Geography Compass 9/5 (2015): 237–250, 10.1111/gec3.12213

A Review of Volunteered Geographic Information for Disaster Management

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Abstract

The immediacy of locational information requirements and importance of data currency for natural disaster events highlights the value of volunteered geographic information (VGI) in all stages of disaster management, including prevention, preparation, response, and recovery. The practice of private citizens generating online geospatial data presents new opportunities for the creation and dissemination of disaster-related geographic data from a dense network of intelligent observers. VGI technologies enable rapid sharing of diverse geographic information for disaster management at a fraction of the resource costs associated with traditional data collection and dissemination, but they also present new challenges. These include a lack of data quality assurance and issues surrounding data management, liability, security, and the digital divide. There is a growing need for researchers to explore and understand the implications of these data and data practices for disaster management. In this article, we review the current state of knowledge in this emerging field and present recommendations for future research. Significantly, we note further research is warranted in the pre-event phases of disaster management, where VGI may present an opportunity to connect and engage individuals in disaster preparation and strengthen community resilience to potential disaster events. Our investigation of VGI for disaster management provides broader insight into key challenges and impacts of VGI on geospatial data practices and the wider field of geographical science.

Introduction

Natural disaster events, such as the recent Typhoon Haiyan in the Philippines, floods and bushfires (wildfires) in Australia, or Hurricane Sandy in the United States, remind us of the importance of geospatial data and the need for timely and reliable communication in all aspects of disaster management. New opportunities for the creation and dissemination of important disaster-related geographic data from a dense network of intelligent observers are now provided through online user-generated geospatial data termed volunteered geographic information (VGI) (Goodchild 2007; Elwood et al. 2012). Like geographical information systems (GIS), VGI involves the sharing and mapping of spatial data, however, through voluntary information gathered by the general public, though extant debates question the appropriateness of the adjective 'volunteered' noting differences between crowdsourced data that is actively contributed with the individual's awareness and user-generated data that is harvested otherwise (Harvey 2013; Stefanidis et al. 2013). Similarly, definitions of the 'general public' and who produces VGI are often blurred (Budhathoki et al. 2008), with contributions coming from disparate sources (Haklay 2013a; Coleman et al. 2009; Schlossberg and Shuford 2005). VGI represents various opportunities and threats for traditional data production systems, as summarised by Genovese and Roche (2010), some of which are particularly relevant to disaster management, including the opportunity for citizens to actively contribute to public issues with personal local knowledge and the threat that VGI may reduce the importance of authoritative mapping.

Disasters create a time-critical need for geographic information that is unlike the normal pace with which geographic information was traditionally acquired, compiled, and disseminated, and VGI is ideally suited to fill the need for near real-time information (Goodchild and Glennon 2010). Management of disasters follows the four phases of the disaster lifecycle: prevention, preparedness, response, and recovery (PPRR) (Abrahams 2001; Zakour and Gillespie 2013; Crondstedt 2002). Reduction of negative impacts of disasters requires improving approaches in all four phases (Zakour and Gillespie 2013). Through rapid exchange of geographic information between authorities and citizens for disaster response, and promoting connectedness and community engagement in disaster preparation practices, VGI can contribute to all phases of disaster management. Further, digital humanitarianism can add to traditional systems with techniques such as crowdsourcing, remote volunteer collaboration, and 'crisis mapping' (Burns 2014b). Authorities and individuals are already exploiting VGI technologies, both for communicating disaster-related information (see Taylor et al. 2012; Bird et al. 2012; St. Denis et al. 2012) and for collating and mapping relevant geospatial data (see Meier 2012; Ziemke 2012; McDougall 2011; Liu and Palen 2010). This has created a new landscape of geo-data production and knowledge sharing for disaster management, generating a need for researchers to explore and detail the implications of these data and data practices.

