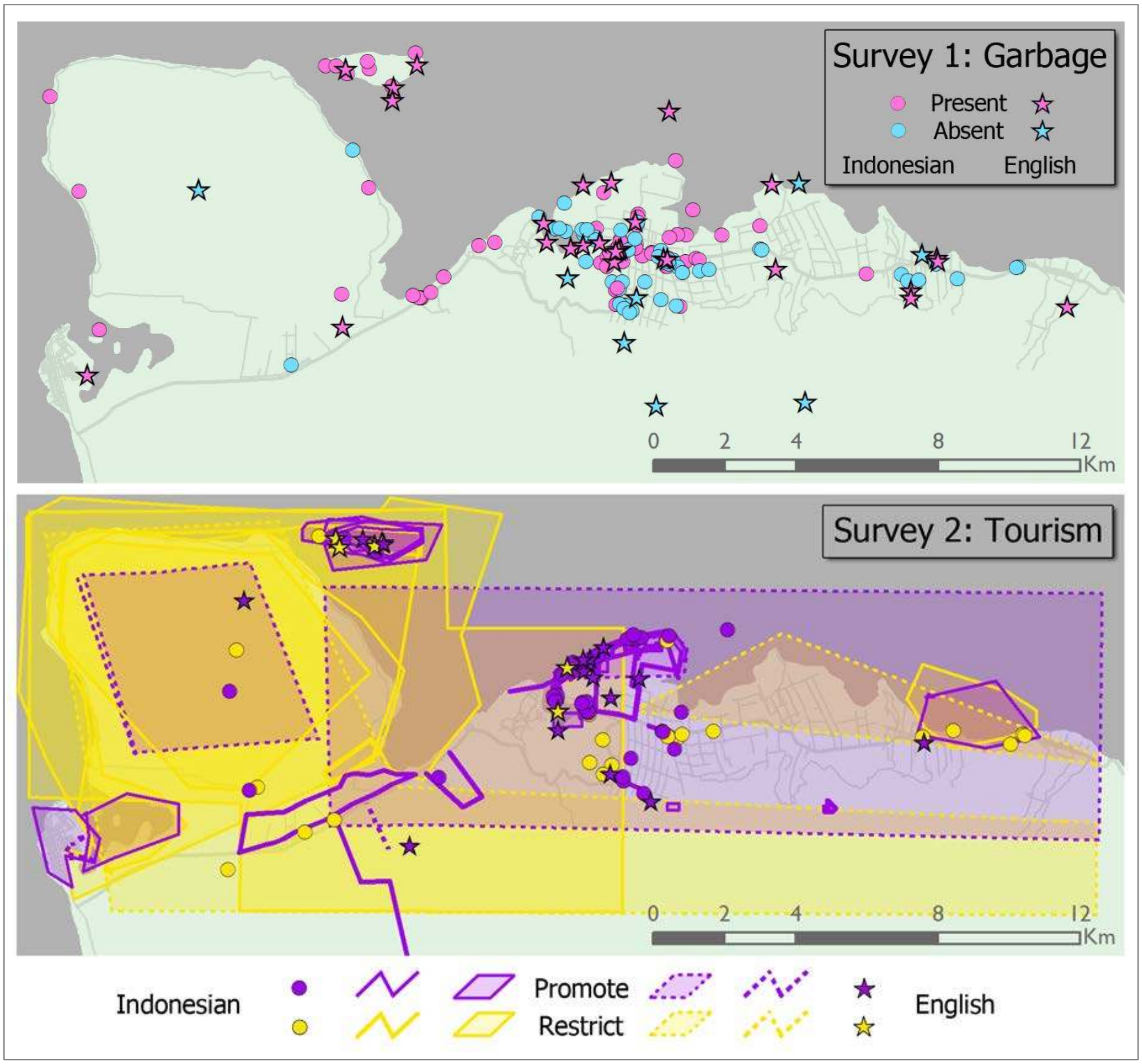


Figure 5. Features mapped by participants, symbolized according to survey language and feature type (garbage present/garbage absent; promote tourism/restrict tourism; not shown: four features mapped outside the survey area of interest)

English-language participants tended to map slightly more places with garbage than Indonesian participants (Figure 7), but the difference in medians was not significant (p=0.07; Mann-Whitney-Wilcoxon test). All other differences in medians between Indonesian and English-language participants were insignificant, including for places without garbage (p=0.15), places for restricting tourism (p=0.75) and places for promoting tourism (p=0.68).

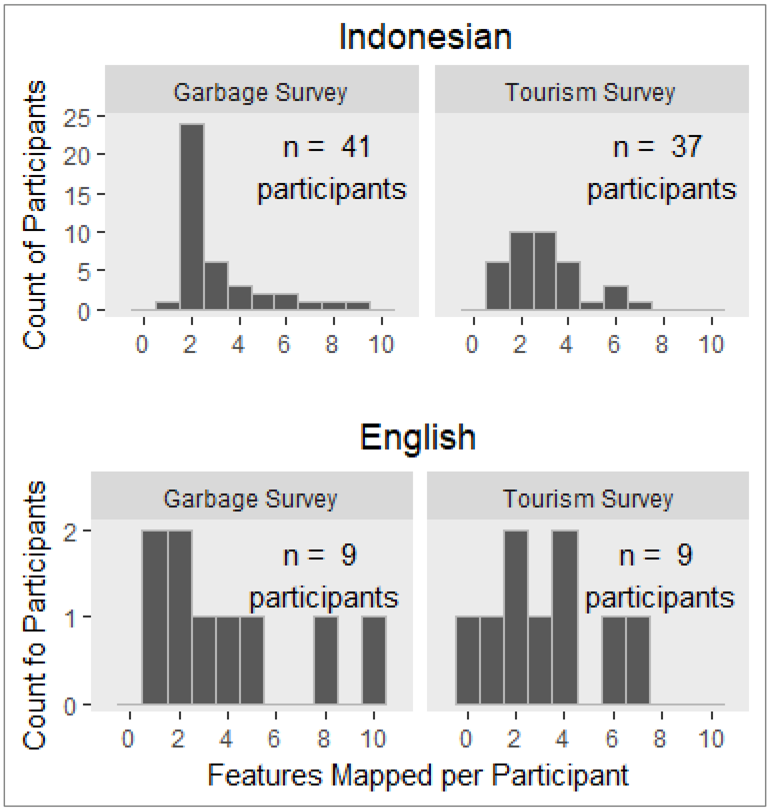


Figure 6. Histogram of participants according to the number of features mapped, by language and survey

Among those who completed both surveys, the total number of features mapped per participant varied from 3–12 for Indonesian-language participants (n=34) and from 2–17 for English-language participants (n=8). There was no significant difference in medians between language groups (p=0.87; Mann-Whitney-Wilcoxon test).

To compare the features mapped per person across frequency of computer use, frequency of Google Maps use and age class, Indonesian and English-language participants were examined separately, to avoid potential confounding effects introduced by culture. While differences in the number of features per participant between language groups were not found to be significant, this result may have been influenced by the small number of English-language participants sampled, especially as some differences in distribution appear to be present in the

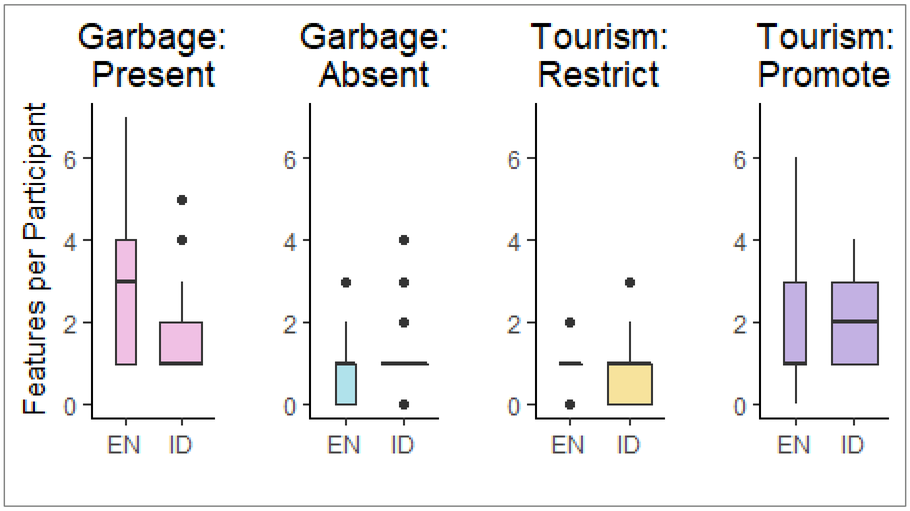


Figure 7. Number of features mapped per participant by feature type and language (EN = English; ID = Indonesian)

data. In addition, a Levene's test for homogeneity of variance suggested that the distribution of features per participant according to age class was heteroskedastic ($p<0.05$) when considering both language groups together. When the language groups were separated, heteroscedasticity among age classes was no longer significantly indicated ($p=0.11$ and $p=0.14$ for Indonesian and English groups, respectively), suggesting that the two samples were drawn from populations with unequal distributions for this, and possibly other, factors and further justifying language group separation in subsequent tests.

Among the characteristics examined, only frequency of computer use of Indonesian participants and age class of English-language participants appeared to influence the total number of features mapped by individuals (Figure 8). Frequency of computer use was found to have a significant effect on the mean ranks of features mapped by Indonesian participants ($p<0.05$, Kruskal-Wallis test) while age of English-language participants was not ($p=0.17$). A Spearman's rank correlation test suggested that a moderate positive association exists between

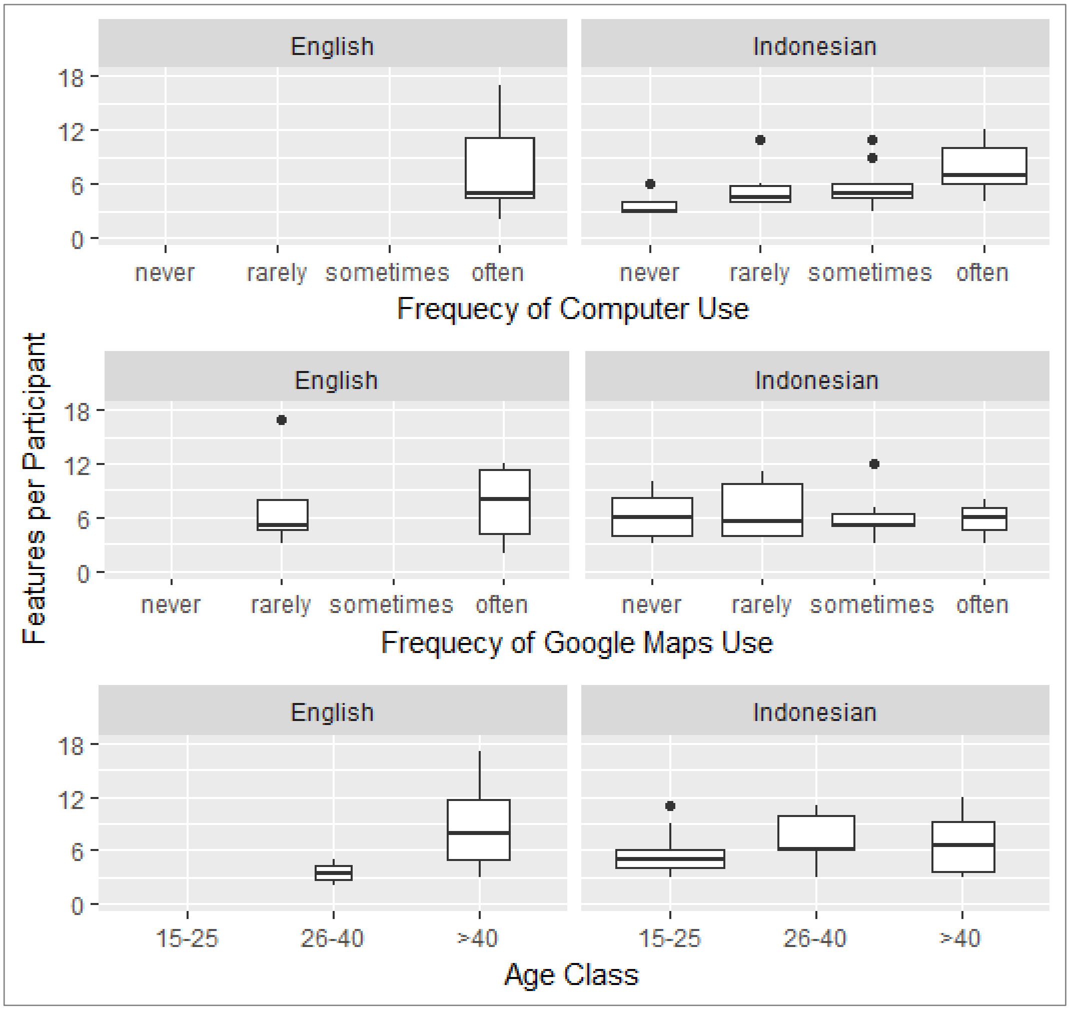


Figure 8. Total number of features mapped in both surveys per participant by frequency of computer use, frequency of Google Maps use and age class (n=8 for English, n=34 for Indonesian language participants)

frequency of computer use and total number of features mapped by Indonesian participants ($\rho=0.56$, $p<0.001$).

3.1.3 Scale class and geometry of features

Of the 300 features mapped in both surveys, 286 included a name or description attribute that was sufficient to assign a scale class to the feature. The mean ranks of features per scale class differed significantly between Indonesian and English-language participants ($p<0.0001$, Kruskal-Wallis test) (Figure 9). In both surveys, Indonesian-language participants mapped more features in class 1 than any other class, while English-language participants mapped more features in classes 4 or 5.

Among Indonesian participants, age class and frequency of computer use yielded no significant differences in the mean ranks of features mapped per scale class (p=0.78 and p=0.42, respectively). Frequency of Google Maps use, too, yielded insignificant results at the 95% confidence level, though barely so (p=0.054). The distribution of features among scale classes mapped by Indonesian participants who reported using Google Maps *often*, i.e., more than once per week, appears to have a more normal distribution than the other classes (Figure 10). A Fisher's exact test of independence did not indicate, however, that the relative

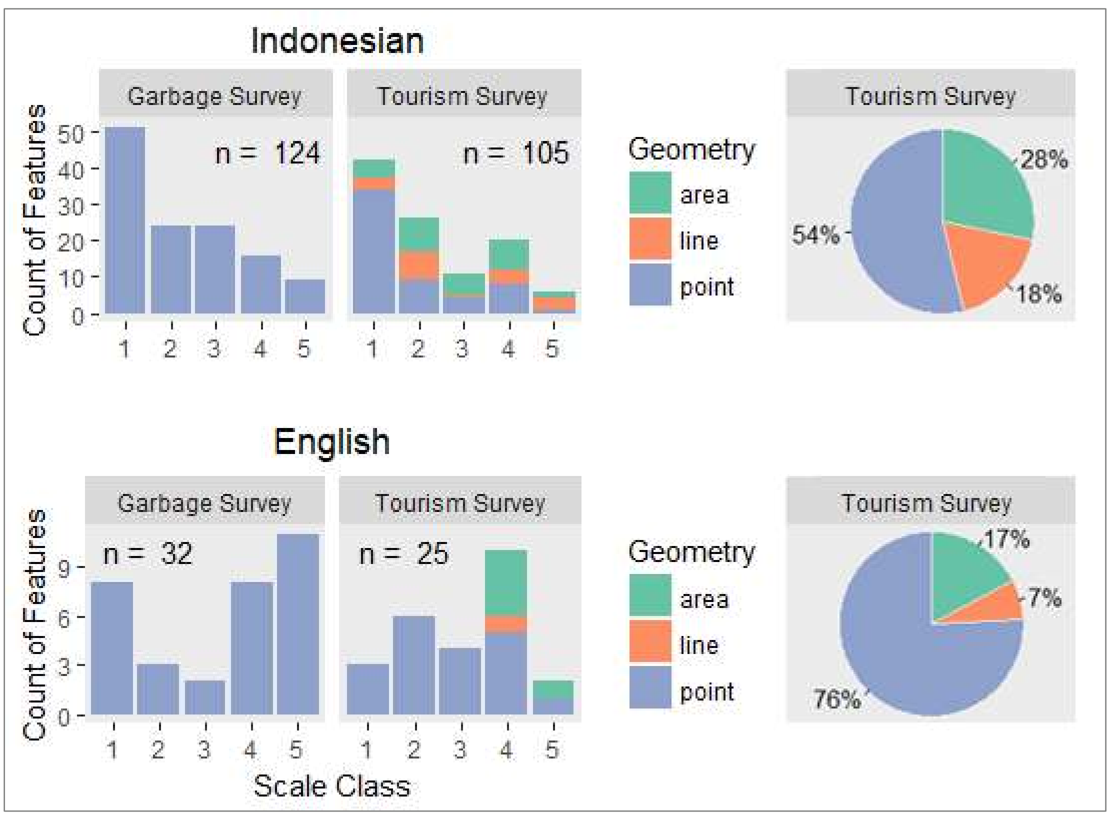


Figure 9. Features by scale class, geometry, language and survey

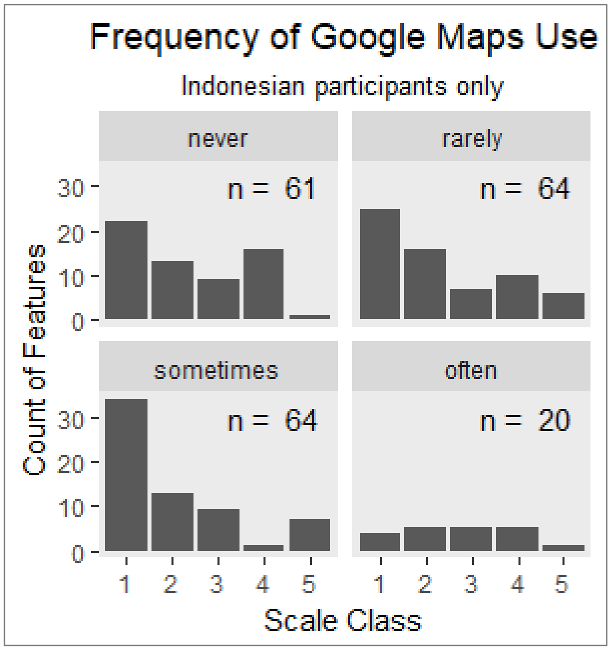


Figure 10. Distribution of features by scale class and Google Maps use frequency of participant who mapped them, Indonesian participants only

proportions of features per scale class are significantly different between participants who use Google maps often and those in all other frequency classes (*never*, *rarely* and *sometimes*) (p=0.17).

In the tourism survey, where participants had their choice of geometry type to represent features, the proportion of points, lines and areas mapped by both Indonesian and English-language participants differed significantly from those expected under random choice (p<0.0001, exact test of goodness-of-fit). Points were chosen most often by both Indonesian and English-language participants, including 54% of Indonesian-mapped and 76% of English-mapped features (Figure 9). The proportion of points, lines and areas did not differ significantly between language groups (p=0.11, Fisher's exact test of independence). However, when the lines and areas were pooled into a single class, subsequently comparing point to non-point features, English-language participants were found to have chosen points significantly more often than Indonesian participants over other geometry types (p=0.035). Within Indonesian participants, no significant differences in the proportion of geometry types were found among groups based on frequency of computer use (p=0.64), frequency of Google Maps use (p=0.58) or age class (p=0.35). Pooling lines and areas did not result in significant differences among these groups, either.

The distribution of features by geometry type and scale class appears to differ between Indonesian and English-language participants (Figure 9). Features mapped by Indonesian participants included at least one point, line and area in every scale class, while lines and areas were confined to represent features in classes 4 and 5, only, among English participants. When aggregated into four classes according to scale class and geometry type—"scale 1, 2 or 3/point", "scale 1, 2 or 3/non-point", "scale 4 or 5/point" and "scale 4 or 5/non-point"—the difference in proportions between languages was significant (p<0.001, Fisher's exact test of independence).

3.1.4 Locational error

Of the 242 point features mapped, 234 were candidates for validation—i.e., included a sufficient name or description attribute—and 196 were successfully validated. Locational error for individual features ranged from no measurable error to 4,830 m for those mapped by Indonesian participants and from no measurable error to 7,840 m for those mapped by English-language participants. The median measurable feature error in both groups was 0 m (Figure 11). Though the proportion of point features with measurable error was higher for Indonesian participants (26%) than English-language participants (14%), the proportion of features with no measurable error was roughly the same between groups—58% for Indonesian and 57% for

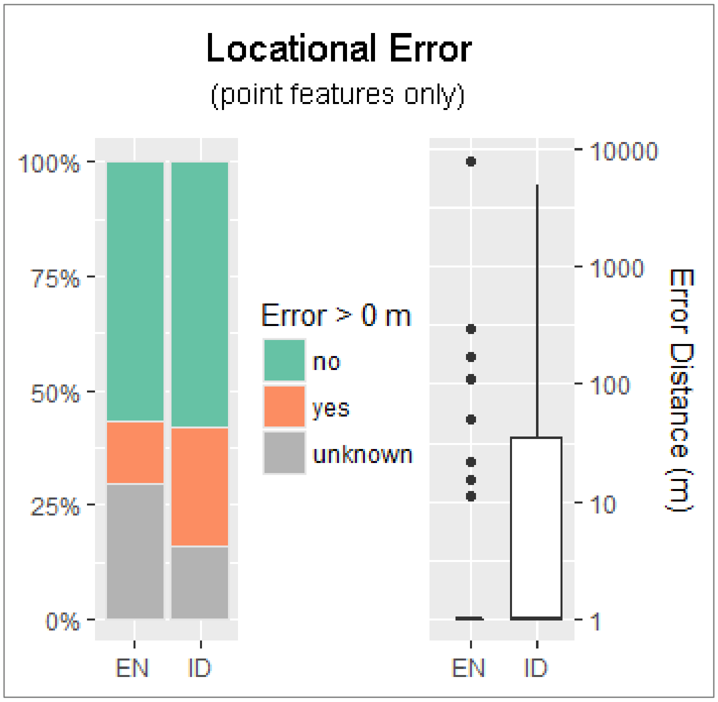


Figure 11. Proportion of features mapped by English (EN) and Indonesian (ID) language participants with and without measurable locational error (n=242) (left); distribution of feature error distances, plotted as [error distance + 1] on log scale (n=196) (right)

English-language participants. Point feature that could not be validated made up a larger proportion of English-language participants' total (29%) than Indonesians' (16%). When excluding the non-validated features, no significant difference was found in the proportion of features with and without error between language groups (p=0.18, Fisher's exact test of independence).

Considering Indonesian participants only, there appear to be slight differences in the average error per feature mapped per participant according to frequency of computer use and Google Maps use (Figure 12). Error scores, in general, were lower for those who had never used the technology than those in any other class. However, no significant difference in the mean rank of error scores was found among classes defined either by frequency of computer

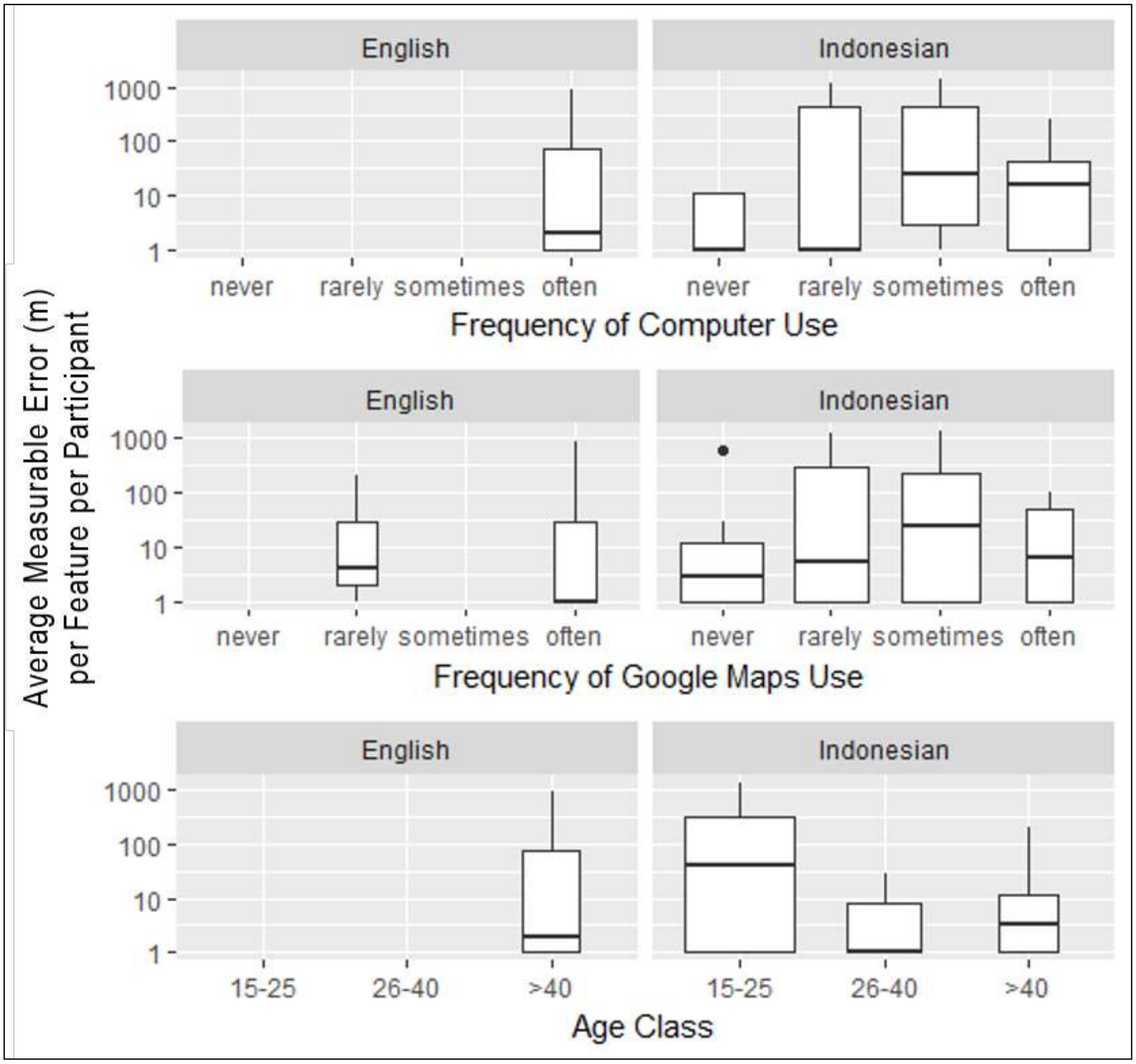


Figure 12. Distribution of average measurable error per feature mapped per participant by frequency of computer use, frequency of Google Maps use and age class (n=6 for English, n=36 for Indonesian language participants); plotted as [error distance + 1] on log scale

use (p=0.34, Kruskal-Wallis test) or Google Maps use (p=0.64). Regarding age class, the youngest class, 15–25, had the highest median error score, though the difference in median error score rank among age classes was not quite significant at the 95% confidence level (p=0.066).

3.2 Discussion

Motivations for participatory mapping have changed little since the 1980s, when it was first used in Indonesia. The methods and technologies available to facilitate it, however, have evolved substantially, bringing both opportunities and challenges. Indonesia's government has embraced online participatory mapping, at least outwardly, but the software and hardware that mediate it have rarely been tested in rural settings, which comprise most of the country's land area. This study attempted to do just that, anticipating that laptop and desktop computers will one day become more common in these places, just as smartphones have become in the last ten years.

3.2.1 Factors affecting participants' cartography

Level of computer experience had little detectable effect on participants' responses. The only significant correlation found was in the total number of features mapped—the more frequent a participant's computer use, the more features the participant tended to map. Experienced computer users may have found the mechanics of the mapping task easier and were therefore able to map more places in a given amount of time. Less experienced users may have spent more time and mental energy performing operations that were already second-nature to more experienced users, thereby producing fewer mapped features in the same amount of time. Less experienced users may have also become frustrated and quit the exercise sooner. The amount of time each participant spent on each survey was not available in this study, but it could illuminate these possibilities.

This finding challenges the suggestion that number of places mapped is a reasonable proxy for mapping effort, and, by extension, data quality (Brown 2017), as no other indicators suggested that less experienced computer users expended less effort. Among participants who have all achieved a certain level of computer competency—as is the case in many Western countries—this suggestion may be valid. However, in a case where experience levels vary dramatically, the tendency for less experienced computer users to map fewer places must be considered. In a situation where mapped features provide the basis on which to judge public opinion, an approach to avoiding bias in favor of prolific mappers might be to weight individual features inverse proportionally to the total number of features mapped by the participant.

The amount of locational error, another potential indicator of data quality, was not found to correlate with level of computer experience. In fact, participants who had never used a computer before had the lowest median error score of any experience group. Perhaps members of this group were more conservative in their mapping behavior, only marking places whose locations they were reasonably certain they could identify on the map.

Time to complete a mapping exercise has also been suggested as a proxy for mapping effort (Brown 2017). Observation of Indonesian participants who took the surveys in person suggested that most participants spent longer than expected to complete the surveys. The surveys were designed to require around 10–15 minutes each, for a total of half an hour, maximum. Upon observation, informal estimates of one to two hours were more realistic. In one case, a participant had nearly completed one survey when a mistaken mouse-click deleted all his responses. The participant was reassured that he did not need to repeat the survey, as he had already spent considerable time on the activity, but the participant decided to repeat it, anyway. This participant's response to technical challenges of the survey tool contrasted with that of another would-be participant—in the English-language group—who reported starting the survey and quitting out of frustration with the tool's limitations. Anecdotally, these cases suggest a difference between Indonesian and English-language participants in the amount of time each was willing to spend on the activity. Given that there was not a significant difference in the total number of features mapped per participant between Indonesian and English-language participants, was there a difference in the amount of time invested by participants in each group? Anecdotal observation would suggest yes.

The difference in scale of features mapped—that Indonesian-language participants tended to map more resort-sized features, whereas English-language participants tended to map more village-sized features—may be related to the level of participants' familiarity with West Bali. Indonesian participants, most of whom have spent their whole life in West Bali, may have associated the questions about garbage and tourism with more specific places, friends or relatives, while English-language participants may have generalized based on their more limited experience. Brown and Reed (2009) suggest that gender, age, level of education, and knowledge of the landscape may influence the types of spatial features mapped. Scale is only one very general place characteristic of many that could be examined; places could be classified according to the activities the place enables; whether it is public or private; whether it includes built infrastructure, natural environments or both; and many other dimensions.

An activity-based place classification might help explain differences in the places mapped by Indonesian and English-language participants in the garbage survey. While no significant difference was found between the number of places with and without garbage mapped by the two groups, a larger survey might amplify the apparent tendency for English-language participants to map more places with garbage than Indonesian participants. The classification of material as *garbage* is not universal, and differences in culture and education may have influenced each group's perception of what constitutes "a lot of non-biodegradable garbage in the environment". In societies where religion is an integral part of daily life, spiritual systems—not Western science—define what materials and forces cause pollution in the world (Allison 2014). In Balinese Hinduism, a dichotomy between purity—embodied by mountains and natural lakes in volcanic craters—and impurity—related to biological processes of birth, menstruation, excretion, sickness, sexual activity and death—pervades every aspect of daily life (MacRae 2012). Bali's geography and hydrology are an integral part of this spiritual system, its high mountain lakes and springs representing a purifying force that flows downward through villages and rice paddies, collecting impurities that are eventually deposited in the sea. The sea is regarded as a force that absorbs and transforms impurities, sending clean water back up to the mountains as rain to begin the cycle again.

In addition to a concept of pollution that is defined by spiritual beliefs, garbage may be characterized as *matter out of place* (Douglas 1966), where eliminating it is an effort to organize the environment. This model would explain why a palm leaf lying in the middle of an otherwise clean-swept yard appears to offend some Balinese more than a pile of discarded diapers in a ditch. Even when equally visible, one seems much more irksome.

A third model characterizes pollution as something that poses risk, for example, to human or environmental health (Drackner 2005), or by extension, to economic potential. Western tourists frequently complain about litter in Bali, a fact not lost on the Balinese. The perception of risk to economic potential may cause Balinese to consider plastic wrappers in places associated with tourism a more serious threat than plastic wrappers found elsewhere, regardless of the amount. An investigation into the characteristics of the places mapped in the garbage survey—including the composition and amount of material considered garbage and the type of place, including public or private, touristic or not—might further explain patterns in the features mapped by Indonesian and English-language participants in the garbage survey.

The pattern of geometry types selected by Indonesian and English-language participants to represent places may reflect a difference in how each group conceptualizes places. English-language participants, who used only points to represent places with smaller footprints, may be more accustomed to this symbol in maps presented through Western media and applications. Indonesian participants, who used points, lines and areas to represent places across all scales, may not hold the same convention. Another possibility is that Indonesian participants interpreted the instructions differently, believing that they were supposed to draw one or more of each type—points, lines and areas. Within language groups the same feature was frequently represented with different geometry types by different participants, suggesting that an association between a place and the type of geometric representation it warranted wasn't clear. One local conservation area, for example, was represented variously by points, lines and areas by different Indonesian participants, and West Bali National Park was represented by both points and areas by participants in both language groups.

The survey design decision regarding whether to allow lines and areas, in addition to points, may affect both the interpretation of results and the number of participants required to determine spatially significant places in a participatory mapping survey. Brown and Pullar

(2012) suggest that spatially significant places can be determined with fewer participants who use areas, rather than points, in mapping. However, they caution that the risk of including locations that are insignificant is higher than if only points—mapped by a greater number of participants—are used. Using point densities, rather than area densities, as an indication of significant places is a more conservative approach, though they suggest that 15–28 times more participants are required in a point-mapping survey than an area-mapping survey to determine spatially significant locations. Greater spatial ambiguity is inherent in point features than area features, which increases complexity in the spatial interpretation of point features (Brown 2004).

In the present surveys, this ambiguity was reduced by asking participants to describe each feature they mapped. In many cases, participants mapped features with names, like Mimpi Resort or Menjangan Island. When validating responses, more weight was given to the name of the feature than the location of the marker, assuming that participants were more likely to misplace a marker than misremember or mistype a name. In most cases, the results suggested this was a valid assumption. For example, in cases where a point labeled as a building was placed in a field, it is reasonable to assume that the participant intended to map a building and put the point in the wrong place, rather than assuming the reverse—that the participant intended to map a field and mislabeled it as a building. However, some cases were more ambiguous. For example, when one participant placed a marker on a school but labeled the marker with the name of a different school, the mapper's intentions were less clear: did he mean to map the school indicated by the name or the marker's location? By assuming the named or described place reflected the mapper's intention over the feature's location, error may have been misattributed.

Contradictions like this could be reduced by giving participants the option to map the location only when necessary. When a name or description is sufficient to answer to a place-based question, the act of mapping becomes less useful and may introduce uncertainty. It also imposes a constraint that may detract from the answer. For example, one participant offered the response "uninhabited mountain areas" as a place with garbage—a sufficiently descriptive answer that needed no point on the map. The author of this response seemed undaunted by the requirement that a point be placed *somewhere*, though the exact location mattered less than the description. Another would-be participant reacted quite differently to this constraint, however, refusing to continue the survey out of frustration that a point on the map—even if associated with a text description—was insufficient to convey his answer.

The utility of mapping is most apparent when the answer to a question has no commonly recognized boundary, place name or description, and instead, it must be illustrated on a map. This is common in the case of marine spatial planning, where participants are questioned about locations in the ocean, where boundaries are less readily apparent (National Marine Protected Areas Center 2005; Whale and D'Iorio 2010), or in landscape values mapping, where wilderness locations may be difficult to describe and easier to map (Alessa, Kliskey, and Brown 2008; Brown and Reed 2009). Beyond communicating spatial information, however, there are other benefits to map-based surveying, such as improving participants' geographic knowledge of local resources (Meta and Ironside 2005). In addition, the act of exploring a map may provoke responses to a question or help participants connect concepts that they previously held as unrelated.

Characteristics of the basemap and thematic layers presented through SeaSketch may have influenced the amount of error associated with some features. Observation of Indonesian participants suggests that they relied most heavily on the imagery basemap, rather than the OpenStreetMap or plain gray basemaps. The imagery basemap was several years out of date, and several participants reported confusion when they could not find a structure that had been built more recently than the date of the imagery. When features were not visible in the imagery, participants sometimes attempted to map them in their approximate location, which sometimes resulted in error. Features representing villages or other places annotated on the map tended to cluster around the map's annotation, even when the annotation was offset from the feature. This has been documented in other mapping studies, where researchers have questioned whether absolute location or a map label guided participants' choices of marker placement (Boschmann and Cubbon 2014).

3.2.2 Participation challenges

Perhaps the most significant factors limiting this study's generalizability were the composition and number of people who participated. The pool of Indonesian participants suffered from a gender imbalance—only about 35% were female, and they were all part of the youngest age class, 15–25 years old. Difficulties in encouraging women to participate in similar survey efforts have been documented elsewhere; Meta and Ironside (2005) cite reasons including preoccupation with household tasks like caring for children or cooking, and the perception that mapping and decision-making are "men's work". The small number of English-language participants prevented an analysis of results based on the same characteristics—age class, level of computer experience and level of Google Maps experience—that were analyzed among Indonesian participants.

The key informant and snowball sampling methods used in this study failed to produce a representative sample by gender, age, occupation or residential location within West Bali. The English-language participants sampled, too, did not encompass the range of tourists and expats who live in or visit West Bali. These deficiencies would need to be addressed to interpret the results of the surveys as representative of West Bali's local and visitor populations. However, as this was a case study, the conclusions suggested by the inferential and descriptive statistics may be considered preliminary hypotheses regarding the effects of culture, level of computer experience and the other demographic variables tested on Web-based participatory mapping. These hypotheses would require further testing with a more rigorous random sampling strategy, performed in a variety of cultural contexts to validate.

An assumption of the statistical analyses in this study, and of most survey-based research, is that participants respond independently of one another. In practice, this assumption was not met, as many of the Indonesian participants were observed conferring with each other during the surveys. While an inconvenience for researchers, this behavior appears to be a cultural feature in Indonesia and perhaps other non-Western countries—one that needs to be considered when interpreting results rather than prohibited in a narrow-minded attempt to achieve statistically unbiased results on the part of outside researchers. Collaboration among participants appeared to serve a useful purpose; often, particularly when beginning the surveys, participants would help each other locate places on the map or share with others when they figured out how to perform some critical function with the survey tool. In cases where independence is truly necessary, perhaps individual household surveys are more appropriate than the Internet café-style workshop environment through which most Indonesians participated (Figure 13).

Translating the SeaSketch interface into the Indonesian language presented additional challenges. A bilingual Indonesian expert in GIS performed most of the translation, so lack of appropriate cartographic expertise was not an issue, but translating words that have no equivalent in Indonesian was challenging. Many English words surrounding technology have been adopted by Indonesian speakers, like *download*, *email* and *layer*, but they may be unfamiliar to those who rarely use computers. In addition, the formal, polite Indonesian translation necessary for a professional product may be difficult to understand for rural people with little formal education, as everyday speech relies on a different vocabulary of slang and

Figure 13. Participants take surveys in the Internet café-style workshop environment, temporarily established in the Pejarakan Village administrative office, with guidance from student assistants

informal words. While *bahasa Indonesia* (Indonesian language) is the *lingua franca* of the country, most Indonesians grow up speaking local languages—in Bali, one of several forms of Balinese. School is taught in Indonesian, but among the elder generation there are still people who only speak their local language and would not be able to complete a survey offered in Indonesian.

The features mapped by one participant suggested that this individual either did not understand how to read a map or use the mapping tools, or deliberately ignored the survey's instructions. Four out of 300 features were mapped outside of the surveys' area of interest, and three of those four were mapped by a single individual. Two of those features were mapped in other parts of Bali, 40 km and 80 km away, and the third was mapped on a different island, entirely—over 1,000 km away. Of the five validated point features mapped inside the area of interest by this individual, three were mapped with over 600 m of error. The collection of features mapped by this individual call into question the validity of his responses, but perhaps it is surprising that there were not more participants with similarly suspect collections of responses. In the context of volunteered geographic information, carto-vandalism, or the intentional defacing of collaboratively constructed maps, may be motivated by frustration with mapping tools, boredom, political ideology, self-expression or profit (Ballatore 2014). While characterizing responses to a participatory mapping survey as carto-vandalism is unjustified, individuals whose responses deviate significantly from what was instructed may be similarly motivated. It is conceivable that an individual might try to influence the results of a survey by submitting multiple identical responses—such as mapping the same place to promote tourism over and over—but this behavior was not observed here.

The mapping classes offered prior to the surveys, while not formally evaluated for their effectiveness in teaching cartographic skills, appeared to foster local interest in the project and certainly produced valuable survey assistants. The kite aerial photography mapping activity was met with universal enthusiasm among Balinese students, and the subsequent efforts to create aerial photomosaics appeared to help students cognitively connect their everyday, ground-based perspective with the aerial perspective of a typical map, a prerequisite for successful participatory mapping. While time-consuming, the mapping classes may have generated a more lasting local impression than the surveys or their results will produce, an interesting outcome to investigate in the future.

Despite challenges of unbalanced participation, achieving an adequate translation, time-consuming preparation and delivering the surveys in a culturally appropriate manner, this study demonstrated that people with varying levels of experience with computers and digital maps could successfully complete, and perhaps even enjoy, a computer-based mapping survey. Perhaps the most surprising outcome was that none of the participants, including those who lacked prior experience, accepted the offer of assistance in operating the computer—they all chose to input their answers, themselves. One participant's delight upon completing the surveys—his first time using a computer—was evident when he stood up from the table, raised his arms over his head and exclaimed "I did it! I did it!" Another participant approached the researcher after completing the surveys and offered to supply missing street names to improve the basemap, demonstrating engagement that extended beyond simply completing the survey.

The people who chose to participate in the survey, of course, were a self-selecting group: all potential participants were aware of the surveys' digital nature, so if they did not want to use a computer, they simply declined to participate. This is a significant limitation in the use of digital technology—it may intimidate some potential participants, reinforcing social inequalities (Fox et al. 2005; Elwood 2006). However, as with all efforts to inspire change, often a central goal of participatory mapping, an informed approach that tailors the tools and methods to the local context while mitigating potential difficulties has a chance at success. The results of this case study suggest that inexperienced computer users are capable of completing a computer-based mapping survey with no more likelihood of mapping features with greater locational error than more experienced users, though they may map fewer features overall. Collaboration among participants is likely when surveys are delivered in a workshop-type setting, which violates the assumption of independence that inferential statistical tests require. However, perhaps collaboration enables some individuals to participate who would otherwise lack the necessary self-confidence.

This case study could have been improved by increasing the number of female Indonesian participants of different ages to achieve a sample that better reflected the gender balance of West Bali's population. A greater number of Western participants would have allowed stronger cross-cultural comparisons to be made, and specifically targeting Western tourists would have introduced a viewpoint that was not well represented among the expats and NGO volunteers who comprised most of the English-language participants here. An interesting extension to the study might offer the same survey questions but require participants to answer using paper maps to compare how the mapping medium influences participants' responses.

3.3 Lessons learned

Indonesia has a history of grassroots participatory mapping initiatives that have coalesced into organizations like the Participatory Mapping Network and the Ancestral Domain Registration Agency. These organizations demonstrate their determination to influence Indonesian policy through direct interaction with central government ministries, and it appears the government has taken note, if its geospatial agency's national participatory mapping portal is any indication. Lack of computer hardware might seem a formidable barrier to widespread participation in geographic information-gathering initiatives. However, as Facebook's fourth-largest user base by country, with an average of 1.26 active mobile phone subscriptions per citizen (Loras 2016), Indonesia has demonstrated a propensity for adopting technology, provided it is cheap enough. Rather than focus on hardware, which tends to spread as the price falls, proponents of Internet-based participatory mapping must adapt existing approaches to account for differences in culture and varying levels of computer experience—issues that tend to be overlooked in Western contexts but cannot be ignored in developing countries.

In Indonesia and other places where laptop and desktop computers are uncommon, Web-based tools for participatory mapping may inspire a sense of accomplishment among participants upon successfully creating a digital map; motivate participants to improve local geographic information resources; and prompt new insights by offering participants a chance to explore interactive maps both collaboratively and individually. Challenges of this approach include time-consuming recruitment and preparation of local assistants and the obligation on the part of the facilitator to spend sufficient time embedded in the community to understand how participatory mapping may be locally useful. Encouraging participation that is representative of rural populations is an additional challenge. Successful Web-based participatory mapping efforts in places without abundant computer hardware must provide these resources, along with a reliable Internet connection and basic training on their use. The mapping tools must communicate using language that is accessible to the local population, and local experts who can serve as ambassadors of the technology and method to the community must be trained. Facilitators must realize that participants' responses may not be independent, but that benefits of collaborative participation may outweigh the disadvantages in statistical interpretation. Through patience and persistence, the participants in this study showed that lack of computer experience is an insufficient reason for avoiding Internet-based participatory mapping surveys in rural Bali, a finding worth exploring in other non-Western contexts.

This and the previous chapter described a Web-based participatory mapping survey conducted in a region of Bali, Indonesia, where computer use ranges from frequent to none. It investigated the mechanics of participants' cartographic choices and compared the results across several demographic variables including age class, frequency of computer use and frequency of Google Maps use. The next chapter explores participants' responses in depth to understand their perspectives on the issues of garbage and tourism development. Density mapping is combined with text mining techniques to consider both the spatial pattern of mapped features and natural language descriptions of those features provided by participants. The advantages and disadvantages of the visualization and analysis techniques are discussed, and common themes inferred from the participatory mapping data are summarized as a preliminary step towards designing waste management and tourism development plans for West Bali.

Chapter 4

Integrating Spatial Analysis with Text Mining to Identify Common Themes in Annotated Participatory Maps

Maps are rarely the only product of participatory mapping. Demographic data describing participants, such as the examples of age, culture and level of computer experience discussed previously, can help contextualize the social setting in which the data were generated. To reduce participants' effort, the structure of a mapping exercise sometimes limits participants to marking points on a map, only, in response to a question. This leaves ambiguity in understanding *why* features were mapped in their locations (Brown 2004). Survey questions that invite participants to rationalize their maps can help resolve ambiguity, and platforms such as MapChat (Hall et al. 2010), Maptionnaire (http://maptionnaire.com/; Kahila and Kyttä 2009a), Geo-questionnaire (Jankowski et al. 2016b) and SeaSketch (http://www.seasketch.org/) have been developed that enable comments, descriptions and entire conversations to be associated with mapped features. However, the task of interpreting and summarizing these heterogeneous data, particularly when datasets are large, presents a challenge for planners. Sophisticated methods such as point density analysis and text mining are used to analyze each type of data separately, but they have not often been combined to interpret participatory mapping responses.

Using the data on garbage and tourism development described previously, kernel density mapping—a popular method for analyzing maps generated by participants—was paired with two text analysis techniques—word clouds and topic modeling—to visualize participants' responses. The goal of this chapter is to evaluate combinations of these techniques for their ability to generalize common themes from freeform text and relate those themes to the spatial pattern of features mapped by participants. In the use case posed here—planning for waste management and tourism development—identifying common themes in the discourse of stakeholders may help planners understand which issues are relevant, their geographic footprint and to whom they are important. These techniques are not intended as a substitute for reading and scrutinizing participants' responses in full; rather, they are meant to highlight trends that might otherwise be difficult for a planner to retain by inspecting individual responses, alone. In addition, they are meant to facilitate communication of these trends in presentations and publications, where revealing participants' full text and mapped responses may be impractical and compromise confidentiality.

The following section presents an overview of techniques commonly used to analyze participatory mapping data and introduces computational methods for analyzing and summarizing text used in the digital humanities, document search and information retrieval communities. In the Methods section the process used here for generating raster surfaces by kernel density estimation are described, including methods for transforming line and area features into points to be compatible with this technique. The process for constructing word clouds, tailored to visualize several metric properties of the text data, are also described, along with the process of generating, evaluating and selecting a topic model to represent the text data. The subsequent feature density maps, word cloud visualizations and topic model term lists are presented in the Results and further explored in the Discussion from a planner's perspective, considering how to improve waste management and develop tourism in a way that respects local opinions in West Bali. Advantages and disadvantages of these visualization techniques are reviewed and extensions to this research proposed.

4.1 Background

Following direct visual inspection, features mapped in a participatory exercise may be analyzed using measures of spatial autocorrelation such as join counts or inferential statistics like the Global Moran's I or locally-focused Getis-Ord Gi* that indicate the degree of clustering or dispersion, or landscape metrics that quantify categorical map patterns (McGarigal and Marks 1994; Brown 2004; de Smith, Goodchild, and Longley 2015). An especially popular form of exploratory analysis is to visualize feature maps as a density surface (Brown 2004; Alessa, Kliskey, and Brown 2008; Zhu et al. 2010; Brown and Donovan 2014; Jarvis et al. 2015). Density surfaces may be generated through geostatistical interpolation or point density estimation methods (de Smith, Goodchild, and Longley 2015), though Alessa et al. (2008) found interpolation by inverse distance weighting to produce a less reliable representation of landscape values as mapped by participants than point density estimation. They note that interpolation is inappropriate when the phenomenon being mapped is not known to follow a smooth spatial gradient, which is often the case regarding places associated with values and opinions reported by participants. In these cases, kernel density estimation based on a quadratic kernel function (Silverman 1986; de Smith, Goodchild, and Longley 2015) is more often used, though the resulting density surfaces depend on how the grid size and search radius are defined (Alessa, Kliskey, and Brown 2008; Brown and Donovan 2014). Hot-spot analysis, relying either on a significance test like the Getis-Ord Gi* or a pre-defined density threshold, seeks to identify locations where the phenomenon being mapped is particularly dense (Alessa, Kliskey, and Brown 2008; de Smith, Goodchild, and Longley 2015). In this study, kernel density estimation was used to generate density surfaces, and visual inspection, only, was used to investigate locations of intense mapping activity, referred to as hot spots. Inferential statistics were not employed, and a density threshold was not set to define hot spots, as the relatively small number of features mapped made a detailed inspection of the entire mapped region—not just hot spots—desirable.

Freeform text in participatory mapping, as in many text-based surveys and interviews, is often manually coded to summarize the subject and content of the response (Scholz et al. 2004; Ramirez-Gomez, Brown, and Tjon Sie Fat 2013). Manual coding is a standard method of *content analysis*, a family of data reduction techniques for summarizing text into categories based on explicit coding rules (Stemler 2001). Although often considered a form of qualitative analysis, particularly when paired with methods such as participant observation, content analysis methods were originally intended to be systematic and replicable (Holsti 1969; Altheide and Schneider 2013). This assumption seems to have been relaxed somewhat as the label *content analysis* is now applied to any method that attempts to derive new meaning from existing material (Leetaru 2011). One widely popularized set of content analysis techniques—the *content cloud* and *tag cloud*, collectively referred to here as *word clouds*—summarizes a body of raw or coded text by illustrating the most common terms, sized and sometimes colored according to their frequency (Viégas and Wattenberg 2008; Cidell 2010). Word clouds created from georeferenced text have been superimposed on maps to visualize, for example, geographic differences in public meeting discussions and media content (Cidell 2010), terms used in georeferenced tweets (Andrienko et al. 2013) and queries for businesses and services made by mobile phone users (Slingsby et al. 2007). Word clouds can be extended by structuring the placement of words using spatial metaphors like proximity and direction that indicate characteristics of the text documents (Skupin 2000).

In this study, word clouds were generated from text associated with features mapped by participants in the garbage and tourism surveys. For every feature mapped in the garbage survey, participants were asked to provide (a) a description of the location for places without garbage; or (b) a description of the location and problem for places with garbage. In the tourism survey, participants were asked to provide (a) a description of the location for places where tourism should be promoted; or (b) a reason for restricting or prohibiting tourism for places where tourism should be discouraged. The color, font size and spatial placement of terms in the word cloud were encoded by metric properties of the text document collection as described in the Methods section.

In their basic form, word clouds provide an intuitive dimension reduction technique for text, capable of representing document collections of hundreds or thousands of words using just the top few dozens most common. While word clouds appear widely in contemporary media, are straightforward to compute and have been found to communicate descriptive information effectively, they generally fail to convey relationships between concepts (Kuo et al. 2007; Viégas and Wattenberg 2008). They also emphasize long words over short ones and words that appear frequently, though a word's frequency is not always a good indicator of its importance within a text collection (Viégas and Wattenberg 2008; Jung 2015). Word clouds fail to compensate for differences in document length, or if a word appears many times in a single document. They are also unable to resolve a single word's multiple meanings, termed *polysemy*, or account for the fact that different words can express the same concept, or *synonymy* (Crain et al. 2012).

Other text analysis techniques attempt to address these deficiencies by preserving the semantic context of terms while still reducing the dimensionality of the text. Manual coding, the mainstay of traditional content analysis, achieves this through one or more human's rigorous application of categorical labels to text data through *descriptive coding*, labels that are then interpreted through *analytical coding* (Jung 2015). Increasingly sophisticated automated methods have been developed in the field of text mining, which uses computational techniques to analyze text with the primary goal of discovering patterns (Aggarwal and Zhai 2012). Computational content analysis borrows techniques from text mining, and its proponents cite advantages of consistency, reproducibility and scalability over traditional content analysis conducted by human analysts, who are unavoidably subjective in their coding process (Leetaru 2011).

For a planner seeking to identify common themes across tens, hundreds or thousands of stakeholder comments, a text analysis method that is automated, reduces the dimensionality of the dataset, clusters comments about similar concepts and summarizes the content of main concepts is desirable. While many different approaches exist, one common workflow is as follows (Crain et al. 2012): A *corpus* for analysis is formed from a collection of *documents*. All documents are pre-processed by *tokenizing*, or separating sentences into individual terms, and reducing related words into a common form, either through *lemmatization* or *stemming*. Lemmatization groups together different forms of a word into their base form, or *lemma*, such as grouping *vacationing* and *vacations* into *vacation*; and *stemming* is a heuristic process that truncates words to their stem, which results in *vacat* for the previous example. A stem may or may not be a real word, while a lemma can be found in a dictionary. *Stop words*, or extremely common words such as *a*, *an*, *and*, *or*, *the*, *is* and so on, are removed from all documents. Each document is modeled as a *bag-of-words* (BOW), a vector that accounts for the number of times each term appears but does not preserve term order, grammar or other contextual information. BOWs are often weighted by *Term Frequency*Inverse Document Frequency* (TF*IDF),

$$tfidf(w) = tf(w) * log\frac{N}{df(w)},$$

where $tf(w)$ is the term frequency, or number of times the word occurs in a document; $df(w)$ is the document frequency, or number of documents that contain the word; and N is the number of documents in the corpus. This weighting scheme lowers the importance of words that occur in many documents and increases the importance of words that occur in just a few documents. Using the weighted BOW model of each document, a corpus can be modeled as a *term-document matrix*, where each row represents a term and each column represents a document, and the values record the number of times each term appears in each document.

The next tasks—dimension reduction of the term-document matrix and clustering of documents into related groups—aim to collapse together terms with similar semantics while separating instances of the same term that have multiple meanings (Crain et al. 2012). This results in a lower-dimensional model of the corpus represented by concepts, rather than raw terms. In planning, when the concepts we are trying to discover are not known a priori, we have no training data with which to train a classifier or regression function, as is required for supervised dimension reduction methods. Therefore, unsupervised methods are more appropriate. A myriad of unsupervised dimension reduction and clustering techniques exist that can be applied to text, such as Principal Component Analysis (Jolliffe 2002), Latent Semantic Indexing (Deerwester et al. 1990), Self-Organizing Maps (Agarwal and Skupin 2008) and topic modeling (Crain et al. 2012). *Topic modeling* is a probabilistic approach that conceptualizes each document in a corpus as a distribution over latent *topics*, and each *topic* as a distribution over the vocabulary of the corpus. *Topics* are patterns of co-occurring words that repeat across documents: words that tend to appear together in different documents are assumed to belong to the same topic (Bansal 2016). As such, a topic may contain words that are semantically related, such as *farm*, *agriculture*, *livestock* and *wheat*, or the words may relate to a particular discourse employed by one or a group of authors (Underwood 2012). Latent Dirichlet Allocation (LDA) (Blei, Ng, and Jordan 2003) has proven to be one of the most popular topic modeling methods, as it specifies a process for generating the observed documents and requires fewer parameters than other methods, such as Probabilistic Latent Semantic Indexing (Hofmann 1999).

LDA is attractive for analyzing participants' feature descriptions in the current research because it produces a list of terms—drawn from the documents, themselves—that constitute each topic. These term lists can be interpreted collectively as a concept that was significant to a subset of participants. LDA also assigns probabilities to each document—feature descriptions, in this case—of belonging to each topic. These probabilities can be used to weight features in calculating a density surface to visualize geographic locations that are highly associated with each topic. The resulting topic density surfaces, coupled with term lists for each topic, relate concepts distilled from the features' descriptions to their geographic locations.

The main parameter that must be specified in LDA is the number of topics, k. Varying opinions exist on how best to select a value for k, but topic models can be evaluated in a number of different ways. *Interpretability* of a model's topic term lists is measured through user studies, and various metrics of model fit such as *perplexity* have been proposed, where a model is trained on a portion of the data and then evaluated using another portion (Crain et al. 2012). User studies have found, however, that perplexity scores do not correlate well with human interpretability (Chang et al. 2009). Another metric, C_V *coherence*, proposed by Douven and Meijs (2007), was found to match user-based judgements of interpretability better than any of the other metrics tested. They describe the *coherence* of a word set as a probabilistic measure that approximates the notion of how well a set of words "hangs together". To measure the overall coherence of a topic model, each topic is evaluated individually as a set of words for testing. The coherence of a topic is measured by (a) subdividing the topic's word set into pairs of words; (b) computing word probabilities based on a reference corpus, typically the original documents used to create the topic model; (c) calculating the agreement between the test set pairs and reference set pairs; and (d) aggregating those values into a single coherence value for the topic model. Since a main goal for topic modeling in the present study was to produce word sets that could be interpreted as concepts by a human planner, C_V coherence was chosen as the primary metric for evaluating alternative topic models.

4.2 Methods

Two sets of techniques are described: (1) text summarization and (2) feature density mapping, each with two components. Text summarization includes word cloud visualizations based on word frequency; and topic modeling, which uses machine learning to reduce the text into a set of hypothetical source topics. Feature density mapping includes calculation of point density surfaces based on feature presence or absence, alone; and surfaces weighted according to the topic probabilities associated with each feature in the topic modeling exercise.

4.2.1 Text summarization

Attribute text associated with each mapped feature is considered a *document*. Every document belongs to a *corpus* defined by survey topic and language, for a total of four corpora: (1) garbage survey, Indonesian language; (2) garbage survey, English language; (3) tourism survey, Indonesian language; and (4) tourism survey, English language. Indonesian and English corpora were processed separately, as translation was suspected to introduce artificial bias that obscured language patterns the technique is meant to uncover. Tasks were scripted in Python version 3.6 (Python Software Foundation 2017) unless otherwise noted.

Text pre-processing

Text from the name and description attributes for each mapped feature were combined into a single field, and spelling was manually standardized. Features without a unique name or description attribute were excluded. English text was further cleaned using the Natural Language Toolkit (NLTK), a suite of program modules, data sets and tutorials for text analysis, written in Python (Bird 2006). English text was tokenized and classified by part of speech (a prerequisite for lemmatization), stripped of punctuation and numbers, made lower-case and lemmatized using NLTK's WordNet Lemmatizer. This pipeline, using part-of-speech tagging and the WordNet Lemmatizer, was selected over other options for reducing words to their base form such as stemming with the Porter (Porter 1980), Snowball (Porter 2001) or Lancaster (Paice 1990) stemmers, as it produced fewer unexpected results. Additionally, lemmatized words—as actual words, rather than word bases, as are produced through stemming—are better suited for visualization in word clouds. Indonesian text was cleaned and stemmed using PySastrawi (Robbani 2017), a Python library that is one of the few tools available for processing Indonesian language text. The resulting text was manually checked, and incorrectly stemmed words were fixed.

Word cloud construction

Each corpus was subdivided according to response type; for example, the garbage survey, Indonesian language corpus was subdivided into features describing places (a) with and (b) without garbage. Word clouds were constructed for each corpus where each word's (a) font size corresponds to its overall frequency in the corpus, and its (b) color and right-to-left placement correspond to its proportional distribution between subgroups. Word clouds were constructed according to the following workflow, explained in detail below: (1) Calculate term frequencies, remove stop words and select top *n* terms in each subgroup for visualization; (2) Import these results into Gephi (Bastian, Heymann, and Jacomy 2009), an open-source software program, to visualize term frequency data as a force-directed graph; (3) Import the graph visualization as a scalable vector graphic (SVG) file into Inkscape (http://inkscape.org), an open-source vector graphics software program, and manually adjust the position of terms so that none are overlapping and the resulting word cloud is visually tidy.

Step 1. The cleaned, reduced text of each subgroup was organized into a list of terms, ordered by frequency. Each term was assigned values for its (a) overall corpus frequency; (b) frequency within subgroup 1; and (c) frequency within subgroup 2, and these values were normalized by the total number of terms in each group as appropriate. A list of stop words was constructed for each corpus by selecting terms that appeared frequently in both subgroups but carried little useful information such as *the*, *and*, *in*, etc. (Appendix C).

After removing stop words, the top 15–35 most frequent terms in each subgroup were retained for visualization. The exact number varied somewhat, depending on the rank of the cutoff term—if the 30^{th} and 31^{st} terms tied for the same frequency, for example, either both were retained or both were dropped to avoid artificial tie-breaking. The subgroup term lists were combined for each corpus, and a normalized proportional distribution of each term between the two subgroups was calculated.

Two CSV files, one for nodes and one for edges, were prepared for encoding the force-directed graph in Gephi, which structured the word cloud (Figure 14). Each node was represented by a term, its overall normalized frequency, and a fraction from zero to one encoding its color, assigned as the proportional distribution in subgroup 2. Two invisible ghost nodes were added to function as the gravitational center of each subgroup. Each term node was connected to one or both ghost nodes by edges weighted according to the term's proportional distribution between subgroups. Terms that appeared exclusively in subgroup 1 were connected only to subgroup 1's ghost node by an edge with a weight of 1.0. Terms that appeared in both subgroups were connected to both subgroups' ghost nodes by edges weighted according to the term's proportional distribution between subgroups.

Step 2. In Gephi, a color spectrum defined by two endmembers was established for each survey's word cloud visualization, including pink–turquoise for the garbage survey and yellow–purple for the tourism survey. These combinations were selected as complementary (yellow–purple) or tertiary (pink–turquoise) hues along the color wheel to provide visually contrasting pure colors that when blended by adjusting their transparencies combined to produce perceptually logical, continuous spectra. Terms used exclusively to describe places

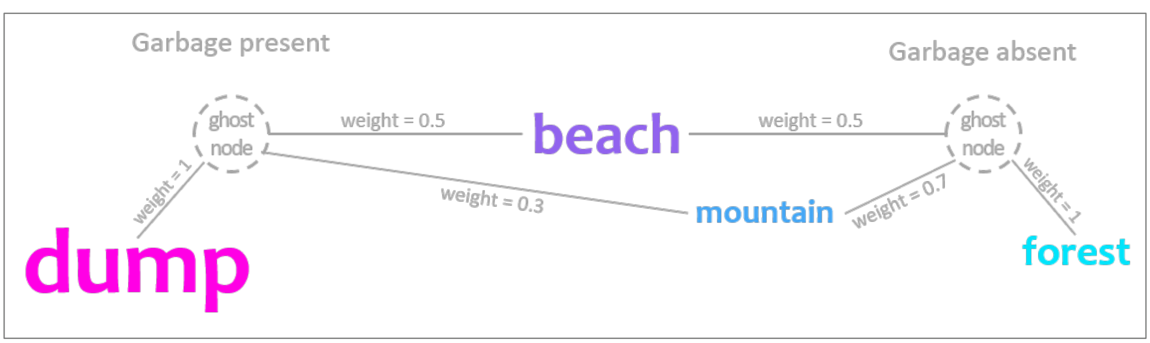


Figure 14. Conceptual layout of a word cloud using a force-directed graph

with garbage were colored pure pink, while terms exclusively associated with places lacking garbage were colored pure turquoise. Those that appeared in both subgroups were mathematically assigned a color along the spectrum according to the fractional value described previously.

The relative size of each term was controlled by the term's overall normalized frequency, with more frequent terms appearing larger, as in a standard word cloud.

The right-to-left position of each term was influenced by the weights of the edges connecting it to each subgroup's ghost nodes. Correspondences were approximate, as Gephi's ForceAtlas 2 layout algorithm (Jacomy et al. 2014) introduced some leeway to distribute the terms vertically so they were not all piled on top of each other along a line between ghost nodes. The default points and lines symbolizing nodes and edges, respectively, were hidden so that only the terms themselves were visible as a word cloud, and the visualizations were exported as SVG files.

Step 3. In Inkscape, the positions of terms were adjusted to avoid overlap, and Indonesian terms were translated into English for clarity.

Topic model development

While topic models were initially developed for all four corpora, only the two Indonesian-language corpora models were carried forward in the analysis, as the English-language corpora's small size called their validity and utility into question. The steps for developing and selecting a final set of topic models for the Indonesian-language garbage survey corpus and tourism survey corpus are outlined here and described in more detail as follows. The Python library Gensim (Řehůřek and Sojka 2010) drove key processing steps with ancillary functions provided by other libraries (Hunter 2007; Walt, Colbert, and Varoquaux 2011). (1) Beginning with the cleaned, stemmed text documents, remove stop words and represent each corpus as a TF*IDF matrix. (2) Generate a set of topic models for evaluation by transforming the TF*IDF matrix into a topic model using LDA while varying the number of topics (*k*) from 2–30. Repeat this process for a total of 290,000 models, evaluate each model using the C_V coherence metric, and retain the top 10 models (i.e., models with the highest C_V scores) for manual inspection. (3) Qualitatively evaluate the models according to criteria described below and select a final topic model to represent each corpus. Use the final topic model to assign topic probabilities to each document (i.e., mapped feature and associated attribute text).

Step 1. The cleaned, stemmed Indonesian text documents of each corpus were pruned of stop words (Appendix C), represented as BOW vectors and transformed into a matrix with TF*IDF weightings.

Step 2. A set of topic models for evaluation was generated using LDA and Monte Carlo methods. Beginning with *k*=2 topics, 1,000 models were generated, the C_V coherence of each model was calculated and the model with the highest C_V coherence was retained. This process was repeated for every value of *k* from 2–30 and the results plotted to examine the variance in the top C_V coherence scores across different *k* values. This process was repeated 10 times, each time plotting the best C_V coherence score at each *k* to examine within-*k* variance of C_V coherence, for a total of 290,000 models generated with 290 top models retained. Of those, the 10 models with the highest C_V coherence scores were selected for manual inspection.

Step 3. Each topic model was qualitatively evaluated by examining the set of top 20 terms and term probabilities generated for each topic. The following evaluation guidelines were used:

1. Each topic should be unique, i.e. two topics should not contain approximately the same set of terms.
2. There should be at least one topic made up of terms that primarily correspond to each feature type within a corpus, i.e. places with garbage and places without garbage for the garbage survey corpus; and places for promoting tourism and places for restricting tourism for the tourism survey corpus. The remaining topics may be a mix of terms from each feature type.
3. A coherent theme, pattern, or vocabulary should be discernable in each topic term set by a person who has read through all documents and is familiar with the geographic and cultural context of the surveys.