This article aims to review the current state of research in this field. The intent of this paper is not to exhaustively document all related literature, but to offer a context for future thinking. An outline of key themes in VGI and disaster research is presented here, with emphasis on present limitations and potential areas for further geographical enquiry. We acknowledge that this review emphasises the post-disaster application of VGI over prevention and preparedness. This is a product of the current state of academic literature in this field and is in itself an important finding which we discuss later in the paper.

The VGI phenomenon may be one of the most important to impact the discipline of geography in recent years, and the associated changes in the production and sharing of geographic information are not just pertinent to the field of natural disasters, but also the broader discipline of GIScience, with geographers in a unique position to examine the impacts of VGI (Elwood et al. 2012).

A Brief Background to VGI and Disasters

VGI is defined as the widespread engagement of large numbers of public citizens in the creation of geographic information (Goodchild 2007). User-generated content (UGC) is exemplified by social media sites such as Twitter and Facebook, and VGI in this context is that subset of UGC that contains a geographic reference, either explicitly or implicitly (Craglia et al. 2012; Elwood et al. 2012). The voluntary nature of data production distinguishes VGI from other spatial UGC (Elwood et al. 2012). Efforts to theorise why individuals volunteer information (see Poser and Dransch 2010; Goodchild 2007; Haklay 2013a; Budhathoki and Haythornthwaite 2013; Starbird and Palen 2011) note that motivations for volunteering or withholding will shape the dynamics of inclusion and exclusion in VGI development and influence data content (Elwood 2008b; Leszczynski 2012; Thatcher 2013; Stephens 2013).

Recent spatially enabling technologies including Web 2.0, georeferencing, geotags, global positioning systems, and broadband communication have enabled mass proliferation of UGC via the internet and allowed citizens to produce maps using free or inexpensive online resources, giving rise to VGI (Goodchild 2007). Further, smartphones equipped with location and data recording sensors have enabled near-instant geospatial data collection and dissemination using mobile platforms (Raento et al. 2009; Lane et al. 2010).

The ease of volunteers to create and publish geographic information combined with the need for rapid communication during crisis events has created a new disaster management context (Goodchild and Glennon 2010; Wald et al. 2011). Emerging social media platforms are changing the way people create and use information for crisis events (Ostermann and Spinsanti 2011; Liu and Palen 2010) with significant increases in the uptake of internet-based communication technologies reported during recent disaster events (e.g., Fraustino et al. 2012).

The growth of VGI has begun to transform not only practices of technology use for disaster communication, but also attitudes towards the value of user-generated online geospatial data and technologies. For example, in response to flooding in Queensland in 2011, the Australian Broadcasting Corporation utilized data volunteered online by citizens to produce maps of crisis incidents in what was referred to as 'an experiment in gathering information from the community' (Middleton 2011). In contrast, responding to bushfires in January 2013, the New South Wales Rural Fire Service Commissioner urged 'people to stay plugged into social media' (AAP 2013). This reference from authority to social media as a source to trust for crisis information came just two years after it was referred to as experimental, emphasizing the recent and rapid emergence of VGI technologies in the emergency response space. This shift reflects the growing number of citizens seeking to access online technologies for sending and receiving disaster information and, in turn, the response, and often expectation, of many official agencies to exploit these technologies for connecting with citizens (e.g. St. Denis et al. 2012).

The era of 'big data' defined by the exponentially increasing 'volume, velocity and variety' of data (McNeely and Hahm 2014) has also resulted in the emergence of new tools for data curation, management, and analysis (Fischer 2012; Kitchin 2013) with significant potential for disaster management. Although VGI contributes to only one of the three categories of big data sources identified by Kitchin (2013), directed, automated and volunteered, the myriad of challenges and vulnerabilities presented by big data have implications for the application of VGI in disaster management. In supporting disaster management, methods for big data analytics need to optimize the collation of contextual information, contribute to understanding causal mechanisms, and recognise the underlying social processes that are not easily represented, characterised, or interpreted using big data technologies.