The word clouds and topic models described above were retained for inspection together with density maps of features, described next.

4.2.2 Density mapping

Kernel density estimation (KDE) (Silverman 1986), implemented in ArcGIS Desktop version 10.4.1 (Esri 2016), was used to visualize feature maps as a continuous raster surface. Rasters were generated for both surveys, first with unweighted KDE to emphasize areas of intense mapping activity. From these, a difference index raster was computed to highlight locations of disagreement, where features of both types were mapped. The difference index raster was calculated as

```
IF a>0 & b>0 THEN
    a + b - |a - b|
ELSE 0
```

where a and b are the unweighted density rasters of each feature type for each survey (garbage present/absent; or promote/restrict tourism). This index was used instead of a simple difference calculation to give more weight to areas where the number of positive and negative feature types is equal, suggesting that a majority opinion is not clear and may lead to conflict if not resolved.

In addition, weighted KDE was used to generate a set of topic rasters, one for every topic in the models developed above. For each topic, features—considered *documents* in the topic modeling exercise—were weighted according to their probability of containing that topic. The resulting weighted KDE surfaces show areas of intensity where features are both clustered and have a high probability for the topic, demonstrating close geographic and topic proximity.

In most cases, a cell size of 100 m x 100 m was chosen for the KDE. This value represents an estimate of the average precision with which features were mapped, and it approximately corresponds to the size of the smallest features mapped (hotels, shops, etc.; Table 2). A buffer width defined by a fixed search radius of 800 m around each feature was chosen in most cases as a value that would register adjacent features of intermediate size and smaller (neighborhoods, local conservation areas, etc.). Only features or parts of features located within the study's area of interest (AOI) were considered (Figure 1). Density surfaces were generated within a bounding box that extended 1,000 m beyond the AOI in every direction to avoid visible edge effects within the AOI. Each KDE surface was divided into 10 equal-interval classes, and a gradient color scheme was assigned to emphasize areas where at least two features or parts of features fell within the buffer width.

Features mapped in the garbage survey—all points—were directly processed with KDE. Some features in the tourism survey—which included points, lines and areas—were first transformed into a multipoint representation and then processed together with the point features, saved as a multipoint file type for consistency. Lines were transformed by establishing a point every 100 m along the line. Areas were transformed by creating a grid of points spaced 100 m apart in the north and south directions, clipped to the area's footprint. Every line and area feature was represented by at least one point. To avoid arbitrary density estimations introduced by the line- and area-to-multipoint transformations, a separate KDE raster was generated for each feature and normalized so that its highest value was 1. While this method does not produce uniform density values within an area or along a line—density decreases at the edges and corners of areas and ends of lines, and increases near some acute bends of lines—the approximation was sufficient for this visualization. The resulting density rasters for individual features were summed to create a final surface for visualization. For weighted KDE, the individual feature rasters were multiplied by the appropriate weight after normalization, before being summed. KDE and associated data pre- and post-processing were performed in ArcGIS Desktop version 10.4.1 (Esri 2016).

4.3 Results

4.3.1 Text summarization

A summary including the number of documents, total number of terms and number of unique terms in each of the corpora is presented in Table 4.

	Garbage Survey			Tourism Survey		
	Documents	Total Terms	Unique Terms	Documents	Total Terms	Unique Terms
Indonesian	125	2,026	400	109	1,595	406
English	33	570	211	27	590	246

Table 4. Summary of text corpora properties

A complete set of word cloud visualizations can be found in Appendix D; only selected ones are presented and discussed in the text. The garbage survey, Indonesian word cloud contains 53 terms with frequencies ranging from 5–155, and the English word cloud contains 25 terms with frequencies ranging from 2–29. The tourism survey, Indonesian word cloud contains 48 terms with frequencies ranging from 3–38, and the English word cloud contains 68 terms with frequencies ranging from 2–14.

In the topic modeling exercise, which only considered Indonesian documents, the script to produce a set of top models for manual inspection had a runtime of 20:02 hours for the garbage survey and 36:15 hours for the tourism survey. C_V coherence scores failed to converge sufficiently in either survey to suggest one value of k (number of topics) that consistently outperformed the others (Figure 15). Variance within each k-value was fairly consistent across all k-values for the garbage survey, while in the tourism survey, variance within models where k=3 was noticeably greater. This group also included the model with the best C_V score.

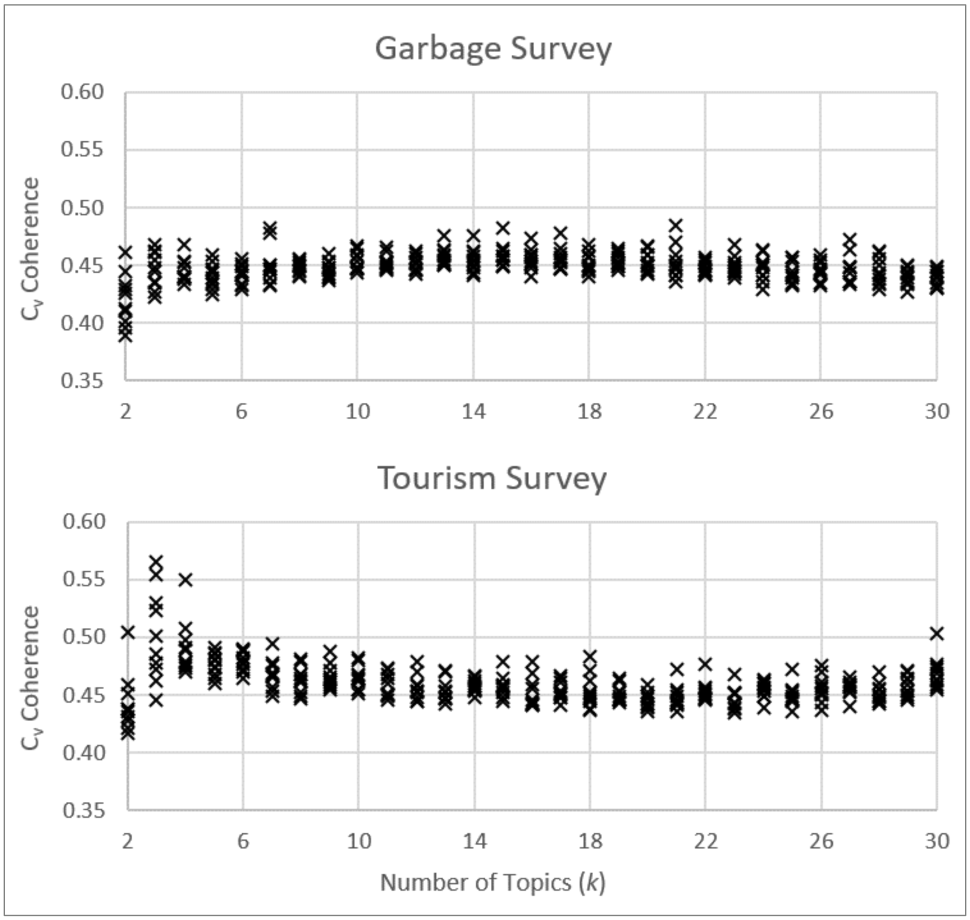


Figure 15. C_V scores of top 10 topic models at each k value, from 2–30 (n=290 models)

The overall top 10 models for the garbage survey contained from 7–27 topics and for the tourism survey from 3–30 topics (Table 5). The garbage survey final model, selected through manual inspection, contains 7 topics with a C_V score of 0.482, while the model with 4 topics and C_V score of 0.550 is the tourism survey final model. These two models are represented in Appendix E by a list of the top 20 terms and their probabilities for each topic.

Garbage Survey		Tourism Survey	
C_V Score	No. of Topics	C_V Score	No. of Topics
0.484	21	0.566	3
0.482	15	0.554	3
0.482	7	0.550	4
0.478	7	0.530	3
0.477	17	0.523	3
0.476	14	0.507	4
0.475	13	0.504	2
0.473	16	0.503	30
0.472	27	0.501	3
0.470	21	0.498	4

Table 5. C_V scores and number of topics for the overall top 10 topic models in each survey

4.3.2 Density mapping

Figure 16 illustrates areas where at least two features were mapped by participants as places with garbage or places with little to no garbage. A difference index map was only generated for Indonesian-language features, as too few English-language features were mapped to generate a useful comparison. The overview maps on the left were created with a cell size of 100 m by 100 m and a search radius of 800 m, while the maps on the right used a cell size of 25 m and search radius of 400 m to resolve detail at a finer scale. The density surfaces show that mapping activity by Indonesian-language participants was primarily focused within the village of Pejarakan, with some apparent overlap between places with and without garbage. English-language participants—who were outnumbered by more than 4:1—failed to map any places without garbage close enough together to register on the density map. Menjangan Island

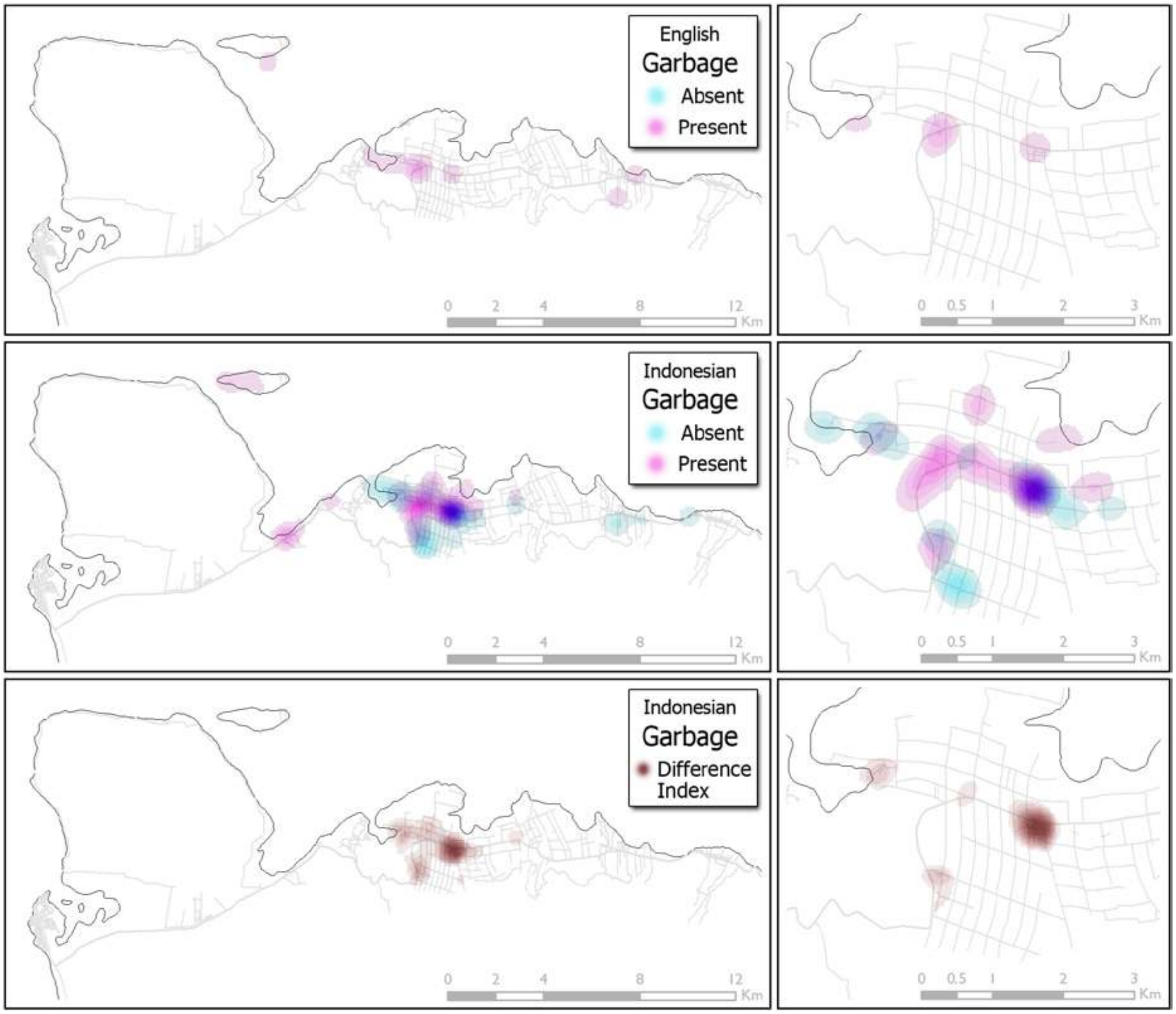


Figure 16. Kernel density maps illustrating places with and without garbage as reported by English- and Indonesian-language participants, and a difference index map emphasizing areas where features of both types were mapped by Indonesian-language participants

and locations along the main east-west road were indicated by both Indonesian- and English-language participants as places with garbage.

Figure 17 illustrates areas of mapping concentration by Indonesian- and English-language participants, including places for promoting tourism and places for restricting or prohibiting tourism. Since participants in this survey could represent places with lines and areas, in addition to points, regions of intensity appear larger than in the garbage survey density maps.

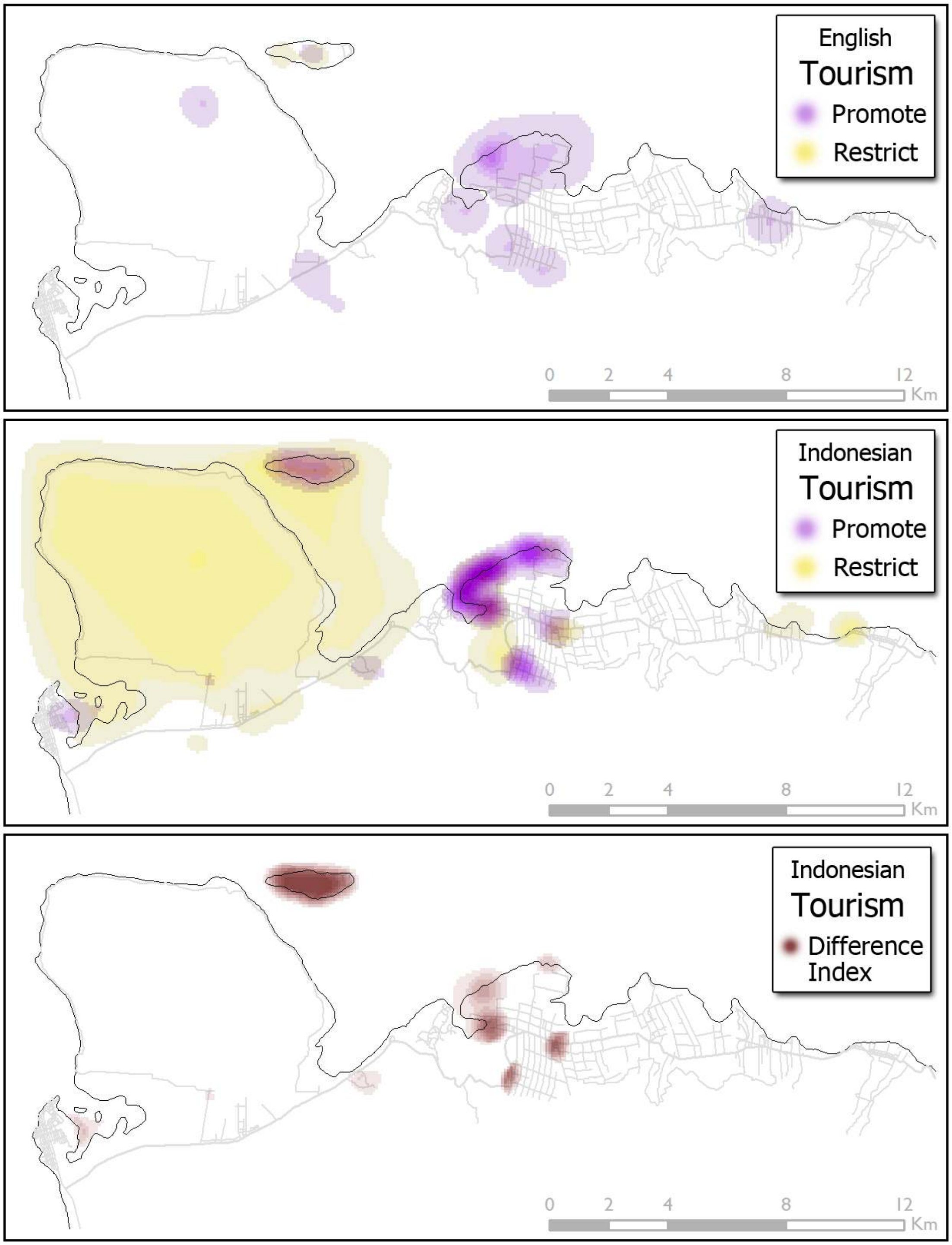


Figure 17. Kernel density maps illustrating places where tourism should be promoted and restricted as reported by English- and Indonesian-language participants, and a difference index map emphasizing areas where features of both types were mapped by Indonesian-language participants

Menjangan Island draws conflicting opinions among both Indonesian- and English-speaking participants, as it is marked as a place for both promoting and restricting tourism. The coastal region of intense purple on the Indonesian map, which is also indicated as a place to promote tourism on the English map, marks a local mangrove and coral reef conservation area. The expanse of yellow that dominates the western portion of the Indonesian-language map highlights the peninsula and surrounding coastal marine area of West Bali National Park.

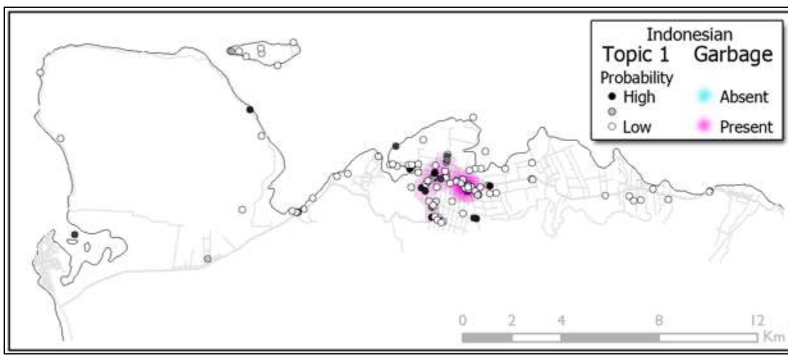
A full set of kernel density surfaces weighted by topic probability for the Indonesian-language features appears in Appendix F; selected examples are presented and discussed in the following section. In the garbage survey, features with a high probability for topics 0, 1 or 5 also showed some geographic clustering by feature type, while features dominated by topics 2, 3 and 4 showed little or no clustering. Topic 1, which was associated primarily with places with garbage, was prominent among features that also exhibited clustering. An analogous situation for places without garbage was not observed. In the tourism survey, topics 0 and 1 dominated features representing places for both promoting and restricting tourism that also exhibited clustering. In contrast, topics 2 and 3 were found almost exclusively in clusters of features representing places for promoting tourism.

4.4 Interpretation and discussion

Several methods for visualizing mapped features and their associated descriptive text have been described. The word clouds, density maps and selected topics from the topic models are interpreted here from the perspective of a planner seeking to identify significant issues, their geographic associations and differing opinions regarding the issues. The visualizations related to waste management are discussed first, followed by those focused on tourism development. Then, advantages and limitations of each technique are discussed, along with recommendations for further research.

4.4.1 Analysis of participants' perceptions of garbage in West Bali

The unweighted feature density maps of Figure 16 suggest that both English- and Indonesian-language participants notice garbage along the main east-west road in Pejarakan Village as well as on and around Menjangan Island. One location in the Indonesian maps, marked by the dark brown hot spot on the difference index map, stands out for its concentration of apparently conflicting opinions. The topic density maps help explain the reason for this hot spot. Topic 1 is strongly associated with features in this location, but only those representing places with garbage (Figure 18). High on the list of terms for Topic 1 are *market*, *merchant*, *careless* and *goris*, which all relate to Goris Market, the source of local meat, fish and produce for the region, universally identified by Indonesian participants as a place with a significant garbage problem. The word cloud for this survey's Indonesian responses includes several of



Topic 1:
"Blame for dirty places"

0.047* market	0.027* no
0.037* merchant	0.025* school
0.036* careless	0.023* pejarakan
0.036* goris	0.021* group
0.035* throw [away]	0.019* plastic
	0.019* [garbage] can

Figure 18. Weighted density map with features superimposed, shaded by features' probability for Topic 1 (left) and Topic 1's top 11 terms with their probabilities, approximately translated from the original Indonesian (right) (garbage survey)

these words, too—*market*, *merchant* and *careless* appear on the left side in pink as terms exclusively used in descriptions of dirty places, while *goris* appears in purple, more centrally located (Figure 19). Goris, in fact, is the name of both the market and a neighborhood of Pejarakan Village, a distinction the word cloud fails to make but that is necessary for interpreting these results.

The term *menjangan*, too, belongs to several places mentioned by participants, including Menjangan Island, the conservation area Putri Menjangan, the Menjangan Resort and the Menjangan View Homestay. In the word cloud (Figure 19), *menjangan* appears at the center left as a term associated with both dirty and clean places, though *island* belongs exclusively to the places with garbage. The unweighted density maps of Figure 16 confirm that participants consistently mapped Menjangan Island as a place with garbage, while the locations of other Menjangan-named places are shaded with a mix of pink and turquoise.

Figure 19. Word cloud of Indonesian-language responses, approximately translated, from the garbage survey

Topic 1, the only topic strongly dominated by places with garbage, includes terms that suggest the label, “Blame for dirty places” (Figure 18). Consulting the original descriptions of several features with a high probability for this topic provides confirmation:

> Because at the market many merchants throw garbage carelessly because there are not satisfactory garbage cans. *(Karena di pasar banyak pedagang yang membuang sampahnya di sembarang tempat karena tidak ada tempat sampah yang memadai.)*
>
> Because students throw garbage carelessly. *(Dikarenakan siswa membuang sampah sembarangan.)*
>
> The school doesn’t have a garbage can. *(Sekolah tidak punya bak sampah.)*

Topic 0, however, is strongly associated with clean places in approximately the same location (Figure 20), causing the hot spot of apparent conflict in Figure 16. With terms such as *citizen*, *house*, *community* and *village*, this topic earns the label, “Civic responsibility”. Descriptions of clean places that are weighted heavily for this topic include:

> Residential region for citizens of Goris Asri Hamlet. Citizens have their own awareness for throwing trash into its place. *(Kawasan perumahan warga Dusun Goris Asri. Warga memiliki kesadaran sendiri untuk membuang sampah pada tempatnya.)*

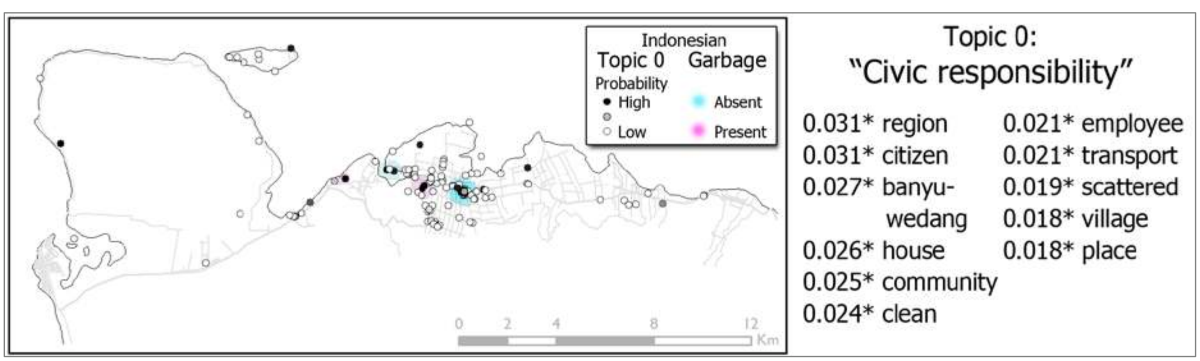


Figure 20. Weighted density map with features superimposed, shaded by features’ probability for Topic 0 (left) and Topic 0’s top 11 terms with their probabilities, approximately translated from the original Indonesian (right) (garbage survey)

Goris Asri Hamlet, which surrounds Goris Market, is described by several participants as a clean place. The spatial resolution of the unweighted density maps (Figure 16) is insufficient to distinguish between Goris Market—a place with garbage—and Goris Asri Hamlet—a place without garbage—and the result is a mixed-color hot spot that suggests conflicting opinions. When participants' responses are parsed by topic, however, the topic density maps and term lists hint at an explanation that is confirmed by directly reading original feature descriptions like the one above.

Not only clean places score high for the "Civic responsibility" topic, however; clusters of features marking places with garbage appear, too (Figure 20). An example of such a feature demonstrates how some of the same terms are used in a different context:

> Several times I've seen rogues/community members throw garbage into the forest or seasonal stream… *(Beberapa kali saya melihat Oknum / warga Masyarakat membuang sampah ke hutan ataupun ke kali mati…)*

This topic appears to have grouped together places where civic responsibility is both demonstrated and neglected.

Topic 5 presents a similar example (Figure 21). At first glance, the term list for this topic, which includes *manage* and *clean*, appears to describe places without garbage. However, the topic density map reveals clusters of places both with and without garbage, suggesting that management—both effective and ineffective—is the common theme. The turquoise hot spots on the map mark the locations of two place names in the term list—the [Naya] Gawana Hotel and Pahlengkong Hamlet—while names of the places colored pink are not included. Descriptions of two features with a high probability for this topic provide context:

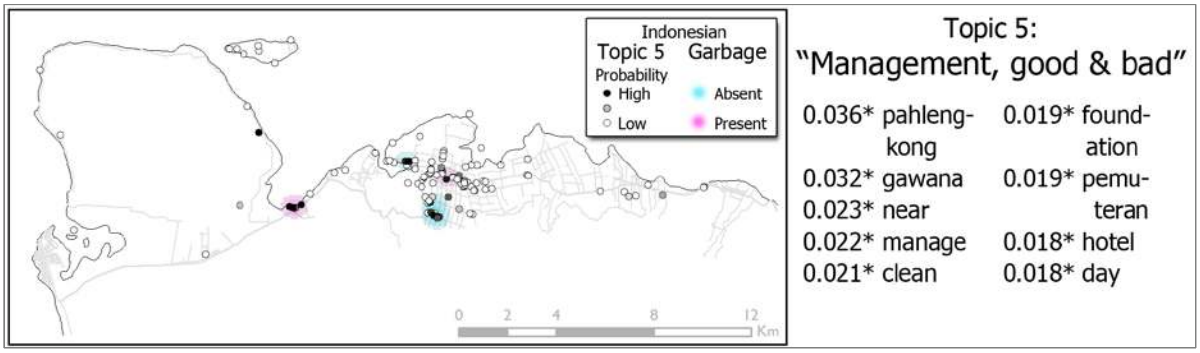


Figure 21. Weighted density map with features superimposed, shaded by features' probability for Topic 5 (left) and Topic 5's top nine terms with their probabilities, approximately translated from the original Indonesian (right) (garbage survey)

> Gunung Pahlengkong Foundation. Because this foundation has a cleanliness program, and every week they hold a clean-up every Sunday. *(Yayasan Gunung Pahlengkong. Karena yayasan ini berprogram tentang kebersihan,dan setiap minggu mengadakan pembersihan setiap hari minggu.)*

> Terima Bay parking lot. This place has a lot of trash, needs good management to handle it. *(Tmpat ini banyak sampahnya perlu penglolaan yang baik untuk menanganinya.)*

The distinction between topics 0 and 5 is not sharp; both include feature descriptions that discuss management activities—either performed or neglected. The maps illustrate, however, differences in their geographic footprints. In some cases, these differences stem from places named in the feature descriptions. In other cases, the vocabulary used to describe an actor—e.g., *foundation* vs. *citizen*—seems to determine their dominant topic affiliation.

Almost no geographic clustering is apparent in features with a high probability for Topic 4 (Figure 22). Glancing through the term list suggests an explanation—Topic 4 is almost entirely comprised of place names, both specific, such as *sumberkima*, and general, such as *field*, that are distributed throughout the map. Even the apparent outlier *family planning* fits this pattern when provided local context; Family Planning Hamlet is the colloquial name of a

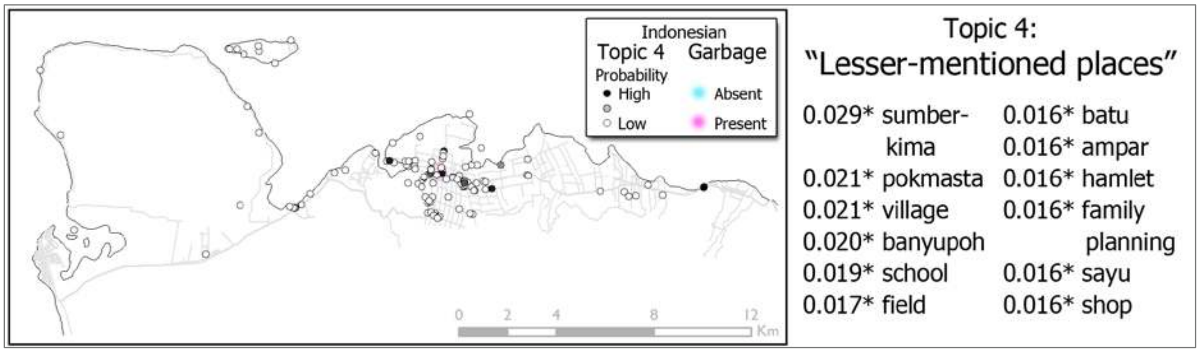


Figure 22. Weighted density map with features superimposed, shaded by features' probability for Topic 4 (left) and Topic 4's top 12 terms with their probabilities, approximately translated from the original Indonesian (right) (garbage survey)

neighborhood in Pejarakan. Nine of the 12 place names in this list are absent from the word cloud of most frequently used terms (Figure 19), and names of some of the places mentioned most often—Menjangan, Pejarakan and Pahlengkong—are missing from this topic term list. The label "Lesser-mentioned places" might be appropriate, as this topic apparently represents a collection of places that were discussed less often, but nonetheless appeared in multiple feature descriptions.

4.4.2 Analysis of participants' opinions regarding tourism development in West Bali

Three regions stand out in the unweighted density maps of Figure 17: the central coastal area, colored purple in both English- and Indonesian-language maps; the expanse of yellow that dominates the peninsula and marine region of West Bali National Park in the Indonesian map; and the dark brown hot spot of apparently conflicting opinions that encompasses Menjangan Island in the difference index map. The density maps suggest that Indonesian- and English-language participants predominantly agree that the nature conservation areas Putri Menjangan and Nature Lestari, located along the central coast, should be promoted as tourist

Figure 23. Word cloud of Indonesian-language responses, approximately translated, from the tourism survey

attractions. The difference index map indicates slight disagreement among Indonesian participants, however, and this is reinforced by the word cloud (Figure 23). The terms *nature*, *lestari*, *menjangan* and *putri* fall in the center, demonstrating their use in descriptions of places for both promoting and restricting tourism.

Two topic density maps and their term lists, which both include *menjangan* and *putri*, suggest an explanation. Topic 3, with top terms including *island*, *tour[ist]*, *bay*, *mangrove* and *relax* and might be summarized with the label "Coastal tourism" (Figure 24). (The top map of Figure 24 illustrates features drawn by participants, including points, lines and areas, with areas symbolized by their outline, only, to avoid obscuring overlapping features.) The topic density map is dominated by places for promoting tourism, symbolized in purple, with the locations of Putri Menjangan and Menjangan Island most prominent. Examples of place descriptions for features weighted strongly for this topic include:

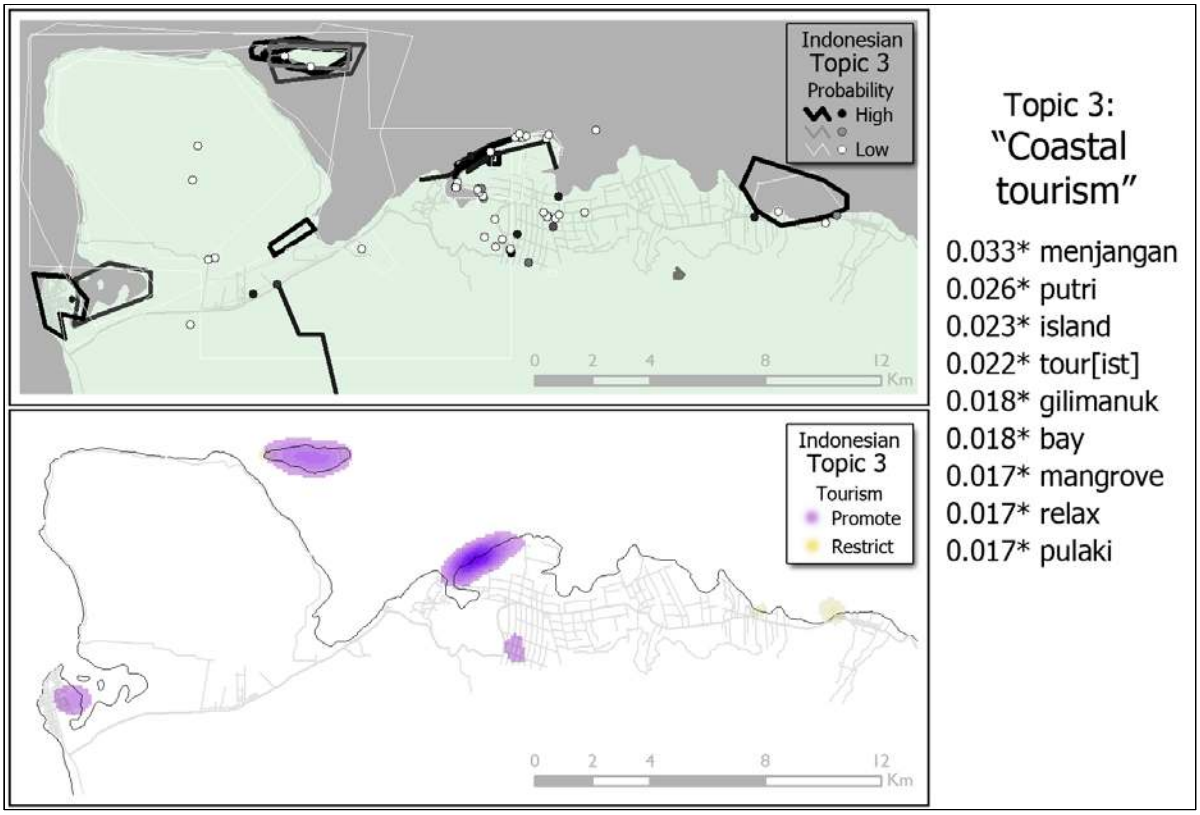


Figure 24. Features shaded in grayscale by their probability for Topic 3 (top) and weighted density map shaded in color by type according to the probability for Topic 3 (bottom); and Topic 3's top nine terms with their probabilities, approximately translated from the original Indonesian (right) (tourism survey)

> At Putri Menjangan there are many mangroves, so many tourists want to immortalize it and also for relaxing. *(Diputri menjangan ada banyak mangrove, jadi banyak wisatawan yang ingin mengabadikannya dan juga untuk santai-santai.)*

> At Menjangan Island we can snorkel and dive and also worship, at Menjangan Island the view of coral reefs is very beautiful. *(Di pulau menjangan kita bisa snorkeling dan diving,dan jga melakukan persembahyangan, di pulau menjangan pemandangan terumbukarang sangatlah indah.)*

The density map for Topic 0, which also highlights Menjangan Island and Putri Menjangan, illustrates a mix of desires to promote and restrict tourism (Figure 25). While Putri Menjangan again appears in this map as a place to promote, Menjangan Island draws conflicting opinions, contributing to the dark brown hot spot over the island in the difference index map of Figure 17. The term list for Topic 0 emphasizes a diversity of marine resources: *fish*, *coral*, *reef*, *kind[s]*, and *a lot* (Figure 25). Descriptions of features strongly weighted for this topic reveal that marine resources are invoked by some participants as a reason to promote tourism, while others cite it as a reason to restrict tourism:

> Putri Menjangan has various kinds of coral and also an abundance of fish that is quite high. *(Putri menjangan memiliki jenis karang yang bermacam-macam dan juga memiliki kelimpahan ikan yang cukup tinggi.)*

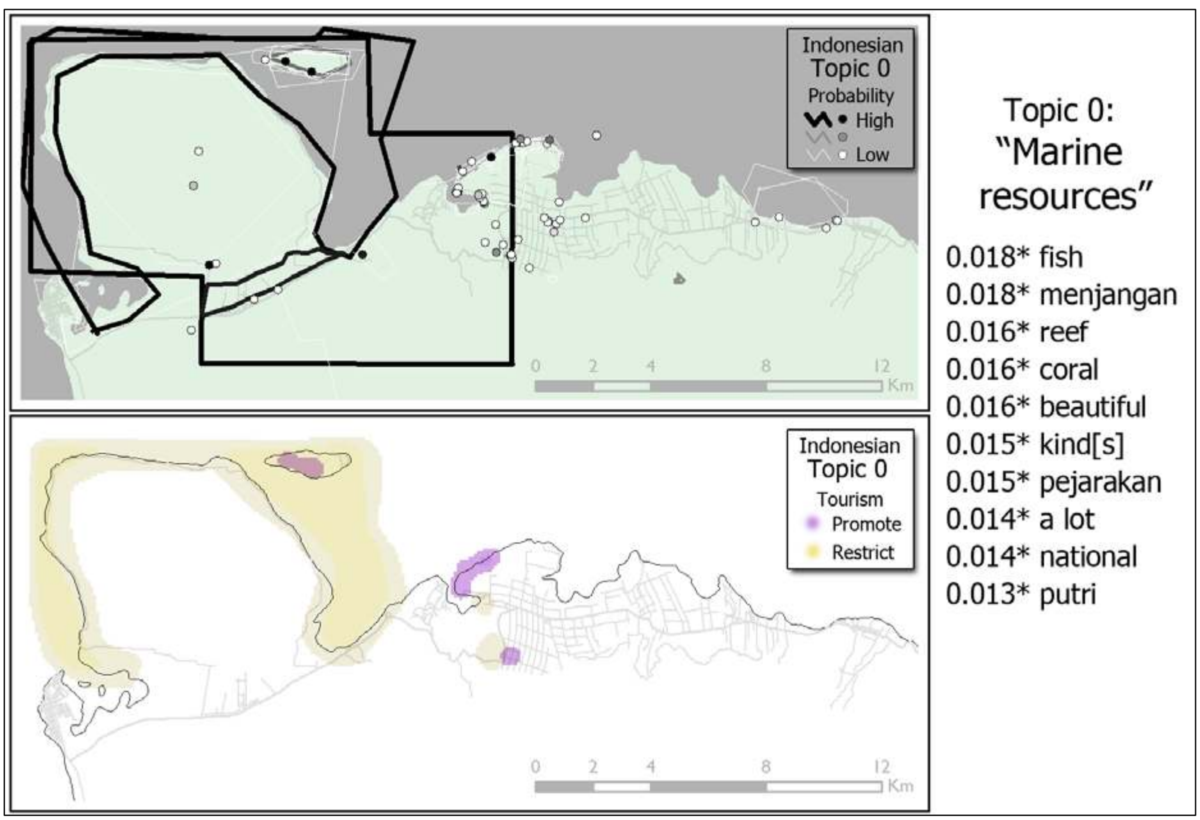


Figure 25. Features shaded in grayscale by their probability for Topic 0 (top) and weighted density map shaded in color by type according to the probability for Topic 0 (bottom); and Topic 0's top 10 terms with their probabilities, approximately translated from the original Indonesian (right) (tourism survey)

> Marine Zone of West Bali National Park. Conservation area with high coral reef cover as fish habitat. Tourism restriction to reduce pressure on coral reefs. *(Zona perairan Taman Nasional Bali Barat. Daerah konservasi dengan tutupan terumbu karang yang tinggi sebagai habitat ikan. Pembatasan pariwisata untuk mengurangi tekanan terhadap terumbu karang.)*

The anomalous features that represent land, rather than marine areas, and yet score high for Topic 0 do so because they reference other, not necessarily marine terms in the list such as *national [park]*, *a lot* and *menjangan*. This demonstrates one of the challenges of interpreting topic models—while the label "marine resources" relates well to most features scoring high for the topic, it does not characterize all of them.

A starkly different set of terms appears in Topic 1, including *holy*, *temple* and *region* (Figure 26). The same words appear in yellow far to the left in the word cloud (Figure 23) as words used to describe places for restricting tourism. Many—though not all—Indonesian participants consider temples inappropriate for tourism:

> Pulaki Temple. There may not be hotels [here] because this area is a religious region and there is a border of the temple's holiness. *(Pulaki temple. Tidak boleh ada hotel karena kawasan ini kawasan religi dan ada batas wilayah kesucian pura.)*

Other Topic 1 terms are associated with place names, earning the label "Special places" for this topic. These terms include *dalem* (Dalem Temple), *white* (White Sand Beach), *dinasti* (Dinasti Resort) and *zone* (zones of West Bali National Park). White Sand Beach and Dinasti Resort are located in an area of purple on the topic density map, as places to promote, while areas within West Bali Natural Park—including Menjangan Island—are colored yellow as places to restrict, explained in this example description:

> Region of West Bali National Park. Because this area constitutes a conservation area where a lot of flora and fauna must be protected. *(Kawasan Taman Nasional Bali Barat. Karena dikawasan ini merupakan kawasan konservasi dimana banyak flora dan fauna yang harus dilindungi.*

This example highlights an interesting contradiction between local opinion and administrative boundaries. West Bali National Park is consistently named and visualized—in the word cloud (Figure 23), Topic 0 (Figure 25) and Topic 1 (Figure 26)—as a place where tourism should be restricted. However, Menjangan Island—which is part of the national park—is frequently named and visualized as a place for promoting tourism. The inconsistency with which Menjangan Island is promoted over the national park as a whole may reflect the

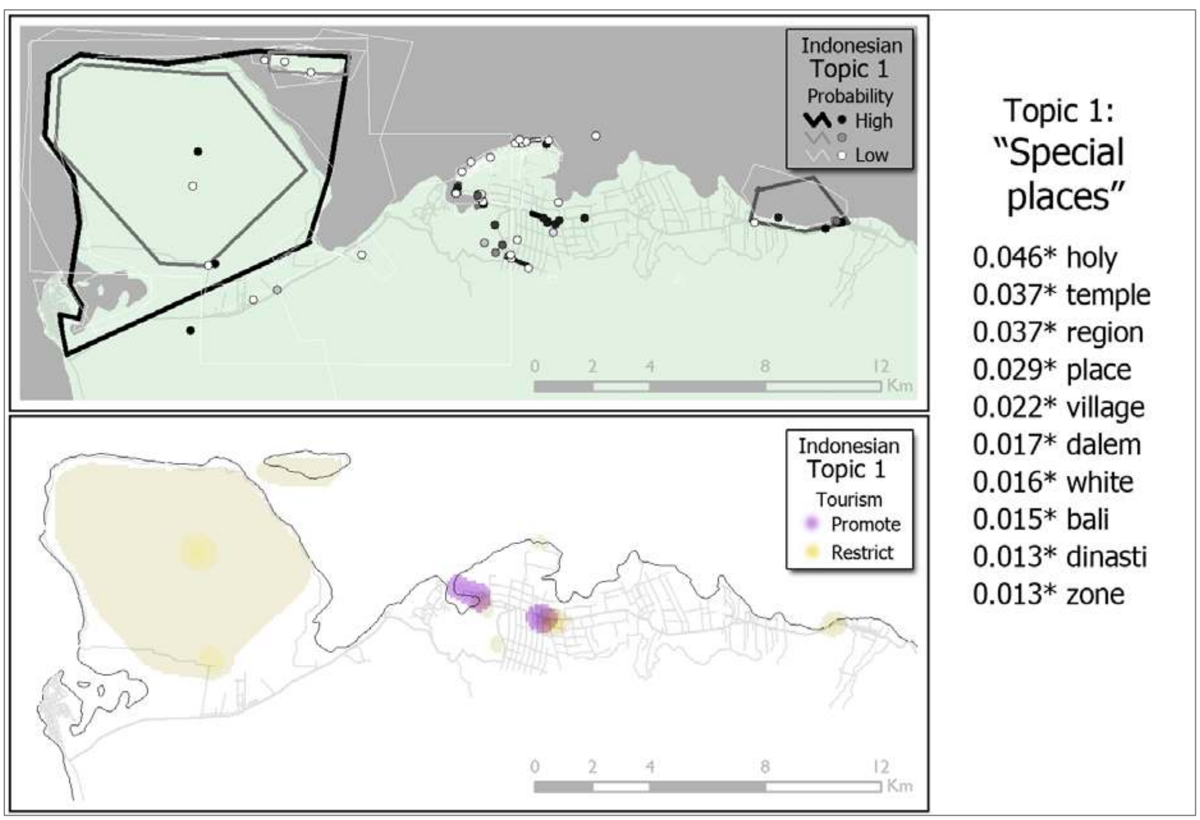


Figure 26. Features shaded in grayscale by their probability for Topic 1 (top) and weighted density map shaded in color by type according to the probability for Topic 1 (bottom); and Topic 1's top 10 terms with their probabilities, approximately translated from the original Indonesian (right) (tourism survey)

tumultuous history between the park, which is controlled by the Indonesian Ministry of Forestry, and the surrounding communities. Early efforts to restrict fishing inside the park led to a series of alleged tit-for-tat incidents; after park officials burned a traditional fishing hut and seized private aquaculture equipment in 1984, residents began a clandestine campaign to steal Bali starlings (*Leucopsar rothschildi*), the iconic and endangered emblem of the park, to discredit the park as an authority capable of protecting wildlife (Mahmud, Satria, and Kinseng 2015a). Since then relations have largely normalized, as many locals who once fished for a living have become boat drivers who ferry visitors to and from Menjangan Island (Doherty et al. 2013). However, Menjangan Island—which houses several Hindu temples—was sacred to the Balinese long before the park existed. Perhaps the apparent contradiction reflects local Balinese pride in Menjangan Island, which they consider a jewel of their own, over the rest of the national park, which they regard as “other”.

4.4.3 Word clouds, topic modeling and density maps: advantages and disadvantages

The three analysis and visualization techniques discussed above can help planners explore data generated through participatory mapping to identify general themes and locations that are important to stakeholders. Word clouds, extended by color and word placement rules as described here, emphasize keywords that may relate to broad concepts discussed by many participants. Here, for example, the words *holy*, *temple*, *conservation* and *protect* (Figure 23) immediately suggest popular reasons for prohibiting tourism. The rules for constructing word clouds are straightforward to apply and produce fairly consistent results. However, word clouds are sensitive to the text pre-processing methods, list of excluded stop words, number of terms included in the visualization and manual adjustments to the words' location within the cloud. It is also impractical to consider text in different languages together for the reasons cited earlier. Jung (2015) describes *code clouds*—word clouds that visualize codes summarizing key ideas and themes from text—that could be used to visualize descriptions in different languages. Bilingual human coders could read descriptions in both languages and assign codes in English for visualization. The codes, however, would necessarily lose some of the lexical richness of the primary documents.

Here, the topic models proved most useful for addressing the problem inherent in word clouds of emphasizing words based on their frequency, alone. In the garbage survey, the topic model isolated a group of place names that were completely absent from the word cloud. While cited less frequently, these places were named in multiple descriptions, suggesting that they are important to more than one participant—a useful fact for a planner to note. The term *garbage*, cited more frequently than any other term in the garbage survey, fails to appear in any topic. This was both expected and appreciated, as the term was so ubiquitous that it carried little useful information. It demonstrates the utility of the TF*IDF weighting scheme applied in the topic modeling process, de-emphasizing the importance of words used across all or most documents.

The greatest drawbacks to topic modeling as described here are the technique's inconsistency, apparent sensitivity to the parameter *k* (number of topics) and the subjective nature of its results, arising from the process of selecting a model on which to base the analysis. As a probabilistic technique, topic modeling is unlikely to produce the same outcome twice, and experiences here suggest that identical input parameters can yield models with significantly different topic term list compositions. Existing methods for evaluating topic models are either labor-intensive—as human user studies for topic interpretability—or they fail to converge on a single winner—as the Monte Carlo/C_V coherence metric evaluation approach used here suggests. Therefore, an interpreter must rely on judgement to select a final model. Choice of model may drastically alter the type of conclusions that are drawn from the topic term lists and topic density maps—a model with only four topics may suggest different trends than a model with 12 topics. A future study could investigate this by selecting several different topic models, generated from the same dataset, and comparing the trends suggested by each model.

The unweighted density maps simplified the raw feature maps into a cleaner visualization that highlighted locations warranting further investigation. The difference index map clearly identified clusters of features representing different place types, though this did not always indicate conflict of opinion. The topic models and associated density maps helped to group features based on patterns in their descriptive text, which in several cases successfully identified why features of different types were mapped in approximately the same location. In the garbage survey, two topics with apparently overlapping geographic footprints identified different concepts—that Goris Market has a garbage problem, but the surrounding Goris Asri Hamlet is very clean. In the tourism survey, the topic model grouped features of both types around a common theme—marine resources—invoked by participants as both a reason to promote and a reason to restrict tourism. The geographic overlap between feature types indicated by the topic density maps in this case indicated a genuine difference in opinion. All density maps, however, are subject to uncertainty, in this case primarily stemming from the locational accuracy with which participants mapped features. Measurable error was found in 14–26% of features that could be validated in this study, with some features mapped kilometers from their actual location (see Section 3.1.4). Mapping errors may have significantly changed the appearance of the density maps, leading to flawed interpretations.

The time and effort required to generate visualizations must not outweigh the techniques' usefulness to be practical for planning. Extensive manual cleaning of the text was required here, especially for the Indonesian text, as multiple spellings were often used for the same word. Text mining is typically applied to datasets much larger than the one examined here, but documentation of data reduction techniques such as text mining typically provides few guidelines regarding the minimum corpus size the techniques are meant to handle. The benefits, therefore, of word clouds and topic modeling in the present case study are questionable. User studies would suggest whether the visualizations change or enhance the types of interpretations possible from the data, or at what size of dataset a human interpreter must rely on summaries such as these to comprehend the dataset as a whole.

Such user tests are confounded, however, by the fact that interpreting data in the context of a planning process demands that the interpreter be familiar with cultural and geographic setting in which the data were collected. Realizing, for example, that *family planning* refers to a geographic location is essential for interpreting a topic term list that contains the expression. In many cases, translation fails to accurately convey the meaning of participants' descriptions. For example, the Indonesian term *kiriman* is directly translated as "dispatch, delivery or shipment; something that comes out of season, or something unexpected" (Stevens and Schmidgall-Tellings 2010). The phrase *sampah kiriman*, therefore, might be translated as "garbage delivery", though this puzzling English rendition fails to convey how the phrase is used in Indonesian, indicating garbage that has ended up somewhere due to external forces, such as a flood or oceanic currents. Text-based analysis techniques are unquestionably better suited for interpretation in the original language.

4.5 Conclusion

Three complementary techniques for visualizing and analyzing participatory mapping data were presented in this chapter: word clouds, topic modeling and kernel density mapping. Each provides a different perspective on the data, and when used together for exploratory analysis revealed the following general themes: both English- and Indonesian-language participants agree that Menjangan Island and locations along the main east-west road are places with garbage; Indonesian participants universally identify Goris Market as having a garbage problem, while the surrounding Goris Asri Hamlet lacks garbage; Pahlengkong Hamlet is highly regarded for a waste management program led by a local foundation; the conservation areas Putri Menjangan, Nature Lestari and Menjangan Island have diverse coastal resources that make them suitable tourist attractions, though some believe that the same resources are threatened by tourism at Menjangan Island; and the prevailing opinion among Indonesian participants is that tourism should be discouraged inside the national park, with the possible exception of Menjangan Island, and discouraged near temples, which are sacred sites.

The perceptions and opinions inferred through the analysis to this point are used in the next chapter as guidelines for designing simple plans to address waste management and tourism development in West Bali. Then, the survey approach taken here is critiqued and an extended methodology for collaborative planning is proposed that attempts to systematically integrate participants' notions of intention, purpose function into a spatial plan.

Chapter 5

From Perspectives to Plan: Designing with Participatory Geodata[1]

Until now the discussion has focused on collecting and interpreting data to learn how people in West Bali think about two issues—non-biodegradable garbage in their environment and the future of tourism in their region. These people, earlier referred to as *participants* in a mapping survey, could be considered *stakeholders* when the conversation shifts from a data gathering exercise to a planning process that considers how systems might be designed to address these topics. Some practitioners and scholars distinguish between *stakeholders*—as people or organizations that may influence or be directly affected by the outcome—and *the public*—as people with limited or indirect interest in the issue (Blaschke 2004). This distinction is not important here, so for the purposes of this discussion *stakeholders* will encompass all parties with a direct or indirect interest in West Bali's future—residents, visitors, businesses, government agencies and other relevant organizations.

[1] Portions of this chapter are reproduced from Currier, K. and H. Couclelis (2014) Geodesigning 'From the Inside Out'. In *Geodesign by Integrating Design and Geospatial Sciences*, eds. D. J. Lee, E. Dias, and H. J. Scholten, pp. 287–298. Cham: Springer International Publishing (with permission of Springer Nature).

While the combination of survey technology and cultural context explained earlier distinguishes this study from others, the substance of the surveys was standard: to address issues of garbage and tourism, ask questions about garbage and tourism. This is an obvious first step, but it assumes a universal common sense and shared understanding of the problem among stakeholders and planners that may not be justified, especially when their cultural and socioeconomic differences are striking. A more comprehensive approach would consider information about the interactions, relationships and functions of the environmental entities involved but also—critically—about the values, interests and intentions of the people contemplating their future.

Such an approach is described later in this chapter. First, two simple plans are presented, developed from the conclusions regarding garbage and tourism summarized in the last chapter. Each plan consists of a map, a set of guiding principles inferred from participants' responses that justify the map and explains how each system should run, with known limitations of each plan. Then, a modified approach to planning is proposed—one that probes beyond the obvious questions posed earlier. It attempts to build a better understanding of the functions a successful plan must support as described by stakeholders who interact with the systems in question. The goal of the proposed approach, called *perspectives mapping*, is to gather information on stakeholders' values, interests and intentions—so-called *soft* information—and systematically relate this to the relevant *hard* geospatial data of the kind normally found in a GIS. The result is a planning methodology that relates geospatial entities to the functions and purposes ascribed to them by people, recognizing that these functions and purposes often vary by perspective. The approach attempts to mix the quantitative modeling and visualization abilities of a GIS with the focus on intentionality, purpose and function regarded by design to realize the intent of geodesign, or "changing geography by design" (Steinitz as quoted in Esri 2013, p. 6).

5.1 Plan proposals

5.1.1 Waste management

Figure 27 depicts the infrastructure of a preliminary waste management plan for West Bali, consisting of (a) garbage cans and (b) consolidated garbage collection points, which do not yet exist; and a (c) landfill and (d) trash bank (recycling facility), which already exist. The garbage cans are located at schools, mosques, temples and Goris Market, as these were identified by participants either as places with garbage or places where garbage is poorly managed. While garbage cans could justifiably be proposed for far more locations, these would be prioritized as the public places most often noticed by stakeholders. The garbage collection points, where each neighborhood's garbage would be consolidated and collected by dedicated sanitation vehicles, are located along the main road and at Menjangan Island, spaced to serve each village in the region.

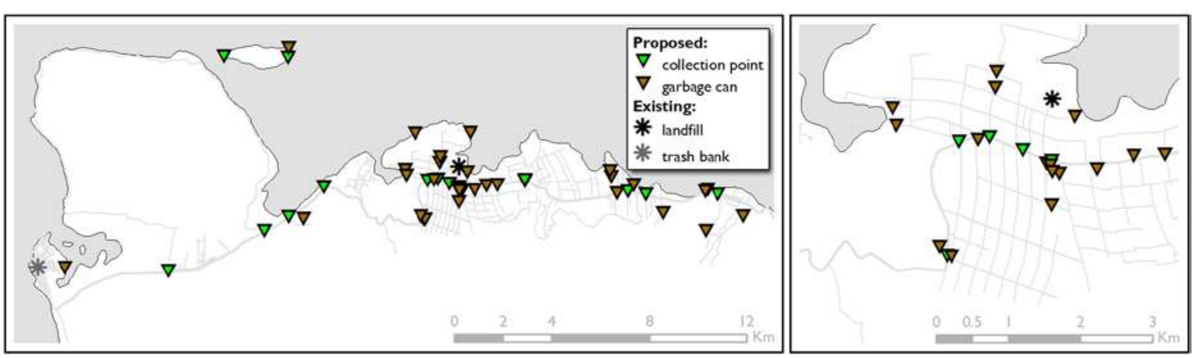


Figure 27. Plan proposal for infrastructure related to waste management in West Bali

The system of garbage consolidation within each neighborhood would be patterned after one that participants frequently credited with success in Pahlengkong Hamlet. Each week volunteers collect garbage from garbage cans around the neighborhood and sort it at a community meeting place, where it is then hauled to the landfill or trash bank. This system functions thanks to a youth organization called Gunung Pahlengkong Foundation, which supplies human and material resources and is funded by local and international donors. Pahlengkong is unique among West Bali neighborhoods for this program, and instituting others like it would probably require funding external to the neighborhoods in which they would operate. However, Bali and Indonesia, in general, maintain a strong tradition of community service manifested through *gotong royong*, or mutual and reciprocal assistance (Bowen 1986). Idealized as a social system and philosophy that prioritizes the collective good, gotong royong is frequently invoked for building roads and other village-level projects through unpaid local labor. The idea of instituting a system to manage waste through community service might be met with less disdain in Indonesia than in the US, where most citizens can pay for the service.

Hauling garbage from the collection points to landfills or trash banks would be done by dedicated service vehicles, trucks on the mainland and tourist boats, perhaps repurposed on a rotating schedule, at Menjangan Island. Funding to provide the vehicles and employees might be supplied by area resorts, as environmental cleanliness serves their own interest as they cater to tourists. This model currently serves Pemuteran Village, where resorts and hotels sponsor garbage collection for the entire village. While other villages in the area do not currently have as many hotels and resorts, this is changing.

This plan is limited by several factors. First, it is based on conclusions drawn from a small, non-representative sample of West Bali stakeholders, as discussed in section 3.2.2. Rectifying this would require a different sampling strategy, dictated by the planner's goals for participation in the process. If the broadest participation possible were sought, a Web-based survey would probably not suffice, both due to computer access constraints and the possibility for technological intimidation among some participants. In this case, a multi-modal strategy—one that used the Web, paper-based surveys, interviews and town hall meetings—to collect stakeholders' opinions would probably yield the most comprehensive response.

An obvious second limitation to implementation of this plan is a source of funding, but perhaps the most perplexing challenge is how to deal with the non-biodegradable, non-recyclable garbage that is collected. Several professional sorting and material recovery facilities operate in the South (e.g. http://eco-bali.com/waste-management/; http://2cdenpasar.com/), where there are also sanitary landfills, but these amenities are not, for the most part, available in the North. Most villages have a TPA—*tempat pembuangan akhir*, or landfill—but usually they are no more than an empty lot where garbage is piled, informally sorted by garbage-pickers and burned. Such open dump sites are ostensibly illegal according to a national law on waste management passed in 2008 (Meidiana and Gamse 2011), yet they persist out of economic reality. Constructing a properly sealed, sanitary landfill is beyond most individual village budgets and would require collective action, possibly sponsored by the regional or provincial government. For the moment, identifying open dump sites that are away from village populations—so residents are minimally affected by vapors of burning plastic—and the ocean—so breezes do not blow refuse into the sea—is probably the most practical way forward. This poses a siting problem, however, that is as wicked in rural Indonesia as it is in urban America.

The plan of waste management infrastructure proposed here is also limited by data availability. The garbage cans mapped in Figure 27 correspond to the locations of schools and places of worship as documented in OpenStreetMap, plus additional areas specifically identified by stakeholders. OpenStreetMap lacks comprehensive data for West Bali, however, so for this plan to be implemented as intended, a more complete map of schools, temples, mosques and churches would need to be compiled. Existing village landfill locations that are presently missing from the map, too, would need to be identified as components of the waste management system.

5.1.2 Tourism development

Figure 28 illustrates a map of proposed tourist attractions, some intended for outright promotion and others to be promoted conditionally. The conditionally promoted attractions, including West Bali National Park, a regency-level coastal marine conservation area and two local coastal conservation areas, require further discussion regarding their management as tourist attractions. All were advocated by some and discouraged by some participants as places for promoting tourism. In most cases, preservation of biophysical resources including fish, coral, mangroves and associated habitats was cited as the main reason to restrict tourism. Tourism and other activities in the national park are already regulated through a system of zones including the Core (*Inti*), Jungle/Marine Protection (*Rimba/Perlindungan Bahari*), Traditional (*Tradisional*), Religious, Cultural and Historical (*Religi, Budaya dan Sejarah*), Resource Utilization (*Pemanfaatan*), and Special (*Khusus*) zones (Mahmud, Satria, and

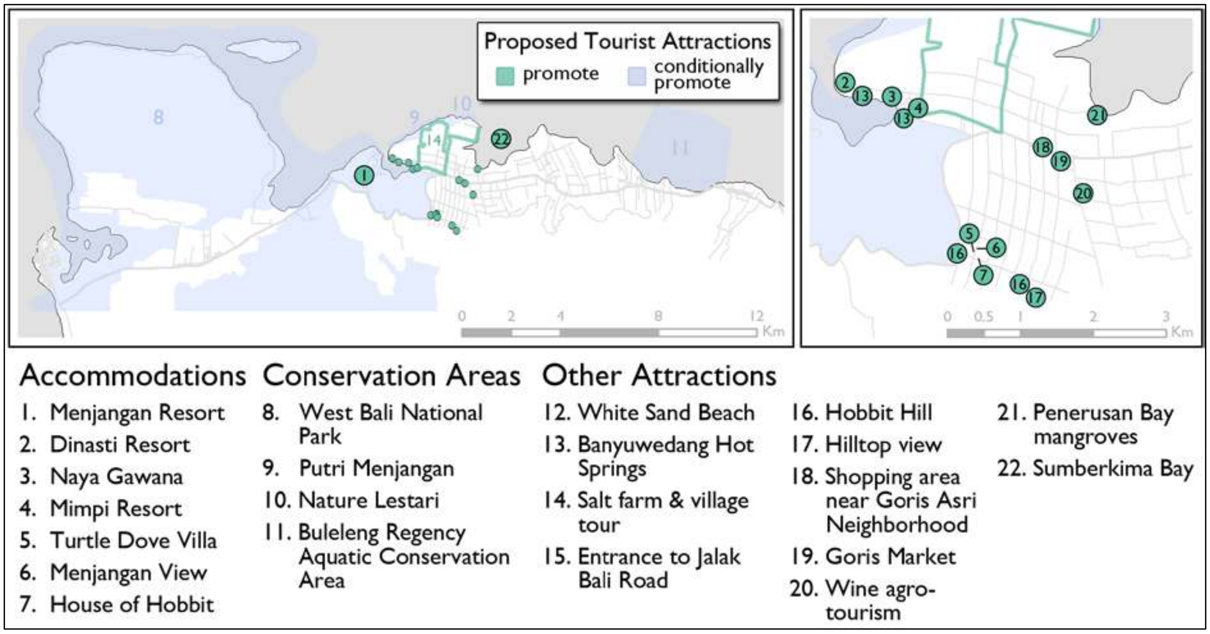


Figure 28. Plan proposal for tourism promotion in West Bali

Kinseng 2015b). The Core Zone is the most highly restricted and closed to tourism. A similar management plan has been adopted by Putri Menjangan, one of the local conservation areas. If adopted and enforced by the others, this kind of spatial management plan may adequately preserve the resources that some stakeholders cited as jeopardized by tourism. Enforcement of—or better yet, buy-in to—these spatial restrictions, however, is key and has proven difficult in the national park, where dynamite and other illegal fishing methods have been observed as recently as 2011 (Doherty et al. 2013).

An informal regulatory system based on social taboos might provide the foundation for tourism management in these areas. Social taboos, or bans on certain behavior that are communally rather than judicially enforced, operate in many traditional societies to guide human behavior toward the natural environment (Colding and Folke 2001). Social taboos can function to regulate removal of a resource, methods of removal, removal during a vulnerable life history stage of a species and access to a resource in space and time. Like the national park's system of zones, a social taboo system might declare certain areas off-limits to tourism either outright or on a rotating seasonal basis. The will to establish and respect such a system, however, would need to come from within the communities that control these resources. Elsewhere in Bali, Hindu customs influence how marine resources may be accessed for transportation, tourism, fishing and other marine-related activities. On the South Bali island of Nusa Penida, for example, during the annual ritual *Nyepi Segara* all marine-related activities cease for one day to honor the god Baruna, ruler of the sea (Adnyani, Prasetia, and Windari 2014). Similarly, all across Bali, residents, tourists, government facilities and businesses are required to modify their usual activities for one day to respect *Nyepi*, called Bali's "day of silence", which celebrates the new year of the Balinese Hindu calendar (Vipriyanti 2008). All businesses are closed, including the international airport, and people must remain inside their homes or hotels or face rebuke by the *pecalang*, or Hindu security force.

The practice of *Nyepi* is generally respected by Hindus and non-Hindus within Bali, though anecdotes circulate of outsiders taking advantage of the day to commit crimes, when they have less chance of being caught. An account from 2011 describes how several national park guides spent Nyepi day on Menjangan Island, expecting fishers from neighboring Java and Madura islands to illegally fish in Menjangan's waters. Fishers allegedly from those islands, indeed, came, bearing arms that easily overpowered the park guides, who were driven to hide on the island (Doherty et al. 2013). Menjangan Island's location—far from villages—makes it vulnerable to outside exploitation in a way that would be less likely for village conservation areas, like the two in Pejarakan illustrated in Figure 28. If local consensus was strong enough that limiting access was necessary for conservation purposes, perhaps justified by Hindu doctrine, informal social taboos regarding tourism might be respected more than zoning regulations imposed by a government authority.

The places marked for outright promotion in Figure 28 consist of resorts, hotels and other accommodations, environmental attractions such as beaches and scenic overlooks, shopping areas and local industrial places. All were recommended by at least one participant and none were specifically discouraged by other stakeholders. Missing from the map entirely are places of worship. While a few participants felt differently, most expressed the opinion that tourism is inappropriate for religious places. Temples were cited most often, as Hindus comprised the majority of those surveyed, but this policy would be extended to other religions' places of worship unless recommended otherwise by their followers.

This plan represents a tiny fraction of the places that could be promoted for tourism in West Bali, following the general types of places recommended by participants. A larger survey would have undoubtedly produced a more comprehensive and geographically diverse collection. Most of the places in Figure 28 are located in Pejarakan Village, where most of the participants surveyed reside. Patterns in their responses, however, provide a starting point to explore policies that could guide tourism expansion in the region. Their clear concern for religious places is an obvious example—any future development of infrastructure, tours, or other attractions must be mindful of local spiritual practices. In addition to conventional attractions such as beaches, hotels and resorts, the survey unearthed some surprising suggestions such as a vineyard and a salt farm—local cottage industries that are not ordinarily advertised as attractions but that offer a unique perspective on West Bali. These types of suggestions demonstrate the advantage of inviting stakeholders, including those not directly involved with the tourism industry, to offer their ideas during planning.