As individuals and authorities continue to utilize VGI for disaster management, important challenges need to be overcome. In the following sections, we present discussion on key issues for the uptake of VGI in disaster management, including questions of data collection and dissemination, data quality and security, data management, and the notion of empowerment.

Data Collection and Dissemination

The emergence of VGI has created a new platform for collection and dissemination of information for disaster management. Authorities can now rapidly communicate important time-critical geographic disaster-related information directly with the public at a fraction of the logistical and resource costs of traditional communication methods. VGI also presents unique ways for the general public to contribute and map important geospatial information for crisis management and engage directly with authorities and each other in alternative ways, even if they are located outside the potentially affected areas (see Meier 2012; Crowley and Chan 2011; St. Denis et al. 2012).

The internet is well structured to facilitate collaboration among individuals, thus increasing utilization of knowledge assets by reducing limitations such as high costs associated with traditional geographic information production (Flanagin and Metzger 2008; Meier 2012). The collection of large amounts of near real-time information by individuals at the disaster location (Gao et al. 2011), and the dissemination of information from relief agencies

(Abbasiet al. 2012) have been shown to be critical for effective response efforts. VGI postings were demonstrated to provide an alternative to official sources during the Santa Barbara wildfires of 2007–2009 with significant time efficiency in the collation and sharing of information (Goodchild and Glennon 2010). A shift away from traditional cartographic practices and protocols has important implications for information contributions during disasters and the role of geographic information producers. The production of disaster-related information is no longer simply an expert's game for those organizations that can resource the acquisition of authoritative data. The emergence of VGI has enabled anybody with access to the technology to contribute in a new disaster management context that has seen knowledge users become knowledge producers, or 'produsers' (Coleman et al. 2009; Budhathoki et al. 2008).

There is value in the depth of information and immediacy gained through people from a breadth of backgrounds contributing and disseminating disaster related information. This was emphasized during the 2007–2009 Santa Barbara wildfires (Goodchild and Glennon 2010) and the 2010/2011 Queensland floods (McDougall 2011). The Queensland flood events were characterised by an unprecedented use of social media to report incidents as they happened (McDougall 2011; Bird et al. 2012), and flood extent mapping for rudimentary post-disaster assessment was enabled by VGI through geotagged images and social media content. VGI contributors with personal cameras and mobile phones often have the advantage of being *in-situ* at the disaster location capturing near real-time data without the constraints associated with other forms of technology, such as cloud-obscured satellite imagery (Triglav-Čekada and Radovan 2013).

Sharing content online facilitates fast and broad information mobility. VGI collection and dissemination through social media in particular has an inherent ability to promote or propagate messages (e.g., Gao et al. 2011). During the 2010/11 Queensland floods, a high level of re-sharing of social media posts was reported, particularly of those publically expressing gratitude for emergency services, even well beyond the disaster, indicating a significant form of emotional engagement with the acute event (Shaw et al. 2013). Technologies and the capacity to spread individual information are allowing individuals to engage, and remain engaged, with crisis events in unprecedented ways. For disaster recovery, there is a need to consider how this new context of engagement may impact the efforts of individuals to recover or 'move on' following a disaster.

It is important to recognise that the same mechanisms enabling messages of support and emergency information to be shared widely and quickly can also work to propagate misinformation, malicious and/or false content. This issue needs to be understood in the broader context of traditional geospatial data dissemination, and efforts should be made to comprehend how these new data sharing practices are impacting the veracity of geographic information as it proliferates through the online arena.