5.2 Perspectives Mapping, an approach to geodesign

The simple plans described previously provide initial drafts for discussion among stakeholders, derived from a participatory mapping process that posed direct questions about garbage and tourism in West Bali. However, the plans would be stronger if they considered comprehensive models of Bali's culture—including its religions, economy, agriculture, recreation, customs and social norms—and environment—its geography, geology, hydrology and ecology. Hindu ceremonies, for example, are not spatially restricted to temple grounds, as the proposed tourism plan assumes; rather, they extend to take over roads and other public spaces at various times throughout the year. The simplification that confines spiritual practices to places of worship misrepresents how and where these practices function. Likewise, to design an environmental management plan that preserves biological resources requires a detailed understanding of species' life history, habitat requirements and ecology. Such specialized knowledge is rare and may be found only among a few stakeholders with deep traditional ecological knowledge, domain experts or repositories of Western science.

5.2.1 Geodesign, the answer to design + GIS?

Layers and overlay analysis, concepts that are now tightly associated with GIS, were used much earlier in analogue form for environmental planning by landscape architect Ian McHarg (Steinitz 2008). While GIS was initially envisioned as a tool for creating designs, among other applications, the continuing stream of academic meetings and journal articles pondering the role of GIS in design suggests that integrating the two is not trivial (Goodchild 2010; Esri 2013; Wilson 2015). The concept of *geodesign*, a term originating from a workshop on Spatial Concepts in GIS and Design in 2008 (http://ncgia.ucsb.edu/projects/scdg/; Goodchild 2010), has been promoted by the Esri software company as a way to introduce geographic analysis to the design process (Esri 2013). Definitions of geodesign include "designing with nature in mind" (Dangermond as quoted in Esri 2013, p. 6), "changing geography by design" (Steinitz as quoted in Esri 2013, p. 6), and "a design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts" (Flaxman 2010).

Indeed, as a science-based approach, GIS involves aspects of scientific inquiry such as measurement, modeling, simulation, optimization, visualization, and the study of uncertainty. Missing for the most part, however, are notions that are integral to the design perspective, *soft* aspects such as intentionality, purpose, and function, and the recognition of functional and other, not directly spatial, relationships that must hold among disparate physical parts. Purpose and function in particular are rarely important themes in GIS, though Couclelis (2010) suggests that they are analytically relevant in two ways: (1) as the motivations for constructing a particular plan, representation, or model; and (2) as fundamental properties of many entities commonly represented in a GIS, i.e. artificial or more generally, human-configured entities. These qualitative dimensions of the design perspective are commonly ignored in GIS applications as being ill-compatible with objective scientific analysis. However, the purposes—often conflicting—that motivate planning and design decisions, and the environmental functions that these decisions may promote or inhibit, are part and parcel of geodesign.

Planning Support Systems (PSS) emerged in the early 1990s as a response to the increasing complexity of planning in societies that value both the diversity of opinions and the scientific grounding of public decision-making (Brail and Klosterman 2001; Geertman and Stillwell 2009). They were enabled by major improvements in computational resources and geospatial data availability, and relied heavily on the rapid expansion and increasing sophistication of GIS. The main purpose of PSS is to integrate the societal and technical aspects of planning with the computational bonanza of our age, and are thus, at least in concept, one of the best incarnations of the idea of geodesign to date. But adoption of PSS has been slow, indicating problems yet to be resolved. Certain ways of thinking characteristic of design remain elusive. For example, sketch*ing*—the process, not the product—is the designer's way of working out her or his notion of the purpose of the object being designed, its function as an expression of the activities or processes that object is intended to support, and the configuration of spatial parts that will afford that function. Sketching is not about producing a design but a *concept* for a design, mixing map-like parts with diagrammatic parts, with pictorial representations, rough drawings, abstract geometric shapes, and textual annotations. While sketching, the designer will sometimes think aloud, or discuss each meaningful stroke of the pen with a colleague, cross out parts of the emerging gestalt and start over. This thinking process, which freely draws upon qualitative and quantitative, and spatial and non-spatial elements, does not easily lend itself to tool development. Equally intractable is the designer's ability to see disparate spatial parts as a *proximal space*—a spatially distributed whole connected through functional, social, ecological, and other relations. Together, the qualitative and non-spatial aspects expressed in sketching and the apprehension of proximal space are essential aspects of design, yet remain very difficult to capture in GIS-based tools (Couclelis 1991).

Missing perhaps from the geodesign literature is a view of design deriving from Simon's (1996) famous essay on "The Sciences of the Artificial". Unlike the traditional analytic sciences, the sciences of the artificial concern objects that would not have existed but for an agent's intention to serve particular purposes through a design or artifact that can support desired functions. As Simon notes, even something as simple and physical as a tin can cannot be fully described or understood unless its purpose and function as a fluid container is also taken into account. This connection between intention and product applies to any artifact, from the rough stone implement of a prehistoric society to the most advanced achievement of today's engineering. It applies equally well to non-material things such as plans and formal models, as these too are products of human ingenuity designed for a purpose. Table 6 summarizes some important contrasts between the traditional analytic sciences and the synthetic design sciences.

GIS & traditional sciences	**Design sciences**
Analysis	Synthesis
From instances to principles	From principles to instances
Causal	Goal-oriented
Descriptive	Prescriptive
Positive	Normative
IS	OUGHT

Table 6. Contrasting the dominant analytic stance of GIS with the synthetic stance of the Design sciences (source: Couclelis 2009)

The methodology outlined here proposes a systematic way to integrate such *soft* aspects of design as described above with the *hard*, science-based capabilities of today's GIS. In many ways, this proposed approach, which will be referred to as *perspectives mapping*, is similar to that of other planners and geodesigners. Best known is probably the framework developed and applied by Steinitz (2012) over several decades, and the six questions at its center. Perspectives mapping differs from this and other well-known efforts in two important respects. First, it takes seriously Simon's (1996) idea that design is a distinct kind of science, requiring a distinct approach. This contrasts with the often-ambivalent attitude towards design of even prominent practitioners. For example, Ervin (2008) wonders whether design is an art or a science or just a kind of problem solving. Secondly, perspectives mapping has direct linkages with certain more theoretical aspects of geographic information science and beyond, and could eventually benefit from these associations. These two aspects will be examined in more detail in the discussion section.

The methodology described here could be applied to the early phases of designing plans for waste management and tourism development as outlined earlier. Perspectives mapping concerns the merging of geospatial and non-geospatial information relating to the views of individual stakeholders. Its place in the overall design process is indicated in Figure 29 (top). The following section explains its relevance to the current environmental planning tasks—waste management and tourism development—and the methodology is described in section 5.2.3. Section 5.2.4 broadens the discussion and is followed by a brief conclusion.

5.2.2 Soft and hard aspects of environmental planning

The participatory mapping exercise and subsequent data analysis described in the previous chapters yielded preliminary insight into participants' perspectives regarding garbage and tourism. Specifically, they revealed which types of places are most often perceived as having garbage or not; and which types of places are socially acceptable as tourist attractions or not. They also suggested forces and behaviors that participants credit with causing the state of environmental cleanliness; and reasons that justify encouraging or restricting tourism to certain types of places. However, the surveys omitted basic questions like "What is your understanding of 'non-biodegradable garbage', and how does it affect your daily activities?" "How does tourism affect you, personally, and your community more broadly?" These questions are less amenable to mapping but just as relevant for planning systems that accommodate stakeholders' lifestyles and beliefs. To a Western audience it is given that a plastic wrapper belongs in a garbage bin, where it is bundled once a week and set out on the curb before disappearing; out of sight, out of mind. To a farmer in rural Bali, the special quality of a plastic wrapper that distinguishes it from a leaf and other materials of similar size and weight is less clear, as they all end up in the same backyard bonfire. Tourism, regarded by some progressive aid organizations as a scourge that brings environmental and cultural devastation is, in contrast, perceived by many inhabitants of West Bali as a positive force that results in cleaner, more prosperous communities.

People's perceptions—as distinct views of the world shaped by individual experiences—affect their behavior towards the environment, as do their values, attitudes, beliefs and knowledge (Stern 1992). Understanding the diverse ways that people perceive and interact with their environment, then, is crucial for designing systems to address social and environmental issues. Menjangan Island, for example, offers different amenities to different stakeholders. Its coral reefs provide fish for fishers, beautiful snorkeling and diving for tourists and indirectly the associated economic benefits of tourism to boat drivers, hotels, restaurants,

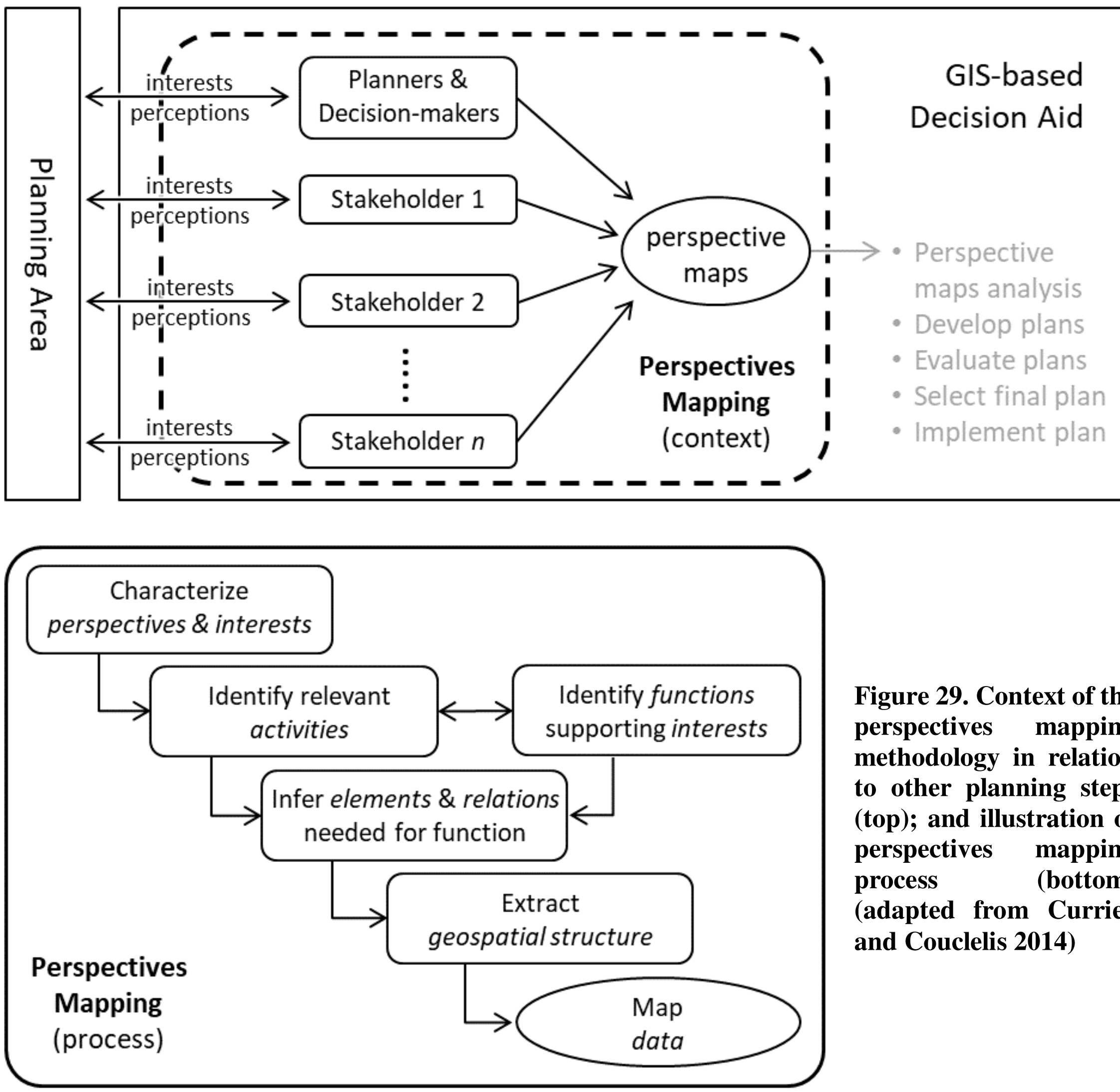


Figure 29. Context of the perspectives mapping methodology in relation to other planning steps (top); and illustration of perspectives mapping process (bottom) (adapted from Currier and Couclelis 2014)

dive shops and other local businesses. The island, itself, provides habitat for deer and birds that attract wildlife enthusiasts, and its temples and history provide spiritual enrichment for Hindu worshippers. The diverse functions that Menjangan Island supports are not obvious as attributes that would normally be found in a GIS database. Its location, extent, topography, soil type, land cover classes and administrative jurisdiction might appear as attributes of a digital object representing the island, yet none of these indicate how it functions within the larger social and biophysical world. This information is crucial to consider when designing systems that enhance, rather than inhibit, an environment's existing functions.

5.2.3 Methodology: From perspectives to maps

Most kinds of spatial planning consist of several standard phases such as collecting and analyzing data, developing and evaluating alternative plans, deciding on a plan, and implementing it (Figure 29, top). The initial phase is addressed here, focusing on the problem of deriving consistent and information-rich digital *perspective maps* from stakeholders' inputs that merge non-geospatial and geospatial information, particularly qualitative information. This methodology is inspired by Simon's (1996) vision of artifacts—plans in this case—as primarily the products of users' intentions and perspectives.

The objective of this initial phase is first, to elicit the necessary qualitative, non-geospatial information from each participant, through interviews, surveys or focus groups, and then to connect this in a systematic way with the appropriate geospatial information, eventually resulting in a digital map. Information is first collected regarding stakeholders' perceptions: their understanding of how the relevant systems function, and their analysis of the parts and relations that allow those functions to exist. Related to waste management and tourism planning, *relevant systems* include not only those necessary to support handling of garbage and operation of tourism businesses, but also those that may be affected by garbage and tourism, such as subsistence fishing, which may be displaced by marine recreation. Professionals and key experts may be treated as mega-stakeholders who contribute quantitative and qualitative information of the same kind as other participants. Their views are weighted as appropriate in later phases of the planning process. This information is documented in the context of a GIS-based decision aid (GDA) such as SeaSketch, which allows narrative text to be associated with explicit cartographic references, including individual geospatial features or entire scenes. After collecting the information from stakeholders—which may be documented in written text, recorded dialogues, hand-drawn or digital maps and other diagrams—the planning team, assisted by knowledgeable stakeholders or domain experts, as appropriate, will relate this information to available geospatial data.

Figure 29 (bottom) illustrates the workflow of this initial stage, where stakeholders are asked to provide information on the following elements:

(a) their *perspective* or *interests* related to waste management and tourism
(e.g., raising a healthy family; earning a living; practicing their religion);

(b) the *activities* that they engage in, related to these interests
(e.g., spending Sunday afternoons at the beach; taking tourists SCUBA diving; farming peanuts or raising livestock; praying);

(c) the *functions* that enable these activities
(e.g., maintain a healthy coral reef ecosystem, provide sufficient water, soil and climate for growing crops and fodder for raising livestock);

(d) the *spatial* and *non-spatial elements* that enable these activities and functions, including the necessary properties of each and their spatiotemporal relations
(e.g., public places for recreation; adequate marine transportation, personnel and shore facilities for a SCUBA dive operation; regulations that permit diving; ecological relationships that maintain a healthy coral reef; land suitable for farming;

irrigation; tree and bush species suitable for livestock fodder; freedom to engage in religious practices).

Based on the information gathered above, the planning team and knowledgeable assistants will:

(e) identify the *geospatial structure* and appropriate models that may be inferred from the information in step (d), above;
(e.g., access to shore facilities and dive sites; spatial layout of farm that provides access to irrigation and livestock fodder; pedestrian-friendly routes that connect religious facilities during special celebrations);

(f) map the relevant *geospatial data* in appropriate detail, along with the appropriate spatiotemporal granularity and extent
(e.g., national park regulatory zones; marine habitats; hydrologic, soil, landcover and topographic maps; transportation networks; cadastral boundaries; building footprints).

The maps obtained for each stakeholder or focus group will be the main inputs of the second stage of the planning process (not described here) in which stakeholders' maps are compared to identify commonalities and conflict hot spots (Figure 29, top).

5.2.4 Discussion

This methodology builds upon years of work in geodesign in the broad sense and on related areas of geographic information science, but it also contributes certain novel aspects. The emphasis on participant perspectives and intentionality is not new. Indeed, as Simon (1996) made clear, without the element of intentionality there is no design. In a planning context, Operations Research formalized this idea in the methodology of multi-objective optimization (Ligmann-Zielinska, Church, and Jankowski 2008). The collection edited by Brail and Klosterman (2001) provides several examples of PSS that take into account stakeholders' differing perspectives, and so do the methodologies developed in the fields of participatory GIS and public participation GIS (Kingston 2011; Ramasubramanian 2011). Some planning-oriented work using multi-agent models (e.g. Ligtenberg 2006) represents not only the differing interests of stakeholders but also their varying perceptions and beliefs about the design issue at hand. Finally, several different GDAs along the lines of SeaSketch support different aspects of communication among stakeholders, the expression and clarification of their ideas about a project graphically or in words, conflict resolution, and the negotiation of possible solutions (e.g. Kahila and Kyttä 2009a; Hall et al. 2010; Jankowski et al. 2016b). However, with rare exceptions, participant perspectives are treated as inputs to the geodesign process and not as an integral part of its structure.

What may be new about perspectives mapping is the notion that a direct, systematic path could be traced from a participant's intentions to geospatial data. Starting with (1) each stakeholder's characteristic interest in a specific design problem, the methodology (2) elicits information about activities relevant to each, (3) focuses on the abstract notion of *function* and associated activities corresponding to that perspective, (4) infers, in sketch form, the structure of physical and non-physical parts and relations that supports that function, (5) extracts from the above the geospatial structure underlying the function in question, and (6) implements the latter in a GIS at the appropriate spatiotemporal granularity and level of detail, to the extent allowed by available data. By contrast, the traditional representation of the planning process is one of many possible variations of the following sequence: (1) Identify and analyze problems in the study area; (2) set goals; (3) generate alternative solutions (plans); (4) evaluate plans; (5) choose a solution; (6) implement and monitor. While the last three steps also follow perspectives mapping, the first three differ in the level of specificity and amount of stakeholder participation. Planning textbooks will immediately add that there should be stakeholder participation in at least some of these steps, as is indeed legally mandated in the US and elsewhere, but there is no indication in this impersonal-sounding sequence as to how this should be done. Whose problems are identified and analyzed? Who sets the goals? How, and by whom are the alternative solutions generated? Steinitz's (2012) version of this model may be the only one that even mentions the investigation of function as one of six necessary steps.

While the feasibility and usefulness of this procedure have not been evaluated, it relates to other work in geographic information science and beyond. The methodology itself derives from a conceptual framework for geographic information ontologies proposed by Couclelis (2010), currently being formalized. The framework, which integrates analytic and design-oriented thinking, is intended to facilitate the generation of user-oriented models of different kinds that are tailored to the problem-solving context. It consists of several levels that may roughly be described as follows:

(a) What is the purpose of the model being built?

(b) How should it function?

(c) What structure is needed to get it to work in the desired way?

(d) What are the necessary parts of that structure?

(e) What information do we need to represent or build that structure?

(f) What spatiotemporal frame is most appropriate?

This sequence may be thought of as a reusable *pattern*, or as a sequence of six linked patterns, in the sense of the notion of *pattern language* as proposed in the design sciences by Alexander et al. (1977). In Alexander's words, "Each pattern describes a problem that occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice" (p. x).

This idea, born in architecture, was adopted by computer science and several other fields to denote a general solution to a recurring kind of problem that may be customized for each specific application. Recent work on ontology engineering design patterns (Gangemi and Presutti 2009), which aims at providing tools for more productive access to the wealth of information available on the web, is inspired by the same source. This broader technical interest in an idea originating in design may bode well for GIS as the geodesign support tool *par excellence*. Further, more distant connections go back to AI and the work on scripts, frames and schemas (e.g. Schank and Abelson 1977) that may also be thought of as patterns in the same sense, while automated planners such as Hierarchical Task Networks provide templates for connecting activities with functions and eventually spaces (Lekavý and Návrat 2007). These rather remote connections are mentioned as they may provide potential leads for new kinds of geodesign tools.

The methodology's emphasis on function complements work in ecology to quantify, model and valuate ecosystem services, or the benefits provided to people by ecosystems (Chan, Satterfield, and Goldstein 2012). Models that represent ecosystem components and functions, originally developed to relate ecology to economics, could be applied in perspectives mapping to help identify the geospatial footprint related to ecosystem functions. The modeling tool ARIES (Artificial Intelligence for Ecosystem Services), for example, integrates a range of deterministic, process-based and agent-based models from the physical, biological and social sciences to answer queries like "Which ecosystem services does this landscape provide, and where are they located?" (Villa et al. 2014). The planning methodology presented here may help close the circle from design to ontology engineering to AI and back to design.

5.3 Conclusion

This chapter described example plans for waste management and tourism in West Bali, derived from maps and written text gathered through a small participatory mapping experiment in which participants responded to simple, direct questions. A network of garbage cans, located primarily at schools and places of worship, and garbage collection points are proposed, to be serviced through a combination of community cooperation and professional sanitation services. While the vexing problem of post-collection garbage disposal has not yet been optimally addressed, this plan may inspire further conversation on the topic. The tourism plan proposes a sampling of accommodations, beaches and vista points, shopping areas and local cottage industries for promotion as tourist attractions, and it highlights several nature conservation areas for promotion qualified by conditions that have yet to be decided. Participants' concerns regarding the potential negative effects of tourism on wildlife and associated habitats need to be addressed in a final strategy for managing tourism to these places.

To enhance a planner's understanding of stakeholders' perspectives, a methodology was proposed for systematically integrating several of the intangible, non-geospatial or otherwise easily measurable *soft* aspects of collaborative design and planning on the one hand, with *hard* geospatial data on the other. While developed with SeaSketch in mind, the perspectives mapping methodology is quite general and should be compatible with any geodesign context that calls for translating participants' intentions, perspectives, and qualitative forms of knowledge into digital geospatial representations. Perspectives mapping traces a path from stakeholder interests to functional considerations to functional structure to the geospatial aspects of that structure, such that geospatial data of the appropriate kind, detail, dimensionality and spatiotemporal granularity corresponding to each perspective may be selected for analysis and visualization purposes. While still untested, the methodology is backed by work in geographic information science and beyond that leaves room for hope that it may be implemented as a general-purpose approach for planning and design problems.

Chapter 6
Conclusions

This dissertation grew out of an observation that maps universally prompt stories. Whether checking into a Southern California bar on Foursquare or finding one's house in Google Earth from a rural Indonesian village, people delight in connecting places on the map with their own experiences. This may be one reason that maps are so useful in collaborative planning; they remind people of their own personal relationship to a place and encourage them to imagine how that relationship may change in the future, for better or worse. The visually rich, interactive digital maps that augment sub-meter satellite imagery with street networks and other layers support daily decision-making in developed Western countries, from where to get lunch to how to evacuate flood victims.

To explore these benefits in the context of a non-Western developing country this dissertation began with two questions: *What opportunities and challenges do Web-based tools for participatory mapping present in a place where laptop and desktop computers are uncommon?* and *What methodological, technological and analytical modifications are necessary to produce results that are useful in a non-Western planning context?* They were addressed through an ethnographic case study that invited locals and residents of rural Bali, Indonesia to participate in two Web-based surveys with strong mapping components. The surveys asked participants to describe their perceptions and opinions regarding litter in the environment and the future of tourism in West Bali. The participants' responses, which consisted of annotated maps, were interpreted by combining a popular spatial analysis technique—kernel density mapping—with two text mining techniques—word clouds and topic modeling. The resulting visualizations illustrated general themes—like *civic responsibility* and *marine resources*—extracted from participants' written descriptions and related those themes to the spatial pattern of mapped features. From these interpretations, two simple plans were proposed, one to address waste management and the other to address tourism development in West Bali. Finally, a methodology for collaborative planning that might improve upon the simple approach tested here was described. Called *perspectives mapping*, the methodology suggests a process for explicitly incorporating intangible elements such as a stakeholder's values, purposes and environmental functions they require into a geospatial planning framework.

6.1 Contributions of the dissertation

As an ethnographic case study, the participatory mapping exercise suggested several generalizations that can be drawn regarding the effects of cultural context and level of computer experience on participants' experience and responses. Among the numerous benefits of participatory mapping described in the literature, like improving participants' geographic knowledge of local resources (Meta and Ironside 2005), a sense of accomplishment upon completing the Web-based mapping task was observed among participants who had little or no prior computer experience. Observation suggested that this outcome was strongly tied to the process of learning—and struggling, in some cases—to operate the hardware and software required to complete the task. The experience also motivated one participant to want to improve the basemap used in SeaSketch, perhaps recognizing it as an information resource whose utility extends to the greater public, beyond these individual surveys. Whether the same response would be inspired by paper maps—perhaps more perceptually ephemeral than a distributed electronic resource—is questionable. This experiment demonstrated that people with little or no prior computer experience could successfully complete—and perhaps even enjoy—a Web-based participatory mapping survey, the most optimistic of any of the results presented here.

The digital approach to participatory mapping in this context is not without challenges, however. The study confirmed that preparation is time-consuming, including securing necessary legal and social permissions; training assistants; designing a survey that is pertinent and appropriate to the local context, which can only be accomplished through a solid understanding of local geography and culture; and recruiting a participant pool that represents the population in terms of age, gender, level of technical expertise and other demographic variables. Certainly, these challenges are well understood by veteran environmental and humanitarian development professionals but may too often be overlooked by researchers on a limited fieldwork schedule.

Adapting a Web-based participatory mapping exercise to a non-Western, developing country context requires both technological and conceptual considerations. A Web-based survey administered in the US implies individual participation, more responses and reduced data-collection effort compared to interviews, meetings or other traditional (offline) means of gathering information. However, in a place where computer literacy is low and hardware is scarce, some of these advantages are lost—hardware, Internet connections and training must be provided, making the exercise more similar in practice to the face-to-face methods that the Internet is meant to circumvent. Collaboration between participants violates the principle of independent responses so often assumed in survey research. However, the benefits of collaboration in this context—enabling individuals with little or no prior computer experience to participate—make it worth a researcher's time to adjust how the results are interpreted, rather than attempting to eliminate collaboration. When participants in a planning process come from different cultural backgrounds, communication of *tacit*, or implied, knowledge is even more critical than within a more homogeneous group. Here, considerable thought and effort were required to explain the concept of *litter* as non-biodegradable garbage in the environment. Even so, whether the concept achieved universal understanding among participants is doubtful.

Culture as a variable has been studied in cognitive and behavioral geography as it affects map reading; for example, it has been shown to affect how people interpret components of visual maps such as color and iconic symbols (Madden, Hewett, and Roth 2000; Slocum et al. 2001) as well as map-reading ability (Chang and Antes 1987). This study suggested some corresponding differences in the way participants represent places on maps—Indonesian-language participants used lines and areas much more frequently than English participants, who used points almost exclusively. This result may indicate differences in the way the two groups conceptualize place types, a generalization that would need wider testing across a broader spectrum of participants to confirm.

Level of computer experience might be assumed to correlate positively with accuracy in a digital mapping task; however, this was not observed here. Computer experience appeared to have little or no effect on participants' ability to map features in the correct location. Computer experience did, however, correlate positively with the total number of features drawn by participants; the more experienced the participant, the more features he or she tended to map. This finding has implications for planners and researchers who use digital map-based responses to draw conclusions about a population's opinions and perceptions; the conclusions may be biased in favor of more computer savvy participants unless responses are normalized.

The perspectives mapping methodology proposed here addresses the critique that cultural values must be spatially referenced to be considered alongside biophysical data for environmental planning, despite the fact that some values are not amenable to mapping (Ruiz-Frau, Edwards-Jones, and Kaiser 2011; Chan, Satterfield, and Goldstein 2012). Rather than asking stakeholders to attach geographic coordinates to intangible information outright, the method suggests a series of questions designed to trace a path from the stakeholders' perspectives on an issue to the geospatial structure implied by their values, purposes and activities and the environmental functions that support them.

To address the practical task of interpreting annotated participatory maps, a challenge faced in both environmental planning and survey research, an analytical approach that combines density mapping and text mining was demonstrated. The ability to create word clouds on the fly in SeaSketch—perhaps by outlining an area of interest that encompasses other participants' mapped responses—might encourage participants to explore content contributed by others, thus further engaging them in a planning process. Especially in cases where sharing participants' raw responses might compromise confidentiality, word clouds provide a veneer of obfuscation while revealing words that hint at popular topics associated with a location. Topic modeling achieves this, too—more effectively in some ways, as words that are mentioned less frequently are preserved—yet the manual effort required to generate and select an appropriate topic model make this approach impractical to implement as an automated tool. By combining topic modeling with weighted density mapping, however, the results can clarify reasons for apparent conflict in a location and suggest lists of related words that participants associate with geographic areas. In situations with many hundreds or thousands of mapped responses, this combination of spatial and text analysis methods may help planners identify common themes across the responses, along with their areas of geographic relevance.

In conjunction with this analysis, a simple technique for generating density maps from combined point, line and area data was demonstrated. By representing areas as a grid of evenly spaced points, and lines as a series of evenly spaced points, features of all three geometry types can be modeled as a raster surface with kernel density estimation and a few extra steps to normalize the values of each feature.

6.2 Limitations

The conclusions regarding cultural context and computer experience in Web-based participatory mapping described above are preliminary, based on a small sample of participants. Stronger conclusions regarding the effects of culture could be made if a greater number of English-language participants had been recruited, instead of the four-to-one, Indonesian- to English-language participant ratio that manifested for this study. The individuals who participated—both Indonesian- and English-language—represented a specialized sample of the population that lives in and visits West Bali. Only individuals who were willing to complete a computer-based survey were represented, which likely excluded a portion of the local population who were not comfortable using this technology. The surveys were only available in the Indonesian and English languages, excluding those who speak only Balinese. The snowball sampling method recruited participants who were more likely to have connections to the American non-profit organization with which the researcher is affiliated, or to political leadership in West Bali, both characterizing positions of relatively high status within the community. A gender and age class imbalance, particularly among Indonesian-language participants, who were mostly male, further biased the sample. As an ethnographic case study, the participatory mapping exercise suggested some interesting conclusions regarding the influence of culture and computer literacy on cartographic choices. However, an actual collaborative planning effort would need much broader participation to qualify as truly collaborative.

The participatory mapping responses were not, in many cases, independent from one another for the reasons discussed above. Collaboration between participants may have caused certain places to be over-represented as ideas spread. This invalidates any strong conclusions based on inferential statistics, but as an observation it represents a useful characteristic of participation in computer-based surveys in this cultural context. Researchers and planners need to consider it when interpreting their results.

Conclusions drawn about participants' experiences using SeaSketch—e.g., that they may have felt a sense of accomplishment—were based on observation, not on direct feedback. A follow-up questionnaire about the user experience would provide more comprehensive and reliable information regarding participants' use of the tool.

Methodologically, the process of selecting a topic model for any analysis usually involves a subjective decision, and a different model may suggest different interpretations of the data. While the procedure for selecting a model followed here partially relied on quantitative evaluation in the form of C_V coherence scores, choice of the final model relied on the researcher's intuition. The intuition depended on a familiarity with the data to identify a model that "looked right"—consequently, confirming interpretations of the data that the researcher had already begun to adopt. If, instead, a topic model was selected at random, the themes suggested by the model, and their geographic footprints, may have looked somewhat different.

6.3 Future research

A sensitivity analysis that tested the effect of topic model selection on the resulting geovisualizations (weighted density maps) and topic term lists would be useful to further evaluate the analysis method described in Chapter 4. Topic modeling is typically applied to corpora that are much larger than the ones analyzed here, which each consisted of around 150 text descriptions containing a total of around 1800 words. Few guidelines are provided in the literature regarding the appropriate size of corpus for this technique, though presumably its utility increases as the corpus size increases. Above a certain threshold size, a human's ability to read and retain information from text is compromised, making topic modeling useful as a text summarization and classification technique. When applied as a component of the analysis described here, what is the minimum size of corpus where interpretation of the data based on topic modeling outperforms simple reading and studying of the raw text responses? For small datasets—probably including the ones collected in this study—the time and effort required to perform topic modeling may not justify the benefits.

Another type of sensitivity analysis—sensitivity to locational error in features mapped by participants—would benefit planners who rely on density maps to infer stakeholders' perceptions or opinions about an issue. How would the density maps generated in this study have changed if the feature maps had been corrected for locational error first? Often in participatory mapping studies, the things being mapped are difficult or impossible to ground truth—landscape values, for example (Alessa, Kliskey, and Brown 2008). Here, however, approximately 80% of the point features were validated, and nearly 30% of those features were found to be mapped with measurable error. These errors could be corrected and the kernel density analysis re-run to generate a second set of density maps for comparison with the uncorrected maps to determine if they suggest different geographic conclusions.

The decision to allow lines and areas in addition to points for representing places complicates data analysis, particularly density mapping, yet it provides flexibility to participants. What consequences for data analysis and interpretation do different feature geometry options entail? When the same place is represented as a point by one participant and an area by another, kernel density maps generated from each may look nothing alike. Brown and Pullar (2012) discuss considerations for participatory mapping with exclusively points vs. exclusively areas, yet analysis of mixed-geometry participatory maps has not been well characterized.

The influence of mapping medium—digital vs. analogue—on the participatory mapping process and respondent pool is worth exploring. If potential participants were offered a choice to respond using either a computer-based or a paper-based mapping survey, which would be more popular, and with whom? Would people tend to spend different amounts of time exploring the maps and preparing their responses? A comparative study of participatory mapping media might further characterize the benefits and drawbacks of each method.

No test of map-reading ability was administered in this study, but previous observations by the researcher suggested that kite aerial photography and follow-up activities with aerial photographs help some people understand the orthographic perspective typically employed by maps. Testing this hypothesis, perhaps by administering before and after tasks that ask participants to map several well-known places might confirm whether, in fact, this activity fosters map-reading skills.