Data Quality and Security

Security and data quality are major concerns for VGI. Individual's physical and online security may be compromised by utilising low-quality VGI. Data from (often) untrained individuals with varying agendas and experience often suffer from an absence of quality assurance (Goodchild and Li 2012). Studies have highlighted the importance of data verification by reporting on issues of quality control, misinformation, spurious or fraudulent postings, duplicate and doctored images, and the lack of 'right' information for disaster relief (see McDougall 2011; Bird et al. 2012; Fraustino et al. 2012; Ostermann and Spinsanti 2011; Gao et al. 2011; Triglav-Čekada and Radovan 2013). Despite these concerns, it has been noted that in some contexts, such as the 2010 Haiti earthquake which occurred with a void of quality authoritative geospatial data, crowdsourced maps produced with volunteered data can be the most comprehensive and up-to-date information available (Meier 2012; Crowley and Chan 2011). In this section, issues of data quality and security are discussed with particular reference to credibility. We then outline and critique reasons why VGI has been recognised for its capacity to complement authoritative datasets.

The lack of adequate security features associated with VGI is a concern pertinent to natural disaster management (Gao et al. 2011; Shanley et al. 2013). The nature of VGI is that it is often made openly available to the general public. Data of this nature may be particularly compromising during a disaster event, especially when those affected are at their most vulnerable and privacy may be less of a priority than in 'normal' circumstances (Crawford and Finn 2014). For example, a geotagged image of a disaster-impacted property provides useful information to emergency authorities if shared through social media, but that same locational information about a vulnerable and potentially vacant property may also be available to those with malicious intent. In the hostile environment of the 2011 humanitarian crisis in Libya, two crowdsourced maps were produced to mitigate security issues; one was password protected for humanitarian workers, and the other contained heavily edited information for the public on a 24-hour time delay (Meier 2012). Crawford and Finn (2014) assert that while it could be assumed people can manage their own privacy settings on public platforms, many are not well informed about who can access the data they contribute.

Furthermore, authorities acting on information posted by members of the public, without credibility assurances, may potentially be exposed to risks beyond those already associated with the hazard event (Shanley et al. 2013). Goolsby (2013) argues disaster responders, relief workers, and digital volunteers who provide support for crisis events should be particularly cautious in regards to social media as a source of VGI. In a study of information posted on Twitter during various high impact events, Gupta and Kumaraguru (2012) showed just 17% of event-related tweets contained credible information, while 13.5% was spam (the rest was either not credible or event-related but not useful, i.e. personal opinions). Uncertainty surrounding credibility of online data and data sources is contiguous with uncertainty surrounding online security. Anxiety associated with data security and privacy of volunteered information may prevent individuals from contributing during a disaster and may limit the uptake and capabilities of the technologies for official emergency agencies (Shanley et al. 2013; Crowley and Chan 2011).

Credibility of data and data sources is thus a concern for VGI in disaster management. Flanagin and Metzger (2008) highlight the difficulty in locating and authenticating digital information sources and the lack of quality control standards as key issues for credibility. By making it possible for more people from a diverse range of groups to produce more data in digital form, the heterogeneity and sheer volume of information and information sources has increased (Flanagin and Metzger 2008; Elwood 2008b; Crowley and Chan 2011), and Callister (2000) argues standard conventions for determining credibility break down in cyberspace. How can such vast amounts of data from non-experts, following no institutional or legal standards, be trusted as credible, particularly in the case of emergencies? Though limited by using Twitter data in isolation, Castillo et al. (2013) describe features that may be effective for automatically classifying microblog posts as credible or not with emphasis on information posted during natural disasters, showing that credible posts tend to be longer, contain a URL, and are questioned less by other users.

Data may contain false positives and negatives (Goodchild and Glennon 2010). For example, a hypothetical oil spill may cause a false positive with an untrue rumour of the chemical spill, or a false negative through absence of information about the spill's existence (Goodchild and Glennon 2010). Information about the spill is time-critical and delay in its availability amounts in effect to a false negative. A false positive may result in unnecessary evacuation. However, if the event was true and people were to wait for official information, the delay could have life-threatening consequences and constitutes high risk. This is not to argue false positives are preferable to false negatives. There are substantial costs to false positives, including the resource costs and danger involved in evacuation, and the weakening of confidence in the system reducing the effectiveness of future true positives. We argue that regardless of use, quality of VGI for disaster management applications is a serious and potentially life-threatening issue, whether false positive or negative.