The mapping survey on garbage could be expanded into a cultural domain analysis, or study of how a culture determines the categorical membership of things (Zacharias, MacMillan, and Van Hemel 2008). In the *matter out of place* model of garbage perception, location and context strongly influence what constitutes *garbage* (Douglas 1966). The places described by participants as having garbage or not could be classified into types—for example, public vs. private, or touristic vs. non-touristic—to determine whether Indonesian- and English-language speakers differed in their tendency to associate certain places with dirtiness or cleanliness. A more objective analysis would attempt to quantify the amount of non-biodegradable garbage (as this was the description invoked in the survey) at each place named by participants to compare their perceptions to an objective measure. A more nuanced understanding of *garbage* as perceived by the Balinese might help well-meaning but naïve international aid organizations design more effective anti-litter campaigns in Bali and Indonesia, in general.

The challenge to understand individuals' perspectives—on litter, tourism development or any environmental issue—motivates the perspectives mapping methodology proposed here. The methodology, as of yet a set of ideas, needs testing in a planning situation for both practicality and utility. Perhaps ultimately it will encourage planners to consider notions of value, purpose, and function—intangible elements that motivate human behavior—to more fully realize the benefits of mapping perspectives for environmental planning.

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Appendix A

Survey Text
Extracted from SeaSketch

Following is the text of all questions and answer choices for the garbage and tourism surveys, including English and Indonesian versions. Nested bullet points indicate questions and answer choices that appear only if the preceding answer choice is selected. Free-text response fields are represented with a box: [ ]

Trash Management Survey

This survey is intended to collect information and opinions regarding trash in the environment of West Bali while introducing participants to SeaSketch's map drawing tools. You may take this survey as many times as you would like.

Purpose

You are invited to participate in a survey regarding perceptions of trash in the environment of West Bali. This information is being collected as part of a planning effort to consider the future of West Bali's Menjangan–Batu Ampar Tourism Area (Kawasan Pariwisata Menjangan–Batu Ampar). This effort is supported by Biosphere Foundation (www.biospherefoundation.org), which has provided the SeaSketch online mapping and survey tool you are now using.

If you choose to participate, you will be asked several questions about trash in West Bali. You will have the option of answering with short text descriptions, marking locations on a map, and uploading photographs.

Completing this survey should take approximately 5–10 minutes.

Responses to this survey will be shared with representatives of the Association of Youth Who Care About Pejarakan Tourism (*Ikatan Pemuda Peduli Pariwisata Pejarakan*), who are planning how to develop tourism in Pejarakan while preserving its art, culture and environment. Anonymized responses may be included in reports or other public documents. No personally identifying information collected through your use of SeaSketch will be released outside of the personnel administering this survey.

There are no anticipated risks to your participation in this survey.

Your responses to all survey questions are voluntary, and you may stop participating at any time.

Use of Responses in Research

If you allow, your responses may be used in research to study how maps drawn by participants in an environmental planning process can be used to understand different opinions.

You will receive no compensation, and there is no direct benefit to you anticipated from your participation in the study.

While no personally identifying information collected in this study will be publicly released, absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena.

This research has been approved by the Ministry of Research and Technology (Kementerian Riset Teknologi dan Pendidikan Tinggi) under permit no. 442/SIP/FRP/E5/Dit.KI/CI/2015. If you have any questions about this project please contact Kitty Currier at +65 812 3709 7510 or currier@geog.ucsb.edu.

If you have any questions regarding your rights as a research subject, please contact the Human Subjects Committee at +1 805 893 3807, or hsc@research.ucsb.edu, or write to the University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050.

Participation in research is voluntary. Your selection below will indicate your decision to participate as a research subject in the study described above.

- I allow my responses to be used in the research described above.
- I do NOT allow my responses to be used in the research described above.

Please indicate your age:

- I am 15 or older.
- I am under 15. (Individuals under 15 may participate, but their responses will not be used in research.)

Your Full Name: [ ]

Your Email Address: [ ]

Is another person operating the computer for you during this survey?

- Yes
    - Name of operator: [ ]
- No

Survey: Trash in West Bali

To your knowledge, which places in West Bali have a lot of non-biodegradable trash in the environment? (E.g., plastic bottles, plastic bags, old tires, etc.) (Add as many points to the map as you would like.)

- [Add a feature]
  - Location Name: [ ]
  - Description of location & problem (optional) (E.g. "During the rainy season there's a lot of plastic trash on the beach."): [ ]

Which places in West Bali have little or no trash that is non-biodegradable in the environment? (Add as many points to the map as you would like.)

- [Add a Feature]
  - Location Name: [ ]
  - Description of location (optional): [ ]

Do you know where any landfills and/or trash banks (places where recyclables can be exchanged for money) are located in West Bali?

- Yes
  - Draw a shape on the map around a landfill or trash bank in West Bali.
    - [Add a Feature]
      - Location Name: [ ]
      - This area is a:
        - Landfill
        - Trash bank
- No
  - Draw a shape on the map around an area that could be used as a landfill or trash bank in West Bali.
    - [Add a Feature]
      - Location Name: [ ]
      - This area could be used as a:
        - Landfill
        - Trash bank

Draw a line on the map that shows a possible route from a place with trash to a landfill or trash bank that you drew on the map.

- [Add a Feature]
  - Location Name: [ ]

Tourism Planning Survey

You are invited to participate in a survey regarding tourism in West Bali.

Purpose

You are invited to participate in a survey regarding tourism West Bali. This information is being collected as part of a planning effort to consider the future of West Bali's Menjangan–Batu Ampar Tourism Area (Kawasan Pariwisata Menjangan–Batu Ampar). This effort is supported by Biosphere Foundation (www.biospherefoundation.org), which has provided the SeaSketch online mapping and survey tool you are now using.

If you choose to participate, you will be asked several questions about yourself and your opinions regarding tourism development in West Bali. You will have the option of answering with short text descriptions and by marking locations on a map.

Completing this survey should take approximately 10 minutes.

Responses to this survey will be shared with representatives of the Association of Youth Who Care About Pejarakan Tourism (Ikatan Pemuda Peduli Pariwisata Pejarakan), who are planning how to develop tourism in Pejarakan while preserving its art, culture and environment. Anonymized responses may be included in reports or other public documents. No personally identifying information collected through your use of SeaSketch will be released outside of the personnel administering this survey.

There are no anticipated risks to your participation in this survey.

Your responses to all survey questions are voluntary, and you may stop participating at any time.

Use of Responses in Research

If you allow, your responses may be used in research to study how maps drawn by participants in an environmental planning process can be used to understand different opinions.

You will receive no compensation, and there is no direct benefit to you anticipated from your participation in the study.

While no personally identifying information collected in this study will be publicly released, absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena.

This research has been approved by the Ministry of Research and Technology (Kementerian Riset Teknologi dan Pendidikan Tinggi) under permit no. 442/SIP/FRP/E5/Dit.KI/CI/2015. If you have any questions about this project please contact Kitty Currier at +65 812 3709 7510 or currier@geog.ucsb.edu.

If you have any questions regarding your rights as a research subject, please contact the Human Subjects Committee at +1 805 893 3807, or hsc@research.ucsb.edu, or write to the University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050.

Participation in research is voluntary. Your selection below will indicate your decision to participate as a research subject in the study described above.

- I allow my responses to be used in the research described above.
- I do NOT allow my responses to be used in the research described above.

Please indicate your age:

- I am 15 or older.
- I am under 15. (Individuals under 15 may participate, but their responses will not be used in research.)

Your Full Name: [ ]

Your Email Address: [ ]

Is another person operating the computer for you during this survey?

- Yes
    - Name of operator: [ ]
- No

Survey: Demographic Information

Are you male or female?

- Male
- Female

How old are you?

- Under 15
- 15–25
- 26–40
- Over 40

Where do you live?

- Pejarakan Village
  - In which dusun do you live?
    - Batu Ampar
    - Marga Garuda
    - Banyuwedang
    - Goris Induk
    - Goris Pasar
    - Goris Kemiri
    - Goris Asri
    - Sandi Kerta
    - Pejarakan
- Pemuteran Village
- Sumber Kima Village
- Sumber Klampok Village
- Gilimanuk Village
- Other location in Gerokgak District
- Other location in Buleleng or Jembrana regencies

- Other location in Bali (outside Buleleng and Jembrana)
    - How often do you visit West Bali?
        - I have never been to West Bali
        - Just once or twice; I do not visit regularly
        - Rarely: once a year or less
        - Sometimes: a few times per year
        - Often: at least once a month
- Other location outside Bali
    - How often do you visit West Bali?
        - I have never been to West Bali
        - Just once or twice; I do not visit regularly
        - Rarely: once a year or less
        - Sometimes: a few times per year
        - Often: at least once a month

What is your primary occupation? [ ]

Where do you work? (Select all that apply.)

- Pejarakan Village
- Pemuteran Village
- Sumber Kima Village
- Sumber Klampok Village
- Gilimanuk Village
- Other location in Gerokgak District
- Other location in Buleleng or Jembrana regencies
- Other location in Bali (outside Buleleng and Jembrana)
- Other location outside Bali

Have you ever used Google Maps on a smartphone or other device?

- Yes
    - How often do you use Google Maps?
        - Rarely: once a month or less
        - Sometimes: about once a week
        - Often: more than once a week
- No

Have you ever used a computer before today?

- Yes
  - How often do you use a computer?
    - Rarely: once a month or less
    - Sometimes: about once a week
    - Often: more than once a week
- No

Survey: Future of Tourism in West Bali

Would you like the number of tourists who visit West Bali to:

- Increase
- Stay about the same as it is now
- Decrease
- I don't know/care

In west Bali, which places should be PROMOTED as tourist attractions? (Below, select which type of place—Point, Line or Area—you wish to draw on the map.)

- Add a Point for a place to promote.
    - [Add a Feature]
        - Name: [ ]
        - Possible activities for tourists at this place: (Select all that apply.)
            - Relaxing
            - Trekking
            - Snorkeling/diving
            - Fishing
            - Wildlife viewing
            - Shopping
            - Observing local traditions/customs
            - Viewing art/architecture
            - Dining
            - Accommodations
            - Praying
            - Other (please describe below)
                - Other activities: [ ]
        - Description: [ ]

- Add a Line for a place to promote.
    - [Add a Feature]
        - Name: [ ]

- Possible activities for tourists at this place: (Select all that apply.)
  - Relaxing
  - Trekking
  - Snorkeling/diving
  - Fishing
  - Wildlife viewing
  - Shopping
  - Observing local traditions/customs
  - Viewing art/architecture
  - Dining
  - Accommodations
  - Praying
  - Other (please describe below)
    - Other activities: [ ]
- Description: [ ]

- Add an Area for a place to promote.
  - [Add a Feature]
    - Name: [ ]
    - Possible activities for tourists at this place: (Select all that apply.)
      - Relaxing
      - Trekking
      - Snorkeling/diving
      - Fishing
      - Wildlife viewing
      - Shopping
      - Observing local traditions/customs
      - Viewing art/architecture
      - Dining
      - Accommodations
      - Praying
      - Other (please describe below)
        - Other activities: [ ]
    - Description: [ ]

In West Bali, at which places should tourism be RESTRICTED or PROHIBITED? (Below, select which type of place—Point, Line or Area—you wish to draw on the map.)

- Add a Point for a place to restrict or prohibit.
  - [Add a feature]
    - Name: [ ]
    - Reason(s) for restricting or prohibiting tourism here: [ ]
- Add a Line for a place to restrict or prohibit.
  - [Add a feature]
    - Name: [ ]
    - Reason(s) for restricting or prohibiting tourism here: [ ]
- Add an Area for a place to restrict or prohibit.
  - [Add a feature]
    - Name: [ ]
    - Reason(s) for restricting or prohibiting tourism here: [ ]

Survei Pengelolaan Sampah

Survei ini bertujuan untuk mengumpulkan informasi dan opini mengenai sampah di sekitar lingkungan Bali Barat, serta memperkenalkan peserta pada alat penggambar peta SeaSketch. Anda dapat mengambil survei ini sebanyak anda suka.

Tujuan

Anda diajak untuk berpartisipasi di dalam sebuah survei mengenai pandangan anda terhadap sampah di daerah Bali Barat. Informasi ini dikumpulkan sebagai data tambahan yang nantinya akan digunakan untuk mendukung perencanaan dari Kawasan Pariwisata Menjangan–Batu Ampar di masa yang akan datang. Survei ini didukung oleh Yayasan Biosphere (www.biospherefoundation.org) yang menyediakan SeaSketch peta online dan perangkat survei yang sekarang gunakan.

Jika anda memilih untuk berpartisipasi, anda akan ditanya beberapa pertanyaan tentang sampah di Bali Barat. Anda boleh memilih untuk menjawab dengan jawaban pendek, menandai lokasi di peta, dan mengunggah foto-foto.

Melengkapi survei ini akan menghabiskan waktu sekitar 5–10 menit.

Jawaban dari survei ini akan diberikan kepada Ikatan Pemuda Peduli Pariwisata Pejarakan, yang mengembangkan pariwisata di Pejarakan dengan cara pelestarian seni, budaya dan lingkungan. Identitas anda bersifat rahasia, tetapi respon anda mungkin akan dimasukkan pada laporan kami atau dokumen lainnya yang bersifat terbuka untuk umum. Tidak ada data pribadi yang didapat dalam penggunaan SeaSketch yang akan dipublikasikan atau disalahgunakan.

Tidak ada risiko yang terantisipasi dalam partisipasi anda pada survei ini.

Respons anda pada semua pertanyaan survei adalah sukarela, dan anda bisa menghentikan partisipasi anda kapan saja.

Penggunaan Respons pada Penelitian

Jika anda mengizinkan, respon anda mungkin akan digunakan dalam penelitian mengenai bagaimana penggunaan peta yang dibuat oleh orang yang berpartisipasi dalam proses rencana lingkungan bisa digunakan untuk memahami pendapat masyarakat yang berbeda-beda.

Anda tidak akan menerima kompensasi apa-apa, dan tidak ada keuntungan langsung yang anda dapatkan dari partisipasi anda di studi ini.

Walaupun data informasi pribadi yang dikumpulkan pada studi ini tidak akan dipublikasikan, kami tidak bisa benar-benar menjamin kerahasiaannya, karena dokumen penelitian tidak terlindungi dari Somasi hukum.

Penelitian ini sudah disetujui oleh Kementerian Riset Teknologi dan Pendidikan Tinggi dengan ijin nomor 442/SIP/FRP/E5/Dit.KI/CI/2015. Jika anda ada pertanyaan tentang penelitian ini, silakan hubungi Kitty Currier melalui telepon: +65 812 3709 7510 atau email: currier@geog.ucsb.edu.

Jika anda memiliki pertanyaan sehubungan dengan hak anda sebagai subjek penelitian, silakan hubungi Human Subjects Committee melalui telepon: +1 805 893 3807; email: hsc@research.ucsb.edu; atau kirim surat ke University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050.

Partisipasi anda dalam penelitian ini adalah sukarela. Pilihan anda di bawah ini akan menunjukkan keputusan anda untuk berpartisipasi sebagai subjek penelitian dalam studi yang dijelaskan di atas.

- Saya mengizinkan respons saya untuk digunakan di dalam penelitian seperti dijelaskan di atas.
- Saya TIDAK mengizinkan respons saya untuk digunakan di dalam penelitian seperti dijelaskan di atas.

Mohon sebutkan umur anda:

- Saya 15 tahun atau lebih.
- Saya kurang dari 15 tahun. (Orang di bawah 15 tahun bisa berpartisipasi, tetapi responsnya tidak akan digunakan pada penelitian.)

Apakah orang lain mengoperasi komputer untuk anda selama survei ini?

- Ya
    - Nama operator: [ ]
- Tidak

Nama lengkap anda: [ ]

Alamat email anda: [ ]

Survei: Sampah di Bali Barat

Sepengetahuan anda, tempat mana di Bali Barat yang memiliki banyak sampah anorganik di lingkungannya? (Contohnya: botol plastik, tas plastik, ban bekas, dan lain-lain.) (Tambahkan titik sebanyak-banyaknya di peta.)

- [Tambah Fitur]
  - Nama Lokasi: [ ]
  - Deskripsi dari lokasi dan masalah (opsional) (Contoh: "Selama musim hujan ada banyak sampah plastik di pantai."): [ ]

Tempat mana di Bali Barat yang memiliki sedikit, bahkan tidak memiliki sampah anorganik di lingkungannya? (Tambahkan titik sebanyak-banyaknya di peta.)

- [Tambah Fitur]
  - Nama Lokasi: [ ]
  - Deskripsi dari lokasi (opsional): [ ]

Apakah anda mengetahui di mana Tempat Pembuangan Akhir (TPA) sampah dan / atau Bank Sampah (tempat di mana sampah yang bisa didaur ulang dapat ditukarkan dengan uang) bertempat di Bali Barat?

- Ya
  - Gambarkan sebuah bentuk di peta yang menunjukkan TPA atau bank sampah di Bali Barat.
    - [Tambah Fitur]
      - Nama Lokasi: [ ]
      - Daerah ini adalah:
        - TPA
        - Bank sampah

- Tidak
    - Gambarkan sebuah bentuk di peta tentang tempat yang bisa digunakan sebagai TPA atau bank sampah di Bali Barat.
        - [Tambah Fitur]
            - Nama Lokasi: [ ]
            - Daerah ini bisa digunakan sebagai:
                - TPA
                - Bank sampah

Gambarkan garis di peta yang menunjukkan kemungkinan rute dari satu tempat sampah ke TPA/bank sampah yang sudah anda buat di peta.

- [Tambah Fitur]
    - Nama [ ] Lokasi:

Survei Perencanaan Pariwisata

Anda diajak untuk berpartisipasi di dalam sebuah survei tentang pariwisata di Bali Barat.

Tujuan

Anda diajak untuk berpartisipasi di dalam sebuah survei tentang pariwisata di Bali Barat. Informasi ini dikumpulkan sebagai data tambahan yang nantinya akan digunakan untuk mendukung perencanaan dari Kawasan Pariwisata Menjangan–Batu Ampar di masa yang akan datang. Survei ini didukung oleh Yayasan Biosphere (www.biospherefoundation.org) yang menyediakan SeaSketch peta online dan perangkat survei yang sekarang gunakan.

Jika anda memilih untuk berpartisipasi, anda akan ditanya beberapa pertanyaan tentang diri anda dan pendapat anda tentang pengembangan pariwisata di Bali Barat. Anda boleh memilih untuk menjawab dengan jawaban pendek, menandai lokasi di peta, dan mengunggah foto-foto.

Melengkapi survei ini akan menghabiskan waktu sekitar 10 menit.

Jawaban dari survei ini akan diberikan kepada Ikatan Pemuda Peduli Pariwisata Pejarakan, yang mengembangkan pariwisata di Pejarakan dengan cara pelestarian seni, budaya dan lingkungan. Identitas anda bersifat rahasia, tetapi respon anda mungkin akan dimasukkan pada laporan kami atau dokumen lainnya yang bersifat terbuka untuk umum. Tidak ada data pribadi yang didapat dalam penggunaan SeaSketch yang akan dipublikasikan atau disalahgunakan.

Tidak ada risiko yang terantisipasi dalam partisipasi anda pada survei ini.

Respons anda pada semua pertanyaan survei adalah sukarela, dan anda bisa menghentikan partisipasi anda kapan saja.

Penggunaan Respons pada Penelitian

Jika anda mengizinkan, respon anda mungkin akan digunakan dalam penelitian mengenai bagaimana penggunaan peta yang dibuat oleh orang yang berpartisipasi dalam proses rencana lingkungan bisa digunakan untuk memahami pendapat masyarakat yang berbeda-beda.

Anda tidak akan menerima kompensasi apa-apa, dan tidak ada keuntungan langsung yang anda dapatkan dari partisipasi anda di studi ini.

Walaupun data informasi pribadi yang dikumpulkan pada studi ini tidak akan dipublikasikan, kami tidak bisa benar-benar menjamin kerahasiaannya, karena dokumen penelitian tidak terlindungi dari Somasi hukum.

Penelitian ini sudah disetujui oleh Kementerian Riset Teknologi dan Pendidikan Tinggi dengan ijin nomor 442/SIP/FRP/E5/Dit.KI/CI/2015. Jika anda ada pertanyaan tentang penelitian ini, silakan hubungi Kitty Currier melalui telepon: +65 812 3709 7510 atau email: currier@geog.ucsb.edu.

Jika anda memiliki pertanyaan sehubungan dengan hak anda sebagai subjek penelitian, silakan hubungi Human Subjects Committee melalui telepon: +1 805 893 3807; email: hsc@research.ucsb.edu; atau kirim surat ke University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050.

Partisipasi anda dalam penelitian ini adalah sukarela. Pilihan anda di bawah ini akan menunjukkan keputusan anda untuk berpartisipasi sebagai subjek penelitian dalam studi yang dijelaskan di atas.

- Saya mengizinkan respons saya untuk digunakan di dalam penelitian seperti dijelaskan di atas.
- Saya TIDAK mengizinkan respons saya untuk digunakan di dalam penelitian seperti dijelaskan di atas.

Mohon sebutkan umur anda:

- Saya 15 tahun atau lebih.
- Saya kurang dari 15 tahun. (Orang di bawah 15 tahun bisa berpartisipasi, tetapi responsnya tidak akan digunakan pada penelitian.)

Apakah orang lain mengoperasi komputer untuk anda selama survei ini?

- Ya
    - Nama operator: [ ]
- Tidak

Nama lengkap anda: [ ]

Alamat email anda: [ ]

Survei: Informasi Demografi

Apakah anda laki-laki atau perempuan?

- Laki
- Perempuan

Berapa usia anda?

- Di bawah 15 tahun
- 15–25 tahun
- 26–40 tahun
- Di atas 40 tahun

Di mana anda tinggal?

- Desa Pejarakan
  - Anda tinggal di daerah dusun mana?
    - Batu Ampar
    - Marga Garuda
    - Banyuwedang
    - Goris Induk
    - Goris Pasar
    - Goris Kemiri
    - Goris Asri
    - Sandi Kerta
    - Pejarakan
- Desa Pemuteran
- Desa Sumber Kima
- Desa Sumber Klampok
- Desa Gilimanuk
- Di luar desa-desa di atas, masih di Kecamatan Gerokgak
- Di luar Kecamatan Gerokgak, masih di Kabupaten Buleleng atau Kabupaten Jembrana

- Di luar Kabupaten Buleleng dan Kabupaten Jembrana, masih di Bali
    - Seberapa sering anda mengunjungi Bali Barat?
        - Saya belum pernah ke Bali Barat.
        - Hanya sesekali, saya tidak sering mengunjunginya.
        - Jarang: sekali setahun atau kurang.
        - Terkadang: beberapa kali dalam setahun.
        - Sering: setidaknya sekali dalam sebulan.
- Di luar Bali
    - Seberapa sering anda mengunjungi Bali Barat?
        - Saya belum pernah ke Bali Barat.
        - Hanya sesekali, saya tidak sering mengunjunginya.
        - Jarang: sekali setahun atau kurang.
        - Terkadang: beberapa kali dalam setahun.
        - Sering: setidaknya sekali dalam sebulan.

Apa pekerjaan utama anda? [ ]

Di mana anda bekerja? (Pilih semua yang sesuai.)

- Desa Pejarakan
- Desa Pemuteran
- Desa Sumber Kima
- Desa Sumber Klampok
- Desa Gilimanuk
- Di luar desa-desa di atas, masih di Kecamatan Gerokgak
- Di luar Kecamatan Gerokgak, masih di Kabupaten Buleleng atau Kabupaten Jembrana
- Di luar Kabupaten Buleleng dan Kabupaten Jembrana, masih di Bali
- Di luar Bali

Pernakah anda menggunakan Google Maps pada smartphone atau alat elektronik lainnya?

- Sudah
  - Seberapa sering anda menggunakan Google Maps?
    - Jarang: sebulan sekali bahkan kurang
    - Kadang-kadang: kira-kira seminggu sekali
    - Sering: lebih dari sekali dalam seminggu
- Belum

Apakah anda sudah pernah menggunakan komputer sebelumnya?

- Sudah
  - Seberapa sering anda menggunakan komputer?
    - Jarang: sebulan sekali bahkan kurang
    - Kadang-kadang: kira-kira seminggu sekali
    - Sering: lebih dari sekali dalam seminggu
- Belum

Survei: Masa Depan Pariwisata di Bali Barat

Apakah anda ingin jumlah kunjungan turis ke Kawasan Bali Barat untuk:

- Meningkat
- Tetap seperti sekarang
- Menurun
- Saya tidak tahu/peduli

Di Bali Barat, tempat mana yang harus DIPROMOSIKAN sebagai daya tarik pariwisata? (Di bawah ini, silakan pilih tempat mana—Titik, Garis, atau Daerah—yang anda inginkan untuk gambar di peta.)

- Tambahkan sebuah Titik untuk tempat yang dipromosikan.
  - o [Tambah Fitur]
    - ▪ Nama: [ ]
    - ▪ Aktivitas yang mungkin untuk wisatawan di tempat ini (Pilih dan tandai aktivitas, boleh lebih dari satu.):
      - Santai
      - Trekking
      - Snorkeling/diving
      - Memancing
      - Melihat binatang liar
      - Belanja
      - Melihat tradisi/budaya lokal
      - Melihat seni/arsitektur
      - Makan
      - Akomodasi
      - Sembahyang
      - Lain-lain (silakan jelaskan)
        - o Aktivitas Lain: [ ]
    - ▪ Penjelasan: [ ]

- Tambahkan sebuah Garis untuk tempat yang dipromosikan.
    - [Tambah Fitur]
        - Nama:
        - Aktivitas yang mungkin untuk wisatawan di tempat ini (Pilih dan tandai aktivitas, boleh lebih dari satu.):
            - Santai
            - Trekking
            - Snorkeling/diving
            - Memancing
            - Melihat binatang liar
            - Belanja
            - Melihat tradisi/budaya lokal
            - Melihat seni/arsitektur
            - Makan
            - Akomodasi
            - Sembahyang
            - Lain-lain (silakan jelaskan)
                - Aktivitas Lain:
        - Penjelasan:

- Tambahkan sebuah Daerah untuk tempat yang dipromosikan.
    - [Tambah Fitur]
        - Nama:
        - Aktivitas yang mungkin untuk wisatawan di tempat ini (Pilih dan tandai aktivitas, boleh lebih dari satu.):

- Santai
- Trekking
- Snorkeling/diving
- Memancing
- Melihat binatang liar
- Belanja
- Melihat tradisi/budaya lokal
- Melihat seni/arsitektur
- Makan
- Akomodasi
- Sembahyang
- Lain-lain (silakan jelaskan)
  - Aktivitas Lain: [ ]

▪ Penjelasan: [ ]

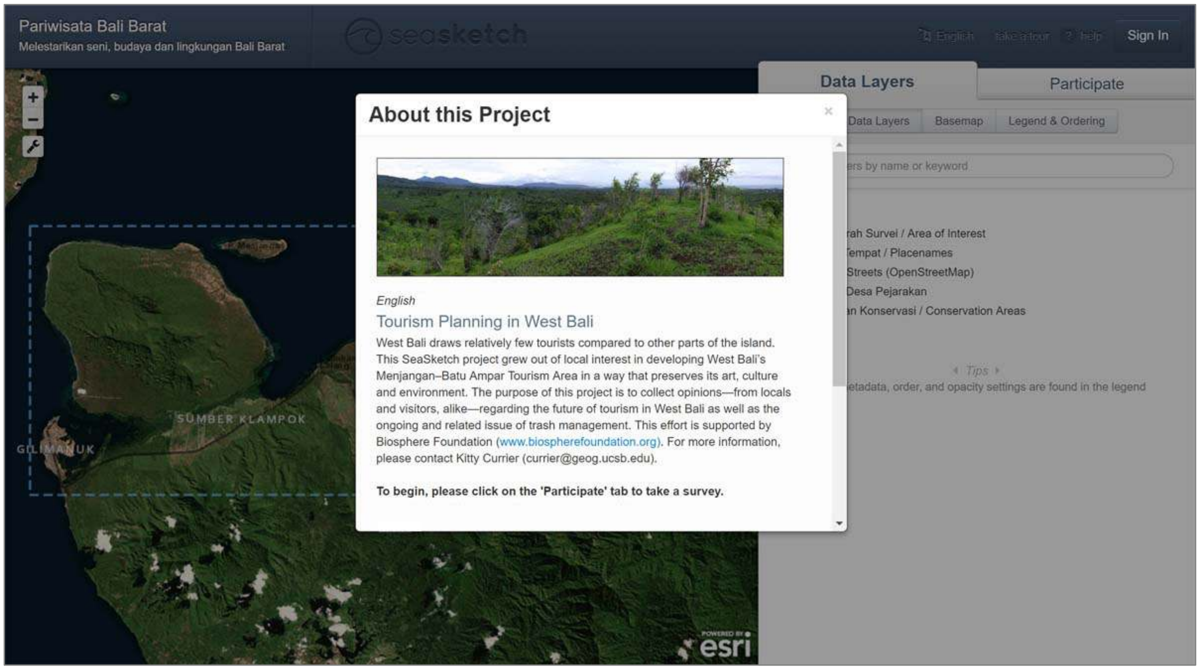
Di Bali Barat, di tempat mana pariwisata seharusnya DIBATASI atau DILARANG? (Di bawah ini, silakan pilih tempat mana—Titik, Garis, atau Daerah—yang anda inginkan untuk gambar di peta.)