Some have argued that VGI may approach the quality standards of authoritative data, offering various justifications (see Goodchild and Li 2012; Goodchild and Glennon 2010). First, sites such as Wikipedia provide evidence that crowdsourcing is an effective mechanism for eliminating propagation of erroneous information via masses of individuals submitting and reading information (Giles 2005). But what threshold volume of contributors is required for the source to be deemed accurate? Linus' Law, which implies that by having more observers fewer errors go unnoticed and data is improved, has been shown to apply to OpenStreetMap (Haklay et al. 2010). But Haklay et al. (2010) could only speculate on VGI more broadly and focused on positional accuracy without considering other aspects of data quality, such as attribute accuracy or the currency of VGI sources. Application of Linus' Law to VGI is problematic for incidents that are obscure, such as those that persist for only a short period of time, which is the nature of many disaster-related incidents (Goodchild and Li 2012). If the 'wisdom of the crowds' can eventually filter out false information, this may happen too late in a time-critical situation like a disaster event (Spinsanti and Ostermann 2013). In addition, is there potential for mass contributions to encourage 'group think' and propagation of misinformation (Murdock 2011)? By its nature, UGC broadly is incomplete, and despite very large volumes of data, bias is not removed (Hollenstein and Purves 2010; Purves 2011; Graham 2010; Stephens 2013; Burns 2014a; Crawford and Finn 2014).

Second, geographic information is rich in context (Goodchild and Glennon 2010). In the context of Tobler's first law (Miller 2004), which states that any location is likely to be more similar to its surrounds than distant things, geographically inconsistent information stands out as erroneous. Tobler's law suggests that information about a location should be consistent with what is already known about the location's surrounding area (Goodchild and Li 2012). Report of a bushfire, for example, is more likely to be true if fire has recently been described nearby.

Third, Goodchild and Glennon (2010) report currency is a feature of accuracy. Rapid generation of VGI has potential to capture changes in landscapes as they occur, which is unachievable with the lengthy delays associated with traditional map production. Thus, data that has currency is potentially more reliable in the sense that it is more up-to-date. But does currency of data indicate accuracy in the form of 'correctness'?

Fourth, advances in positional technology and increase in the ubiquity of technologies that give the average person access to geographically referenced data production may increase data quality, but this does not conclusively eliminate human error. There is no guarantee users consistently operate equipment correctly (for example, use of appropriate map datum settings) or that they are necessarily aware when the technology is not operating properly. As researchers continue to seek new applications for these data, innovative methods are needed for empirical validation of the quality and credibility of VGI.

Data Management

Data from the general public presents a number of challenges for data management which are particularly relevant to disaster management. Key issues include data filtering and verification with increased volumes of data and data sources, the place for VGI in spatial data infrastructures (SDIs), and issues of liability surrounding the use of UGC.

The sheer volume of information provided through VGI is a current obstacle to its efficient use in emergency management, highlighting the need for effective methods to mine, filter, verify, and summarise these data and data sources to ensure credible and relevant content (Bakillah et al. 2015; Spinsanti and Ostermann 2013; Crowley and Chan 2011; Graham 2010). Verifying data accuracy and the potential value of information for a range of purposes under the time-critical and rapidly changing circumstances of a disaster scenario presents significant challenges. Spinsanti and Ostermann (2013) incorporate the knowledge of experts for refining UGC. They present a prototype system to retrieve, process, analyse, and evaluate social media content on forest fire using expert input to establish key words, contextual information, and spatio-temporal clustering parameters (Spinsanti and Ostermann 2013). Gao et al. (2011) note the ability of social media tools to allow for rudimentary analysis and summaries to help observe trends and partition data into predetermined most-urgent categories during disasters, such as medical assistance requests or trapped persons. Social media technologies have the ability to coordinate widespread communication and strengthen information flows, but also to adapt in real time to changing needs of those affected by the disaster (Yates and Paquette 2011).

Traditionally, SDIs are not premised around the need to handle UGC, and SDIs' top-down model of supporting digital data access, storage, and sharing is unlike the bottom-up approach on which VGI is established (Craglia 2007; Gould 2007; Elwood 2008a, 2008b; Díaz et al. 2011; Duce and Janowicz 2010). VGI represents a departure from the assumption with contemporary SDIs that formal organizations are the producers of geospatial information and users are the passive recipients (Budhathoki et al. 2008). Budhathoki et al. (2008) argue for reconceptualization that sees production expanded from expert organizations to user organizations and individuals, establishing two-way interaction and blurring the boundary between producers and users. The sharing and availability of VGI within mainstream SDIs may improve traditional geospatial analysis and decision support tasks (Díaz et al. 2011). Genovese and Roche (2010), however, argue VGI inclusion in official SDIs may pose a threat to data integrity. For disaster management, opportunity exists for VGI to augment existing SDIs, providing valuable localised and contextual information for planning decisions and encouraging information flow between communities and disaster management authorities. De Longueville et al. (2010) illustrated how VGI sensing and SDI components can act as complementary senses for supporting a crisis-related scenario.

Liability questions associated with the use of VGI in authoritative public and private geographic datasets are among the most paramount (Rak et al. 2012). Due to the higher level of inherent risk to life and property in disaster management decision-making, liability concerns may deter organizations from integrating VGI into their datasets (Shanley et al. 2013). Who is responsible if harm results from reliance on volunteered information: the initial contributor; the host or organization responsible for the website or product relying on VGI; the user? Scassa (2013) argues VGI site operators, users, and contributors must all have some awareness of the legal and ethical issues that may be triggered by their activities, including issues of intellectual property, liability for faulty information, and defamation. 'Digital volunteers' are at risk if they disseminate false information, develop sloppy software, or fail to use reasonable care, act in a manner comparable with similarly situated individuals, properly supervise volunteers, or act when they have a duty to do so (Robson 2012; Shanley et al. 2013). Furthermore, as websites have a global reach and laws vary widely between regions, liability risks in and across foreign jurisdictions need consideration (Scassa 2013; Shanley et al. 2013). Robson (2012) argues that evaluating the precise contours of potential liability for 'digital volunteers' can be difficult because of the novelty of issues and a lack of court guidance, but many potential liabilities can be mitigated through planning and organization.

Empowerment Through VGI

A loss of empowerment for individuals has been described during disaster events (Bird et al. 2009), and research has suggested VGI technologies can act to empower citizens (Tulloch 2008; Goodchild and Glennon 2010). Empowerment is described as an individual's capacity to have control over their personal affairs and confront hazard issues while receiving the necessary emergency management support (Bird et al. 2009). The notion of citizen empowerment through VGI must be considered alongside marginalization.

Goodchild and Glennon (2010) argue the average citizen, already equipped with powers of observation, is now empowered through VGI technologies with the ability to georegister those observations, transmit them through the internet, and synthesize them into readily understood maps and reports. But does this indicate VGI can enable individuals to achieve connectedness, more control, and empowerment in disaster management? Numerous papers have discussed the concept of empowerment through public participatory GIS (PPGIS) (Sieber 2006; Harris and Weiner 1998; Elwood 2002), including in natural disaster research (Kemp 2008; Kienberger 2007). In this context, empowerment is a complex social construct and political process, whereby its attainment through PPGIS is contingent upon multiple factors including community make-up, endorsement from local leaders, nature of power relations, and administrative structures within the community (Kyem 2002). The relationship between VGI and citizen empowerment is similarly complex. Elwood (2008b) claims discussions about the societal significance of VGI are similar to 'GIS and Society' debates during the mid-1990s, in which GIS was welcomed by some as a tool for the empowerment of marginalized individuals and decried by others as a mechanism of exclusion and disempowerment (Schuurman 2000). Research has similarly considered how VGI may aggravate existing inequalities and create new forms of exclusion (see Zook and Graham 2007a, 2007b).