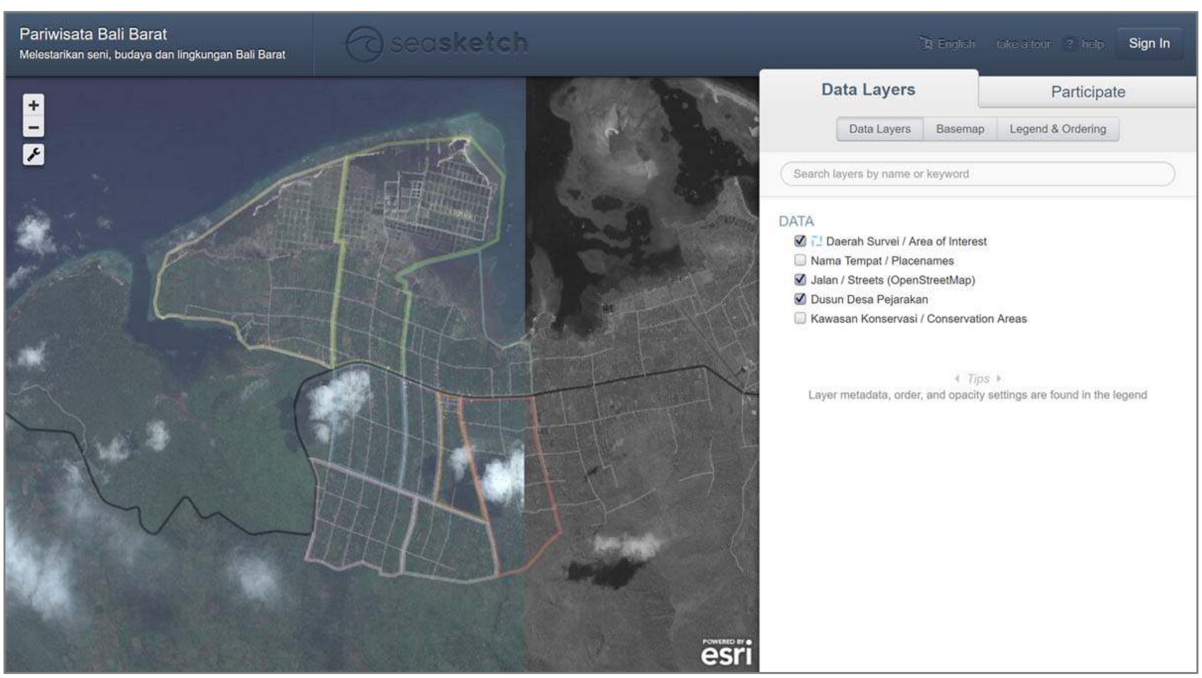
- Tambahkan sebuah Titik untuk tempat yang dibatasi atau dilarang.
  - [Tambah Fitur]
    - Nama: [ ]
    - Alasan untuk pembatasan atau pelarangan pariwisata di sini: [ ]

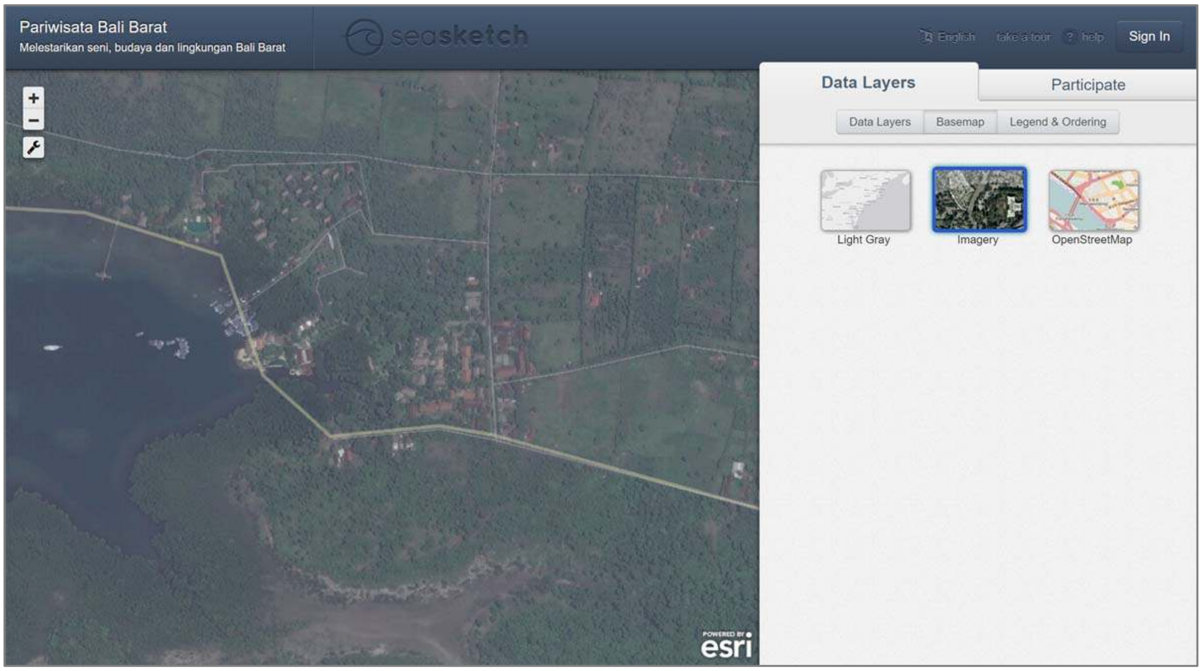
- Tambahkan sebuah Garis untuk tempat yang dibatasi atau dilarang.
  - [Tambah Fitur]
    - Nama: [ ]
    - Alasan untuk pembatasan atau pelarangan pariwisata di sini: [ ]

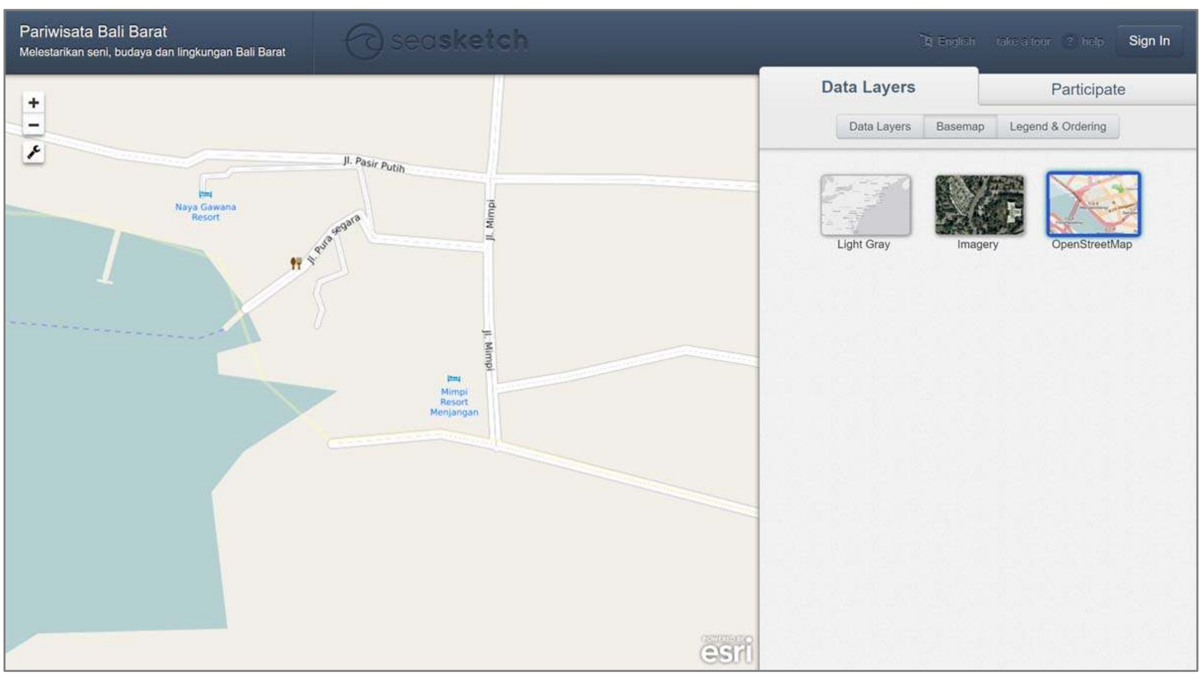
- Tambahkan sebuah Daerah untuk tempat yang dibatasi atau dilarang.
  - [Tambah Fitur]
    - Nama: [ ]
    - Alasan untuk pembatasan atau pelarangan pariwisata di sini: [ ]

Appendix B
SeaSketch Survey Platform Screenshots, English Version

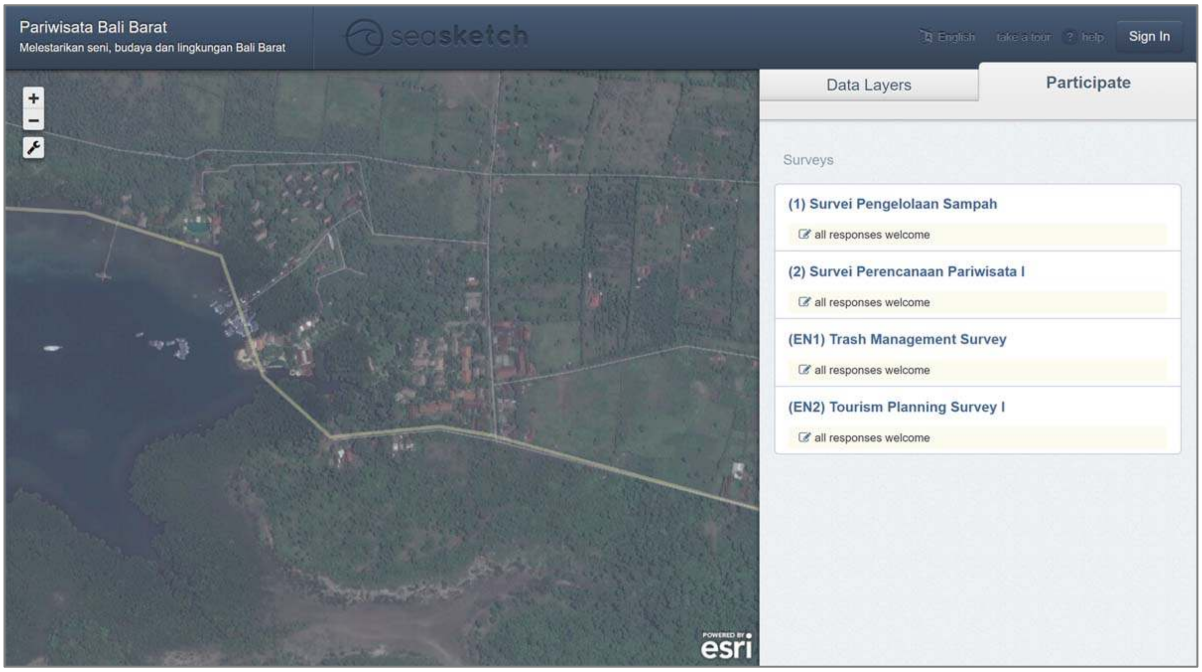

Pariwisata Bali Barat
Melestarikan seni, budaya dan lingkungan Bali Barat
Sign In
Data Layers
Participate
About this Project
English
Tourism Planning in West Bali
West Bali draws relatively few tourists compared to other parts of the island. This SeaSketch project grew out of local interest in developing West Bali's Menjangan–Batu Ampar Tourism Area in a way that preserves its art, culture and environment. The purpose of this project is to collect opinions—from locals and visitors, alike—regarding the future of tourism in West Bali as well as the ongoing and related issue of trash management. This effort is supported by Biosphere Foundation (www.biospherefoundation.org). For more information, please contact Kitty Currier (currier@geog.ucsb.edu).
To begin, please click on the 'Participate' tab to take a survey.
SUMBER KLAMPOK
GILIMANUK
esri

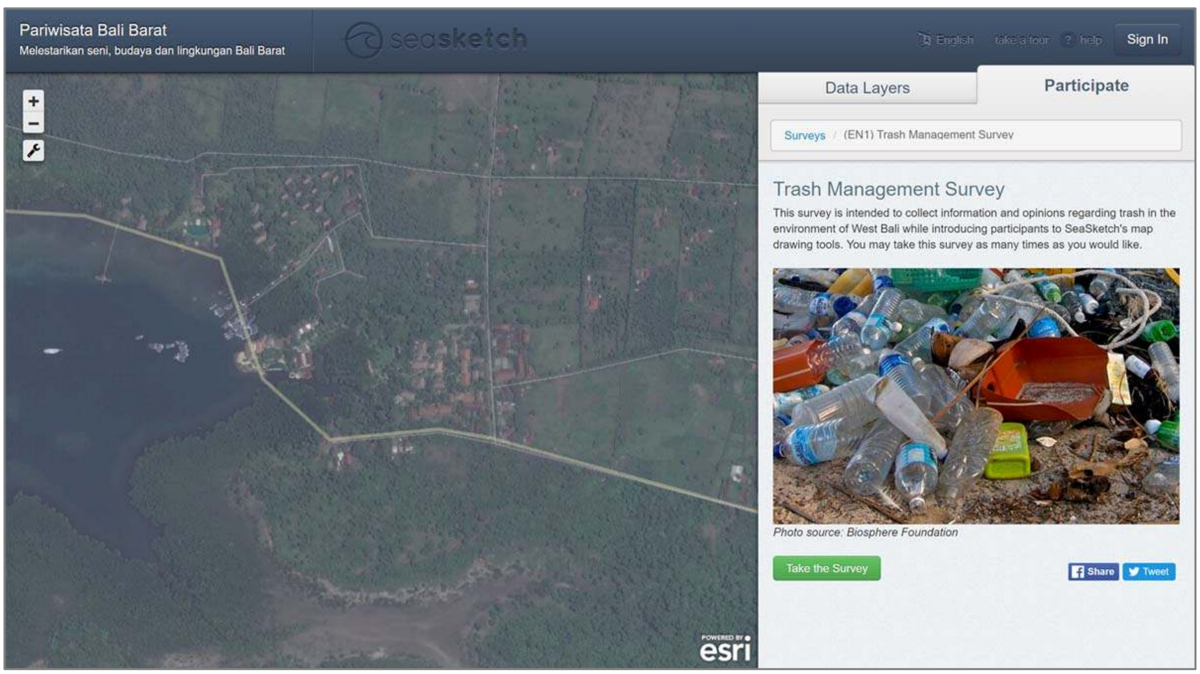

Pariwisata Bali Barat
Melestarikan seni, budaya dan lingkungan Bali Barat
seasketch
Sign In
Data Layers
Participate
Data Layers
Basemap
Legend & Ordering
Search layers by name or keyword
DATA
Daerah Survei / Area of Interest
Nama Tempat / Placenames
Jalan / Streets (OpenStreetMap)
Dusun Desa Pejarakan
Kawasan Konservasi / Conservation Areas
Tips
Layer metadata, order, and opacity settings are found in the legend
esri

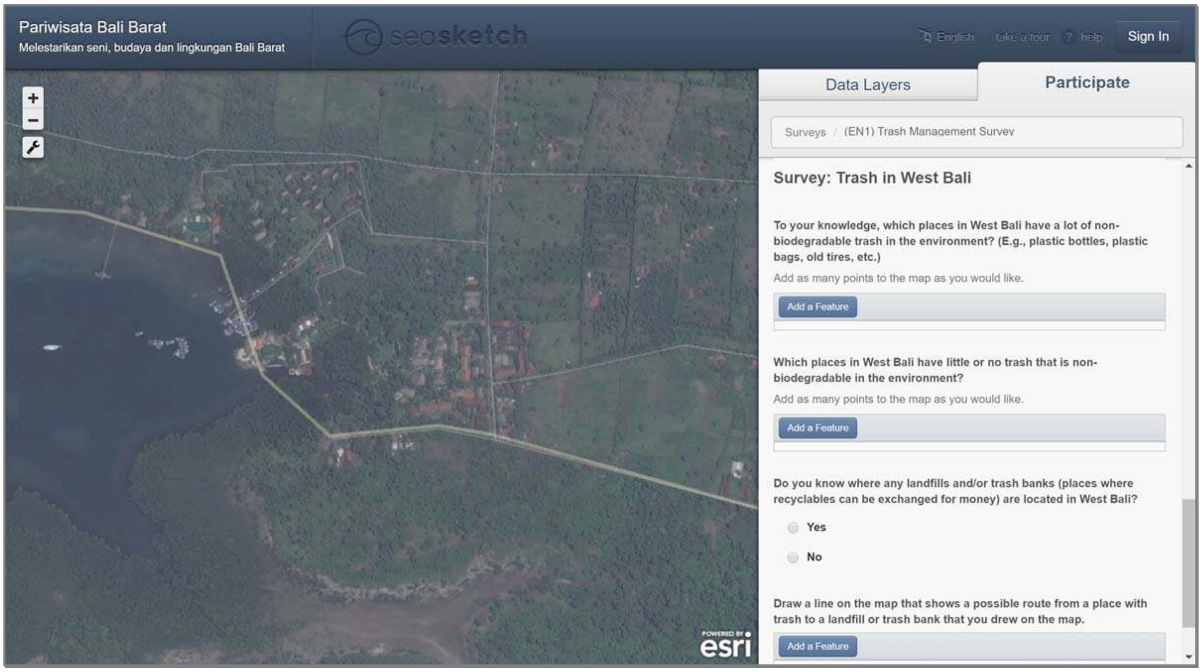

Pariwisata Bali Barat
Melestarikan seni, budaya dan lingkungan Bali Barat
seasketch
Sign In
Data Layers
Participate
Data Layers
Basemap
Legend & Ordering
Light Gray
Imagery
OpenStreetMap
esri

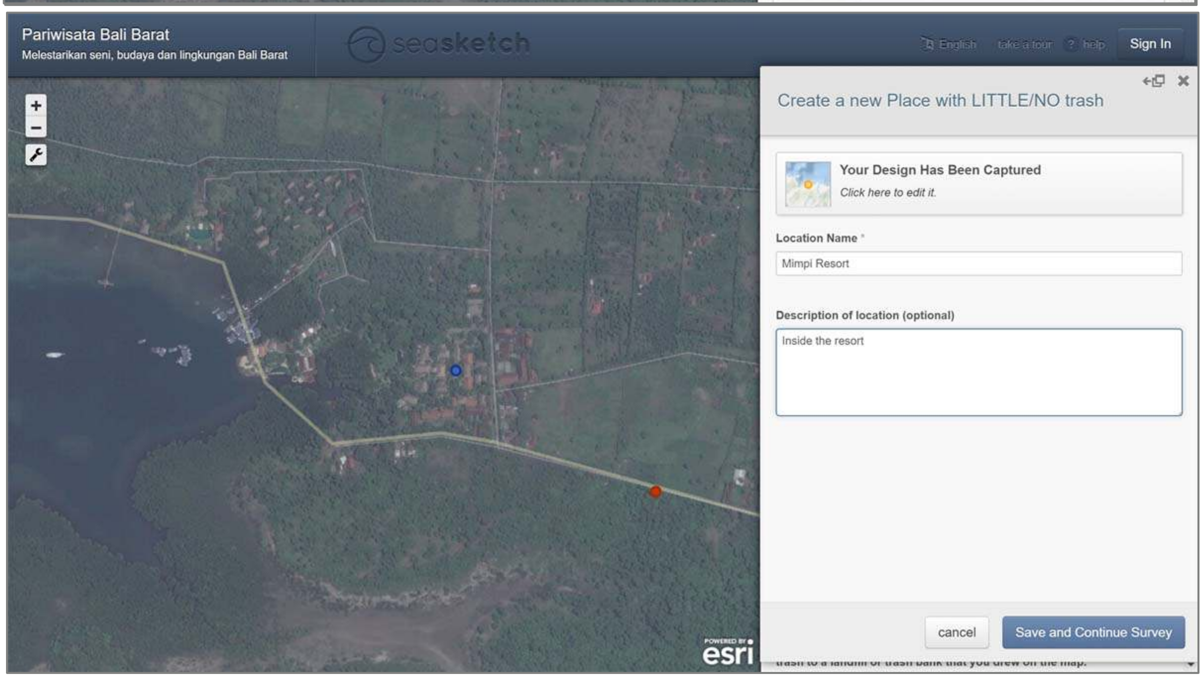

Pariwisata Bali Barat
Melestarikan seni, budaya dan lingkungan Bali Barat
seasketch
Sign In
Data Layers
Participate
Data Layers
Basemap
Legend & Ordering
Light Gray
Imagery
OpenStreetMap
Jl. Pasir Putih
Naya Gawana Resort
Jl. Pura segara
Jl. Mimpi
Mimpi Resort Menjangan
esri

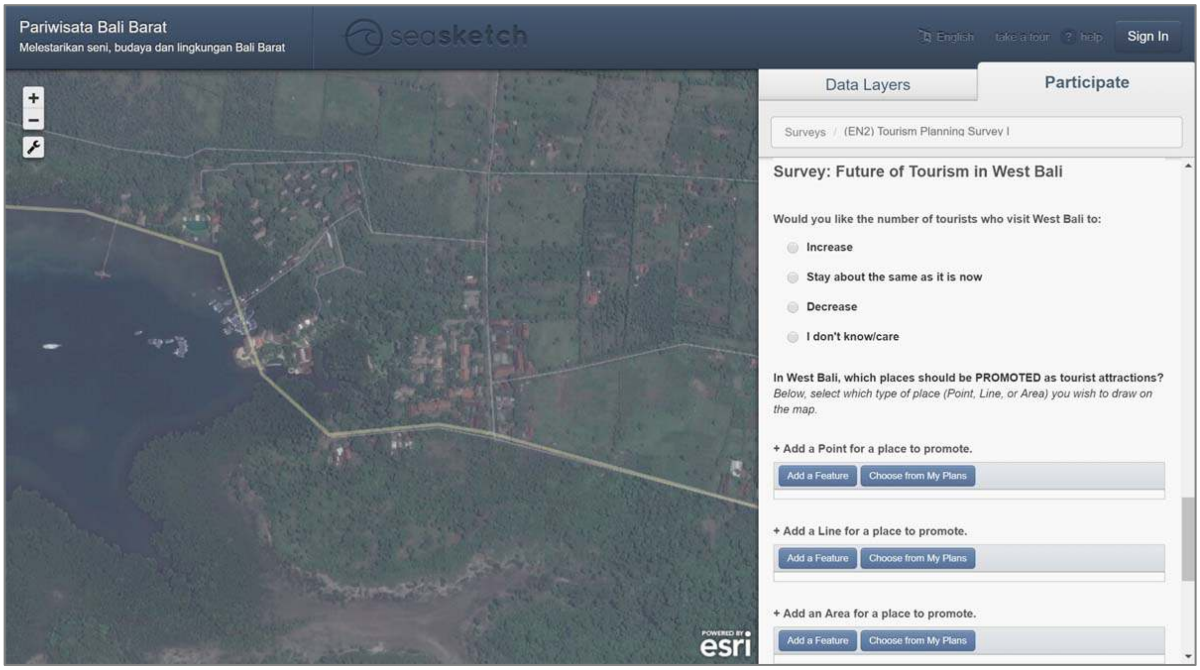
APPENDIX B: SeaSketch Survey Platform Screenshots, English Version

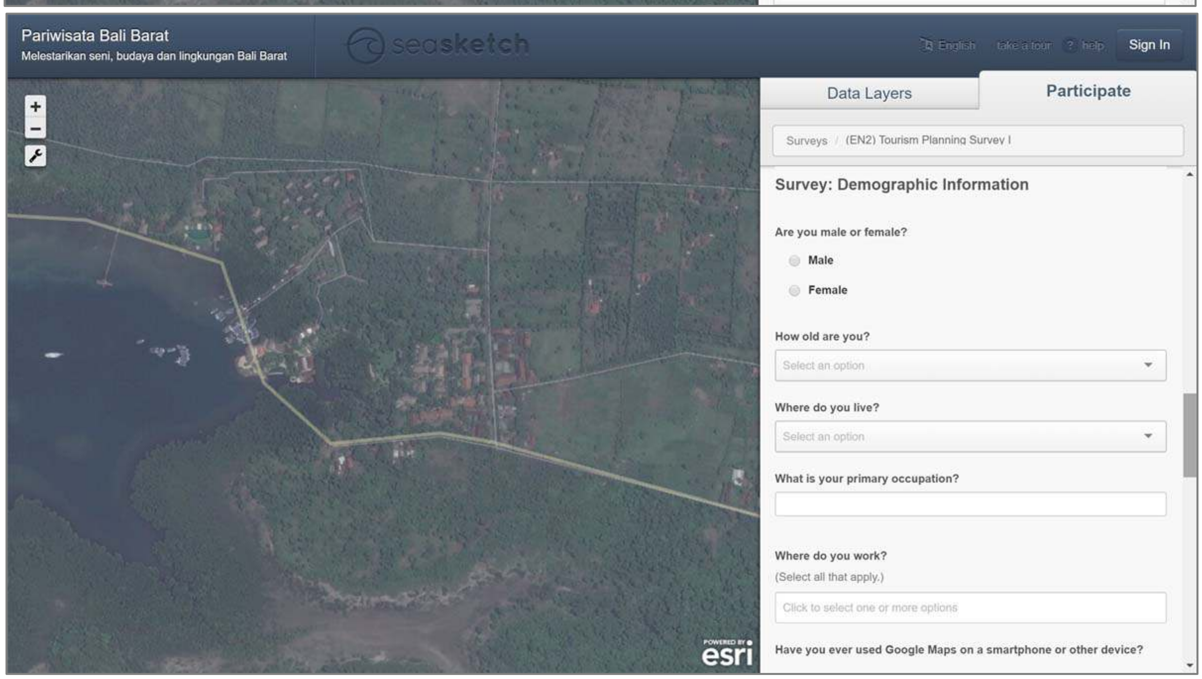


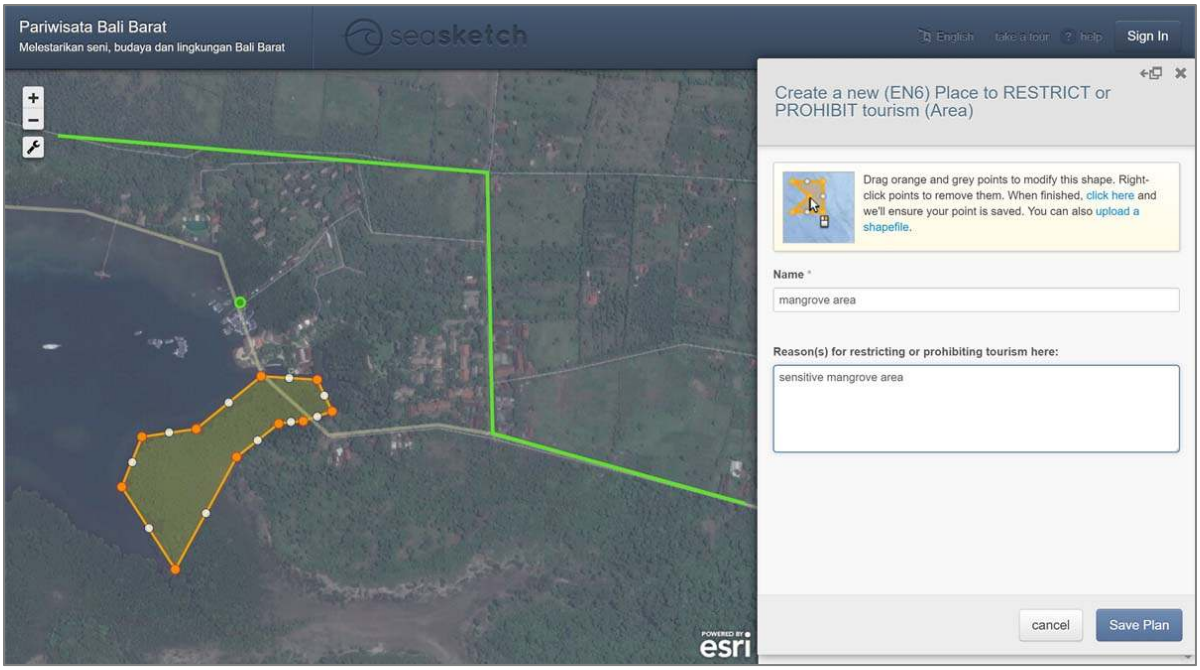



Pariwisata Bali Barat
Melestarikan seni, budaya dan lingkungan Bali Barat
seasketch
Sign In
Data Layers
Participate
Surveys / (EN1) Trash Management Survey
Survey: Trash in West Bali
To your knowledge, which places in West Bali have a lot of non-biodegradable trash in the environment? (E.g., plastic bottles, plastic bags, old tires, etc.)
Add as many points to the map as you would like.
Add a Feature
Which places in West Bali have little or no trash that is non-biodegradable in the environment?
Add as many points to the map as you would like.
Add a Feature
Do you know where any landfills and/or trash banks (places where recyclables can be exchanged for money) are located in West Bali?
Yes
No
Draw a line on the map that shows a possible route from a place with trash to a landfill or trash bank that you drew on the map.
Add a Feature
esri


Pariwisata Bali Barat
Melestarikan seni, budaya dan lingkungan Bali Barat
seasketch
Sign In
Create a new Place with LITTLE/NO trash
Your Design Has Been Captured
Click here to edit it.
Location Name *
Mimpi Resort
Description of location (optional)
Inside the resort
cancel
Save and Continue Survey
esri


Pariwisata Bali Barat
Melestarikan seni, budaya dan lingkungan Bali Barat
seasketch
English
take a tour
help
Sign In
Data Layers
Participate
Surveys / (EN2) Tourism Planning Survey I
Survey: Future of Tourism in West Bali
Would you like the number of tourists who visit West Bali to:
Increase
Stay about the same as it is now
Decrease
I don't know/care
In West Bali, which places should be PROMOTED as tourist attractions?
Below, select which type of place (Point, Line, or Area) you wish to draw on the map.
+ Add a Point for a place to promote.
Add a Feature
Choose from My Plans
+ Add a Line for a place to promote.
Add a Feature
Choose from My Plans
+ Add an Area for a place to promote.
Add a Feature
Choose from My Plans
esri


Pariwisata Bali Barat
Melestarikan seni, budaya dan lingkungan Bali Barat
seasketch
English
take a tour
help
Sign In
Data Layers
Participate
Surveys / (EN2) Tourism Planning Survey I
Survey: Demographic Information
Are you male or female?
Male
Female
How old are you?
Select an option
Where do you live?
Select an option
What is your primary occupation?
Where do you work?
(Select all that apply.)
Click to select one or more options
Have you ever used Google Maps on a smartphone or other device?
esri


Pariwisata Bali Barat
Melestarikan seni, budaya dan lingkungan Bali Barat
seasketch
Sign In
Create a new (EN6) Place to RESTRICT or PROHIBIT tourism (Area)
Drag orange and grey points to modify this shape. Right-click points to remove them. When finished, click here and we'll ensure your point is saved. You can also upload a shapefile.
Name *
mangrove area
Reason(s) for restricting or prohibiting tourism here:
sensitive mangrove area
cancel
Save Plan
esri

Appendix C
Stop Word Lists

Garbage Survey
Indonesian Language

ada	belum	hadap	ketika	sana	seperti
adalah	bisa	hanya	kurang	sangat	sering
agak	cukup	hingga	lain	saya	sini
agar	dalam	ini	masih	sebab	sudah
al	dan	itu	mau	sebut	tentang
atas	dapat	jadi	oleh	sedikit	tiap
atau	dari	jarang	pada	sehingga	tidak
bagi	daripada	juga	panjang	sekitar	tiga
banyak	dengan	kali	punya	selalu	untuk
beberapa	depan	karena	saat	selama	yang
belah	di	ke	sampai	sementara	

Garbage Survey
Indonesian Language
(approximate translation)

there is	not yet	towards	when	there	like
is	can	only	less	very	often
rather	quite	up to	other	i	here
so	inside	this	still	because	already
al	and	that	want	the	about
above	can	so	by	little	every
or	from	rarely	on	so that	no
for	than	also	long	around	three
a lot	with	time	have	always	for
a few	front	because	time	for	which
half	at	to	until	while	

Garbage Survey
English Language

a	and	can	i	off	that	under
about	as	don	in	on	the	up
above	at	down	into	or	there	with
all	be	from	it	over	this	
also	but	have	of	t	to	

Tourism Survey
Indonesian Language

ada	boleh	hanya	juga	mana	sambil	tidak
adalah	dan	harus	karena	maupun	sana	untuk
akan	dapat	ini	karna	milik	sangat	yang
bagai	dengan	itu	kita	oleh	satu	
banyak	di	jadi	kurang	rupa	saya	
bisa	hadap	jika	laku	saja	sebut	

Tourism Survey
Indonesian Language
(approximate translation)

there is	may	only	also	where	while	no
is	and	must	because	although	there	for
will	can	this	because	own	very	which
various	with	that	we	by	one	
a lot	at	so	less	constitute	i	
can	towards	if	do	only	the	

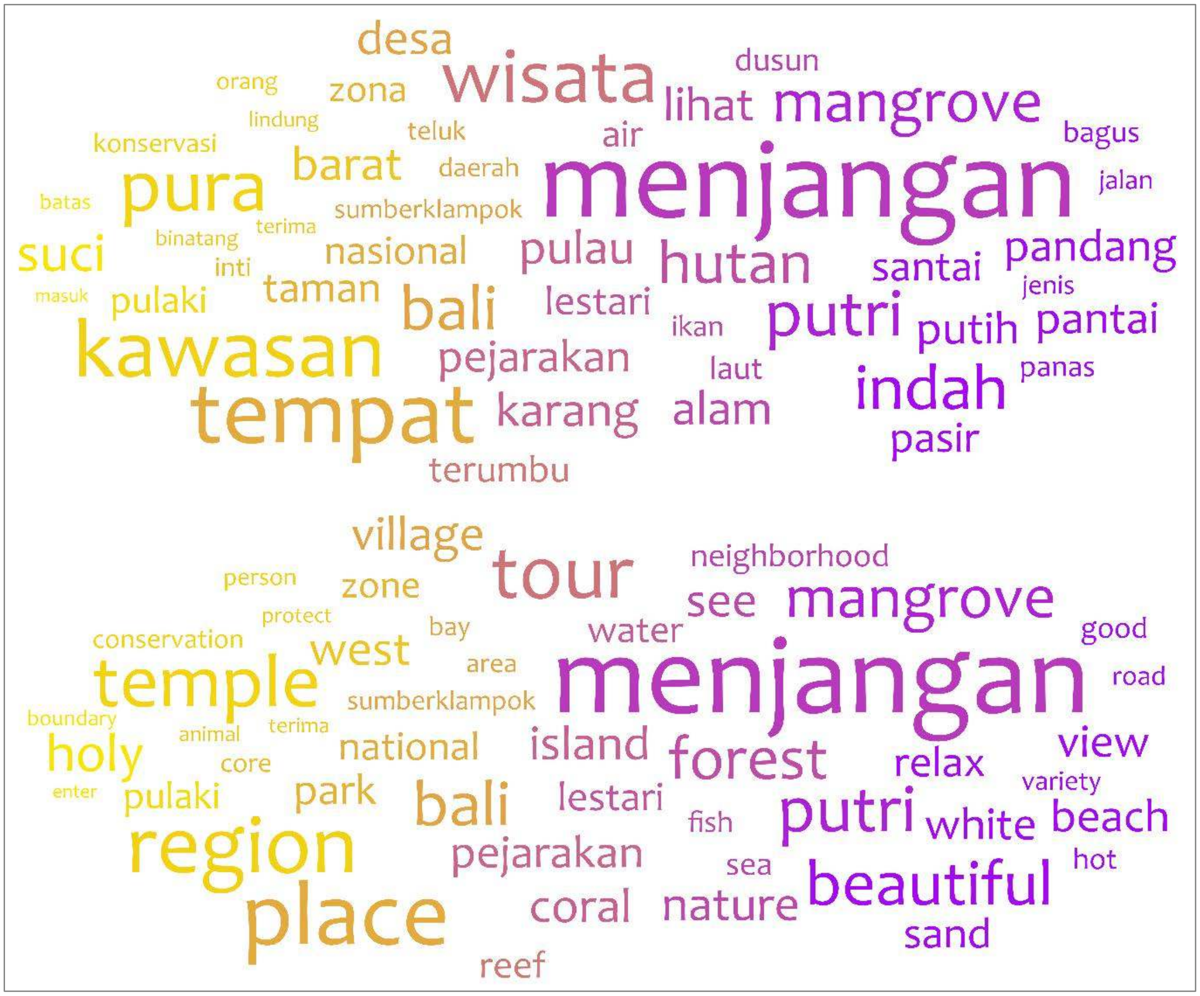
Tourism Survey
English Language

a	are	can	front	of	several	to
about	around	do	have	off	should	up
above	as	does	i	on	side	was
all	at	down	in	one	that	which
along	be	during	into	or	the	will
also	been	each	is	over	there	with
an	but	for	it	right	this	would
and	by	from	left	seem	through	you

Appendix D
Word Clouds

Garbage survey, Indonesian language (with approximate translation)

Garbage survey, English language



Tourism survey, Indonesian language (with approximate translation)

Tourism survey, English language

Appendix E
Topic Models

Included are terms and term probabilities for each topic (Indonesian language only, followed by approximate translations).

Garbage Survey			
Topic 0	**Topic 1**	**Topic 2**	**Topic 3**
0.031 * kawasan	0.047 * pasar	0.037 * menjangan	0.028 * banjar
0.031 * warga	0.037 * dagang	0.023 * warga	0.025 * pantai
0.027 * banyuwedang	0.036 * sembarang	0.021 * pulau	0.024 * disti
0.026 * rumah	0.036 * goris	0.020 * pejarakan	0.021 * perlu
0.025 * masyarakat	0.035 * buang	0.019 * kirim	0.021 * pulau
0.024 * bersih	0.027 * tidak	0.017 * pahlengkong	0.020 * menjangan
0.021 * tugas	0.025 * sd	0.017 * anak	0.020 * kirim
0.021 * angkut	0.023 * pejarakan	0.017 * terima	0.018 * peduli
0.019 * sera	0.021 * para	0.015 * teluk	0.017 * gilimanuk
0.018 * desa	0.019 * plastik	0.014 * desa	0.016 * lingkung
0.018 * tempat	0.019 * bak	0.014 * banjir	0.016 * kelola
0.017 * buang	0.018 * pos	0.013 * dusun	0.016 * tangan
0.015 * pantai	0.017 * banyak	0.013 * buang	0.016 * unjung
0.015 * banyak	0.017 * dekat	0.013 * tempat	0.016 * baik
0.015 * mati	0.015 * sedia	0.012 * zona	0.015 * segara
0.015 * tpa	0.014 * masyarakat	0.012 * plastik	0.015 * banyak
0.015 * hari	0.014 * tempat	0.012 * hutan	0.014 * orang
0.014 * pasir	0.013 * teluk	0.012 * mimpi	0.013 * akibat
0.013 * bd	0.013 * pahlengkong	0.012 * paling	0.013 * tidak
0.013 * ambil	0.013 * sungai	0.012 * musim	0.013 * sumber

Topic 4	**Topic 5**	**Topic 6**
0.029*"sumberkima"	0.036*"pahlengkong"	0.030*"pantai"
0.021*"pokmasta"	0.032*"gawana"	0.030*"jalan"
0.021*"desa"	0.023*"dekat"	0.027*"sumberkima"
0.020*"banyupoh"	0.022*"kelola"	0.027*"pemuteran"
0.019*"sekolah"	0.021*"bersih"	0.025*"wisata"
0.017*"lapang"	0.019*"yayasan"	0.025*"sangat"
0.016*"batu"	0.019*"pemuteran"	0.025*"banyak"
0.016*"ampar"	0.018*"hotel"	0.024*"bersih"
0.016*"kampung"	0.018*"hari"	0.021*"tempat"
0.016*"kb"	0.015*"baik"	0.020*"hotel"
0.016*"sayu"	0.015*"gunung"	0.020*"botol"
0.016*"toko"	0.015*"minggu"	0.020*"pejarakan"
0.015*"masyarakat"	0.015*"garuda"	0.019*"desa"
0.015*"pura"	0.014*"teluk"	0.019*"plastik"
0.015*"baik"	0.014*"tempat"	0.018*"raya"
0.015*"anorganik"	0.014*"pantai"	0.017*"daerah"
0.015*"segara"	0.013*"lingkung"	0.016*"lingkung"
0.015*"nelayan"	0.013*"pasar"	0.016*"kawasan"
0.014*"putri"	0.013*"rumah"	0.015*"pahlengkong"
0.013*"siswa"	0.013*"desa"	0.014*"sd"

Garbage Survey (approximate translation*)

Topic 0	Topic 1	Topic 2	Topic 3
0.031 * region	0.047 * market	0.037 * menjangan	0.028 * neighborhood
0.031 * citizen	0.037 * merchant	0.023 * citizen	0.025 * beach
0.027 * banyuwedang	0.036 * careless	0.021 * island	0.024 * disti
0.026 * house	0.036 * goris	0.020 * pejarakan	0.021 * need
0.025 * community	0.035 * throw [away]	0.019 * [garbage] delivery	0.021 * island
0.024 * clean	0.027 * no	0.017 * pahlengkong	0.020 * menjangan
0.021 * employee	0.025 * school	0.017 * child	0.020 * [garbage] delivery
0.021 * transport	0.023 * pejarakan	0.017 * terima	0.018 * care
0.019 * scattered	0.021 * group	0.015 * bay	0.017 * gilimanuk
0.018 * village	0.019 * plastic	0.014 * village	0.016 * environment
0.018 * place	0.019 * [garbage] can	0.014 * flood	0.016 * manage
0.017 * throw [away]	0.018 * post	0.013 * neighborhood	0.016 * handle
0.015 * beach	0.017 * a lot	0.013 * throw [away]	0.016 * visit
0.015 * a lot	0.017 * near	0.013 * place	0.016 * well
0.015 * seasonal [river]	0.015 * available	0.012 * zone	0.015 * segara
0.015 * landfill	0.014 * community	0.012 * plastic	0.015 * a lot
0.015 * day	0.014 * place	0.012 * forest	0.014 * person
0.014 * sand	0.013 * bay	0.012 * mimpi	0.013 * result
0.013 * admin. gov't.	0.013 * pahlengkong	0.012 * the most	0.013 * no
0.013 * carry	0.013 * river	0.012 * season	0.013 * source

Topic 4	Topic 5	Topic 6
0.029 * sumberkima	0.036 * pahlengkong	0.030 * beach
0.021 * pokmasta	0.032 * gawana	0.030 * road
0.021 * village	0.023 * close	0.027 * sumberkima
0.020 * banyupoh	0.022 * manage	0.027 * pemuteran
0.019 * school	0.021 * clean	0.025 * tour[ism]
0.017 * field	0.019 * foundation	0.025 * very
0.016 * batu	0.019 * pemuteran	0.025 * a lot
0.016 * ampar	0.018 * hotel	0.024 * clean
0.016 * hamlet	0.018 * day	0.021 * place
0.016 * family planning	0.015 * well	0.020 * hotel
0.016 * sayu	0.015 * mountain	0.020 * bottle
0.016 * shop	0.015 * week	0.020 * Pejarakan
0.015 * community	0.015 * garuda	0.019 * village
0.015 * temple	0.014 * bay	0.019 * plastic
0.015 * well	0.014 * place	0.018 * main [road]
0.015 * inorganic	0.014 * beach	0.017 * area
0.015 * segara	0.013 * environment	0.016 * environment
0.015 * fisherman	0.013 * market	0.016 * region
0.014 * putri	0.013 * house	0.015 * pahlengkong
0.013 * student	0.013 * village	0.014 * school

*Words that are not translated are part of proper names.

Tourism Survey			
Topic 0	**Topic 1**	**Topic 2**	**Topic 3**
0.018 * ikan	0.046 * suci	0.031 * hutan	0.033 * menjangan
0.018 * menjangan	0.037 * pura	0.026 * pasir	0.026 * putri
0.016 * terumbu	0.037 * kawasan	0.025 * lihat	0.023 * pulau
0.016 * karang	0.029 * tempat	0.025 * lestari	0.022 * wisata
0.016 * indah	0.022 * desa	0.024 * pantai	0.018 * gilimanuk
0.015 * jenis	0.017 * dalem	0.024 * putih	0.018 * teluk
0.015 * pejarakan	0.016 * putih	0.022 * alam	0.017 * mangrove
0.014 * banyak	0.015 * bali	0.020 * indah	0.017 * santai
0.014 * nasional	0.013 * dinasti	0.017 * mangrove	0.017 * pulaki
0.013 * putri	0.013 * zona	0.016 * pandang	0.015 * sumberklampok
0.012 * alam	0.012 * pasir	0.014 * air	0.015 * ncf
0.012 * dusun	0.012 * jalak	0.013 * tempat	0.015 * pura
0.012 * desa	0.012 * tidak	0.013 * luas	0.014 * milik
0.012 * wisata	0.012 * snorkeling	0.013 * sakti	0.013 * karang
0.012 * taman	0.011 * pemuteran	0.013 * panas	0.013 * banyak
0.011 * tempat	0.011 * jalan	0.012 * view	0.012 * hobbit
0.010 * bali	0.011 * banyuwedang	0.012 * tour	0.012 * daerah
0.010 * jayaprana	0.011 * wisata	0.011 * bagus	0.011 * pemuteran
0.010 * pandang	0.011 * wilayah	0.011 * burung	0.011 * kawasan
0.009 * barat	0.010 * taman	0.011 * santai	0.011 * terumbu

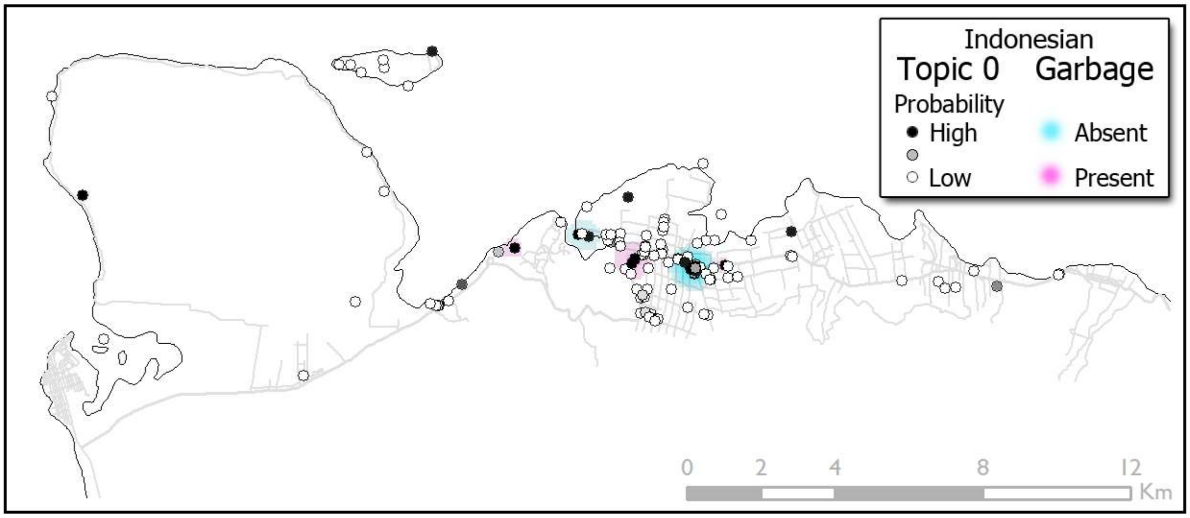
Tourism Survey (approximate translation*)			
Topic 0	**Topic 1**	**Topic 2**	**Topic 3**
0.018 * fish	0.046 * holy	0.031 * forest	0.033 * menjangan
0.018 * menjangan	0.037 * temple	0.026 * sand	0.026 * putri
0.016 * reef	0.037 * area	0.025 * see	0.023 * island
0.016 * coral	0.029 * place	0.025 * lestari	0.022 * tour[ism]
0.016 * beautiful	0.022 * village	0.024 * beach	0.018 * gilimanuk
0.015 * kind[s]	0.017 * dalem	0.024 * white	0.018 * bay
0.015 * pejarakan	0.016 * white	0.022 * nature	0.017 * mangrove
0.014 * a lot	0.015 * bali	0.020 * beautiful	0.017 * relax
0.014 * national	0.013 * dinasti	0.017 * mangrove	0.017 * pulaki
0.013 * putri	0.013 * zone	0.016 * view	0.015 * sumberklampok
0.012 * nature	0.012 * sand	0.014 * water	0.015 * ncf
0.012 * neighborhood	0.012 * starling	0.013 * place	0.015 * temple
0.012 * village	0.012 * no	0.013 * broad	0.014 * own
0.012 * tour[ism]	0.012 * snorkeling	0.013 * sakti	0.013 * coral
0.012 * park	0.011 * pemuteran	0.013 * hot	0.013 * a lot
0.011 * place	0.011 * road	0.012 * view	0.012 * hobbit
0.010 * bali	0.011 * banyuwedang	0.012 * tour	0.012 * area
0.010 * jayaprana	0.011 * tour[ism]	0.011 * good	0.011 * pemuteran
0.010 * view	0.011 * territory	0.011 * bird	0.011 * region
0.009 * west	0.010 * park	0.011 * relax	0.011 * reef

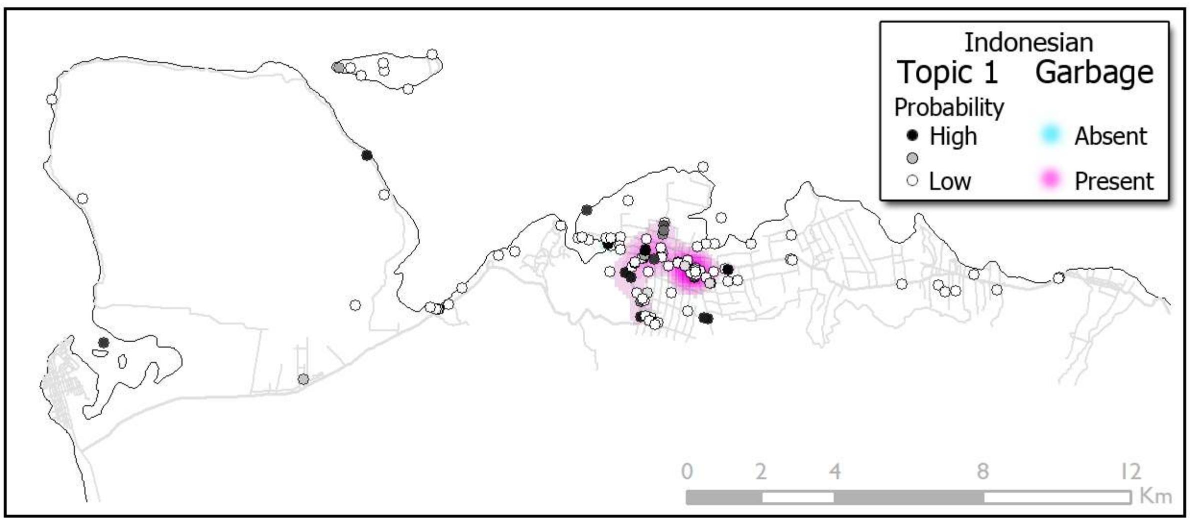
*Words that are not translated are part of proper names.

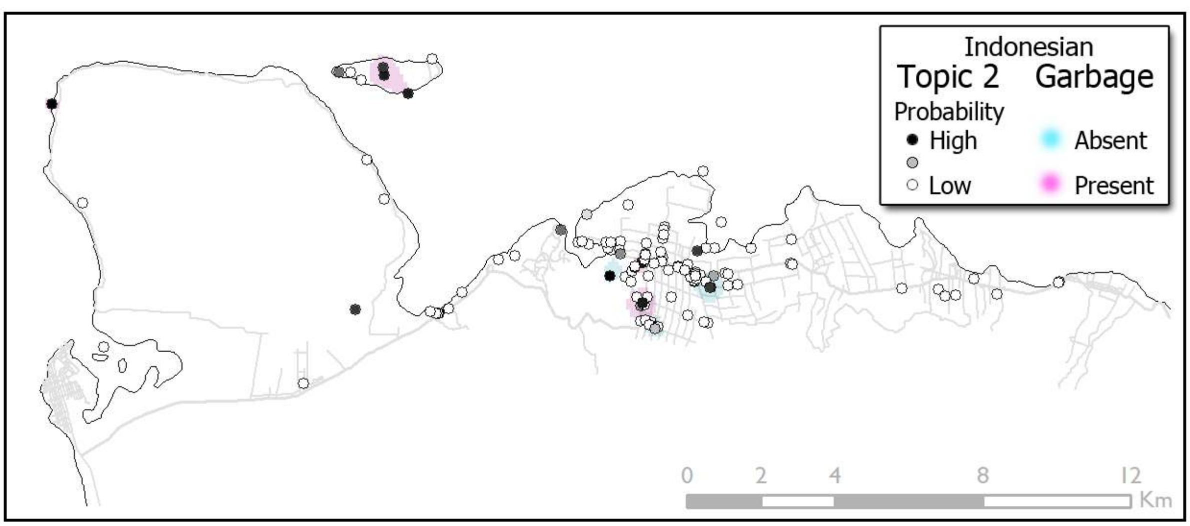
Appendix F
Kernel Density Maps Weighted by Topic Probability

Following are two sets of weighted density maps, one for the garbage survey and one for the tourism survey, completed by Indonesian-language participants. Points, lines and areas represent features mapped by participants, and their grayscale value represents the probability of belonging to a topic, based on the text annotation associated with the feature. Color indicates a cluster of two or more features of the same type—i.e., place with garbage vs. place without garbage; or place for promoting tourism vs. place for restricting tourism—that have a high probability of belonging to that topic.

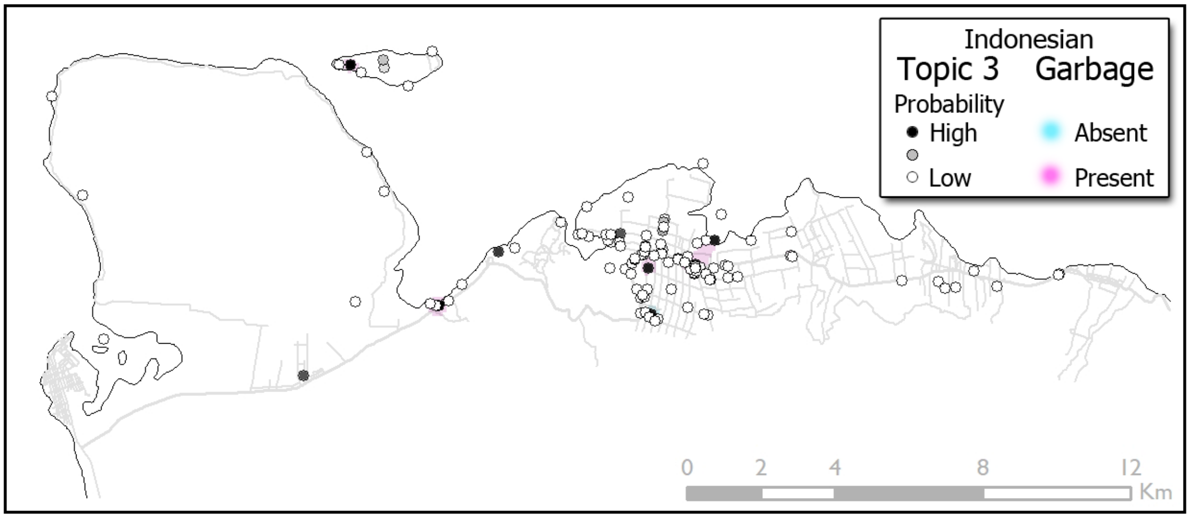
APPENDIX F: Kernel Density Maps Weighted by Topic Probability

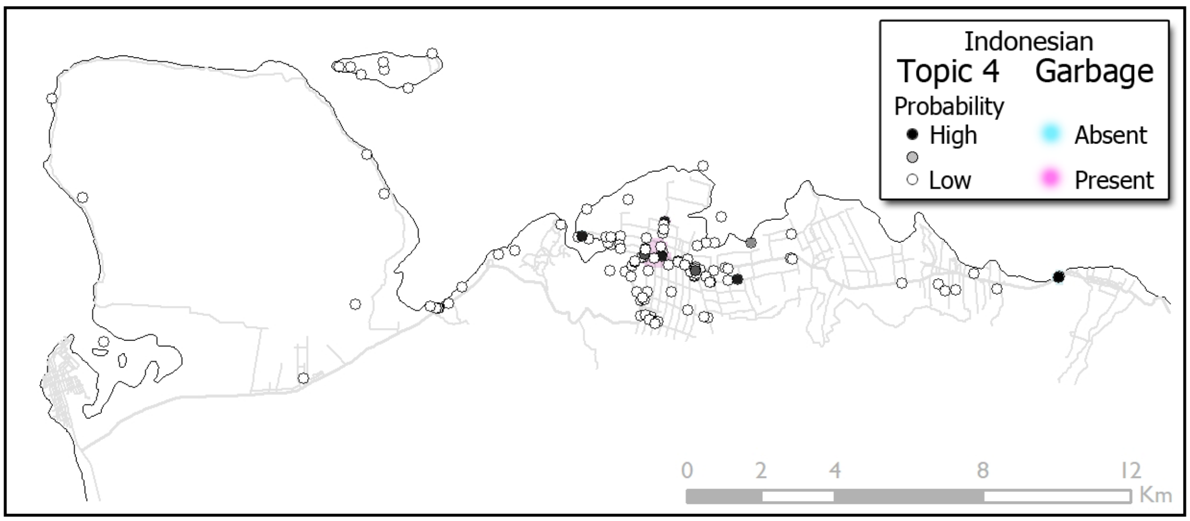


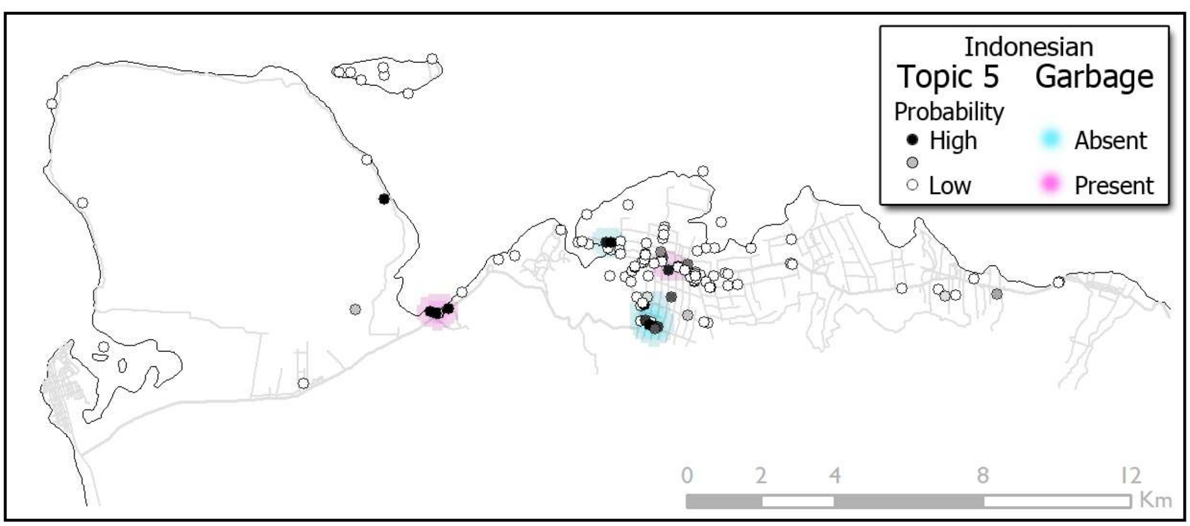




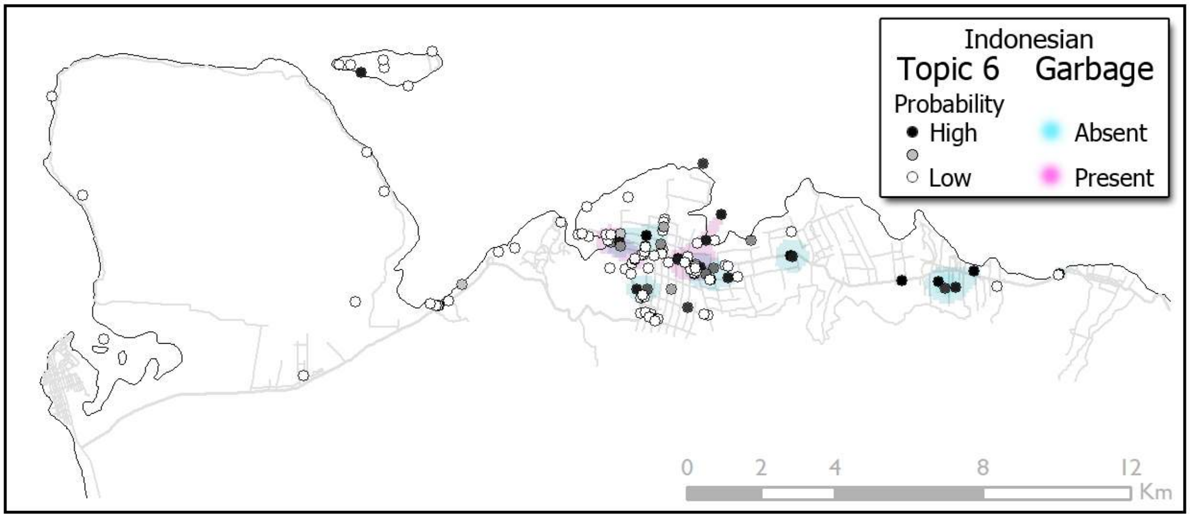
APPENDIX F: Kernel Density Maps Weighted by Topic Probability



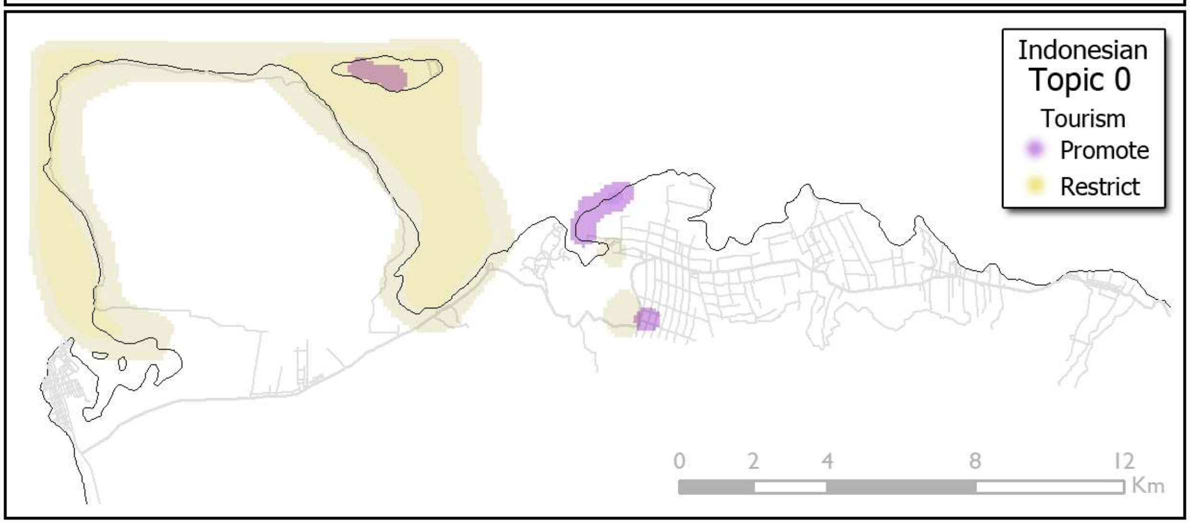




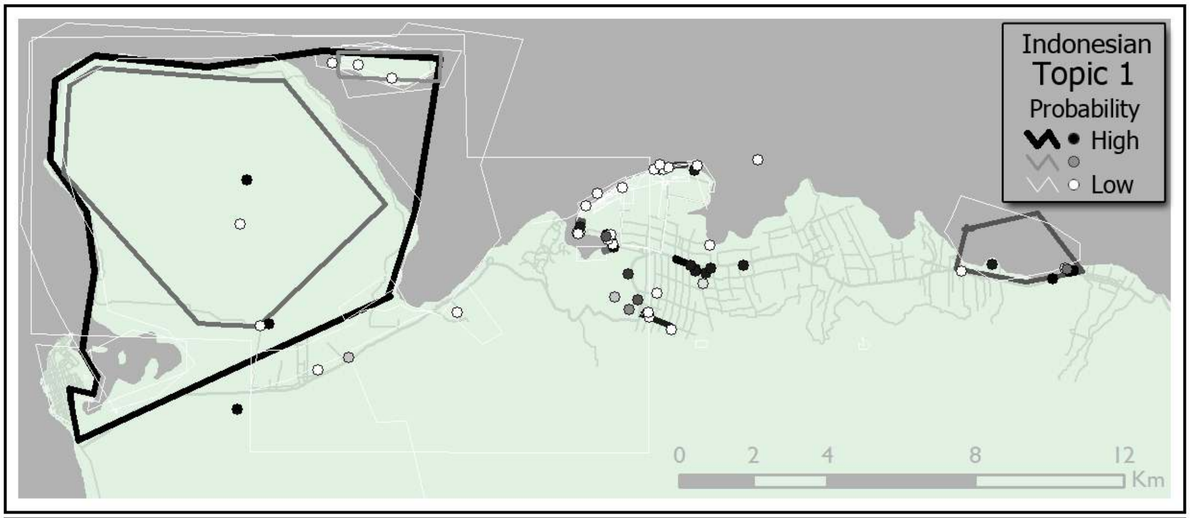
APPENDIX F: Kernel Density Maps Weighted by Topic Probability

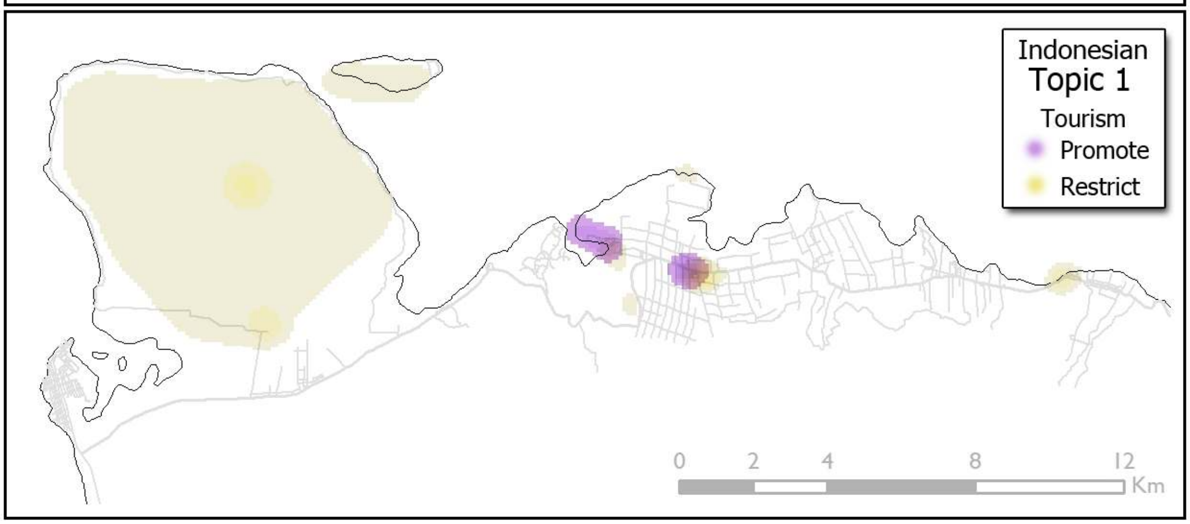


APPENDIX F: Kernel Density Maps Weighted by Topic Probability

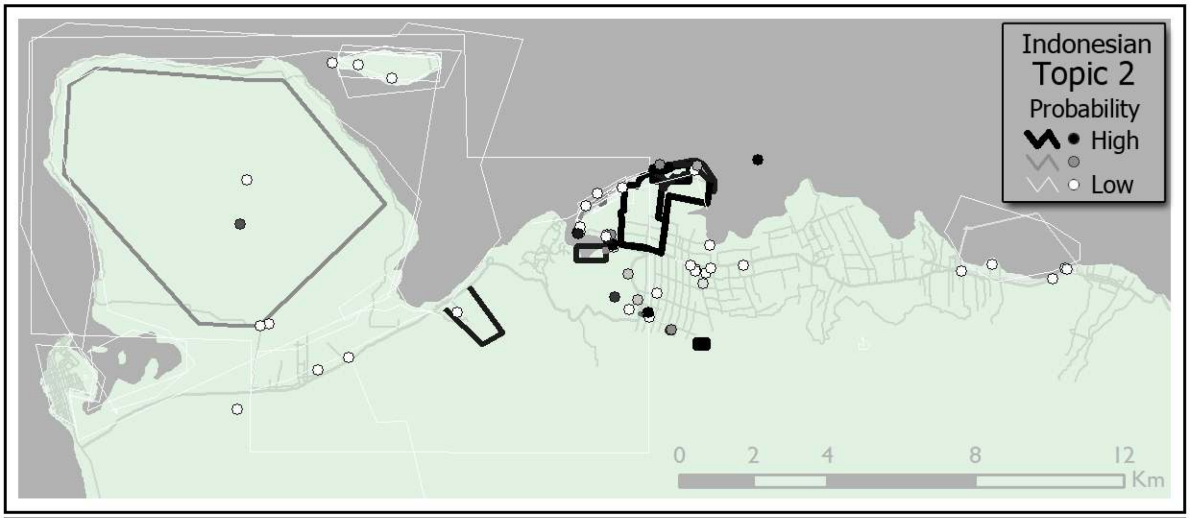


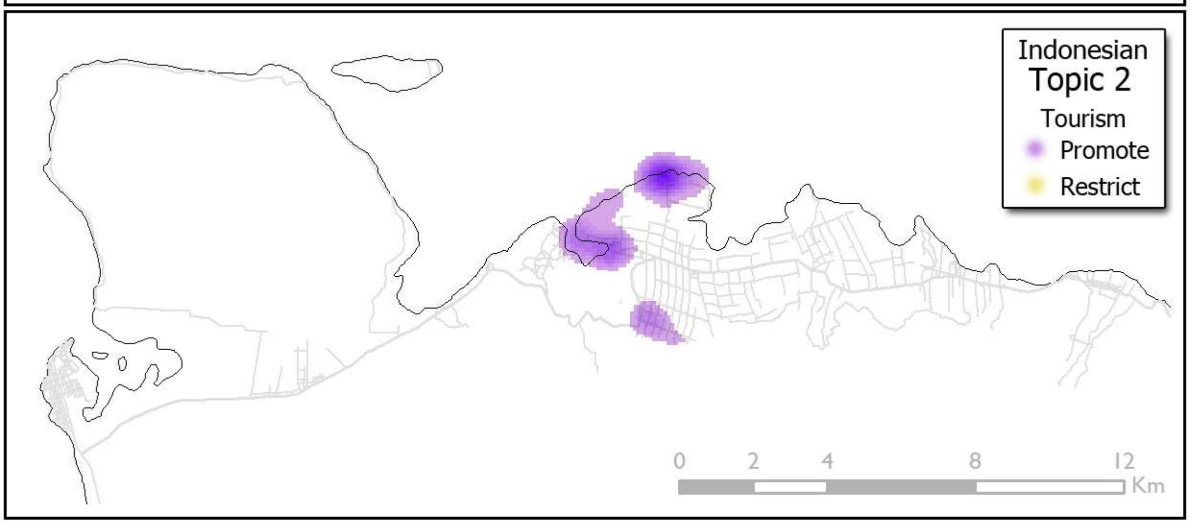
APPENDIX F: Kernel Density Maps Weighted by Topic Probability





APPENDIX F: Kernel Density Maps Weighted by Topic Probability





APPENDIX F: Kernel Density Maps Weighted by Topic Probability