While VGI may empower some citizens to contribute and engage in disaster management, it also acts to marginalize others. If we consider the digital divide (see Van Dijk and Hacker 2003; Chinn and Fairlie 2007; Gilbert 2010; Sui et al. 2013), what is the role of citizens with limiting socio-economic circumstances or those in parts of the world without access to these 'empowering' technologies? Sui et al. (2013) report two-thirds of humanity does not have access to the rapidly expanding digital world. What contribution does VGI have to make to disaster management for these citizens? VGI cannot represent 'the everybody' and in fact favours 'the privileged', or those with money, access, and time to utilize the technology (Haklay 2013b; Crawford and Finn 2014). Just 36% of the population had internet access in the Philippines when Typhoon Yolanda struck in 2013, presenting a partial and skewed picture of the disaster through social media data (Crawford and Finn 2014). We must recognise that UGC will provide only selective representations of any issue, and that there will always be people and communities that are missing from the map (Zook et al. 2010; Burns 2014b).

For those that are 'included', the use of geospatial data from the crowd has been shown to enhance existing inequalities. Text messages sent to the Mission 4636 service (Crowley and Chan 2011; Meier 2012; Ziemke 2012) during the 2010 Haiti earthquake crisis were translated into English and subsequently mapped and reported in English, preventing the Kreyòl speakers who texted for help from accessing the project outputs and benefiting from their own data, thus reproducing unequal power relations between the poor Haitians and the rich who acted on the information (Crawford and Finn 2014). Information is often least available where it is most needed (Sui et al. 2013), and during disasters, those in society already marginalized are often the most vulnerable (Hewitt 1983b, 1997; Watts 1983). Thus, a shift in focus to data sources for emergency management that are potentially excluding of those vulnerable is not plausible. For emergency management, VGI may only be a useful tool alongside more traditional disaster management methods, and triangulation of various spatial data sources should remain a goal of any project leveraging UGC (Ziemke 2012; Hassanzadeh and Nedovic-Budic 2013).

VGI also provides novel capabilities and opportunities for authorities and those undertaking geographical research. By providing new insight into the complexities of disasters at various spatial scales, with increased access to important local and community knowledge, VGI can aid in strategizing and planning for all stages of the PPRR cycle. Studying a community's daily life activities and spatial patterns at a local level may be where VGI offers the most interesting and lasting value to geographers (Goodchild 2007). Material conditions of daily life prefigure disasters (Hewitt 1983a) and there is little long-term value in confining attention to hazards in isolation from local vulnerabilities and their causes (Blaike et al. 2003). Failure to include important local data for management of diverse issues over varying spatial scales and choosing rather to focus on data at broader scales alone can result in ineffective policies (e.g., Haworth et al. 2013). VGI may also have implications for the perceived value of geographers. With skills formerly relied on now enshrined in software, the production of geographic data and knowledge is no longer exclusive to geographers (see NeoGeography, or 'geography without geographers'; Sui 2008; Turner 2006; Liu and Palen 2010; Haklay et al. 2008; Goodchild 2008).

Future Research Recommendations

As citizens and authorities continue to embrace VGI for disaster management, researchers must continue to address important questions surrounding data quality, the social and institutional implications for adopting UGC, and the overall utility of VGI for all stages of disaster management. Further consideration needs to be given to best practices for emergency management agencies to support digital volunteers, and for digital volunteers to support traditional and authoritative disaster management practices. Burns (2014b) notes that no formal relationship exists between digital humanitarians and traditional humanitarian institutions. In this final section, we reflect on the existing literature to offer recommendations for further academic research in the field of VGI and disaster management.

There is limited systematic research on the role of different types of VGI platforms during disasters. Similarly, comparisons are limited between different types of disasters and whether or not the disaster type has any influence on VGI usage patterns. Particular research emphasis should be given to improving data validation and automatic report summation. Several studies have emphasized the need for further research into VGI verification and reporting systems for disaster management to assist in addressing data quality and management issues (see Poser and Dransch 2010; Gao et al. 2011; Abbasi et al. 2012).

Research is needed on more appropriate use of VGI-enabling technologies. The inclusion of geotags in reports from some devices (such as smartphones), for example, can assist in discriminating between reports based on location and allow for more targeted relief action and improved spatial planning. However, it has been observed that less than 5% of users provide location information due to privacy concerns or lack of awareness about the feature (Abbasi et al. 2012). Murdock (2011) estimates just 1.5% of Twitter posts are geotagged, proving a major limitation to the geographic application of tweets and an under-representation of information. Those posts that are geotagged also pose issues, such as whether a geotagged image provides the location of the image-subject or of the photographer (Hollenstein and Purves 2010). Another relevant example is the need for appropriate and effective use of hashtags for managing large volumes of data on social media (Ziemke 2012). New methods for encouraging the most effective use of VGI technologies may lead to increased adoption and improved data accuracy, ultimately increasing capacity for those seeking to engage VGI for disaster management.

Significantly, we propose research is needed on the role of VGI in the preparation and prevention phases of disaster management. This review clearly highlights that contemporary research on the role of VGI in disaster management predominantly focuses on the response phase of the PPRR cycle. Disaster preparation has been considered through spatial data technologies such as GIS (Asante et al. 2007; Chou 1992; Atkinson et al. 2010; Atkinson et al. 2007), but the use of VGI for pre-disaster planning and preparation has not received the same attention. Burns (2014a) also describes the need for inclusion of preparedness and risk information in volunteered humanitarian databases. In the preparedness phase of the PPRR cycle, a range of possible events must be analysed for both hazards and vulnerabilities, providing a useful opportunity for effective risk analysis (Asante et al. 2007). Several researchers have argued there is potential for social media to assist in building pre-disaster resilience (Dufty 2011, 2012; White 2012). Boon (2014) reports the most effective emergency communication is two-way and locally derived, enabling those at risk to obtain more personalised information and advice about their preparations. Specific local knowledge shared via a VGI platform may assist individuals and communities better understand local vulnerabilities and risks, and develop effective planning and response procedures for a variety of hazards. Directing increased attention to the pre-disaster phases may present an opportunity for VGI to foster community engagement and empower individuals to be more directly involved in risk reduction practices.

Conclusion

Academic commentary on VGI in disaster management is recent; however, a body of work exists that demonstrates utility and significance. Through VGI, vast amounts of diverse, local knowledge can now be collected and shared for disaster management at a fraction of the costs associated with traditional data collection and map-making, while at the same time potentially fostering community engagement in disaster prevention, preparation, response, and recovery. We have argued that alongside these opportunities, there are important challenges for VGI, chiefly issues of data quality, bias in contributions, data management, and the security of individuals, authorities, and their information. Addressing limitations will build confidence in VGI as a reliable resource for disaster management, ultimately adding to its utility for citizens as well as emergency services, policymakers, and GIScientists. There is an urgent need for further research on the technical and critical dimensions of VGI and for human geographers to engage with GIScientists to comprehend the implications of these data and data practices for citizens, traditional methods of disaster management, and geography as a discipline more broadly.

Short Biographies

Billy Haworth is a PhD candidate and tutor in the School of Geosciences at the University of Sydney. Billy's key research areas involve using GIS and spatio-temporal analysis technologies to explore relationships between people and places. Previous work has examined graffiti policy and patterns of graffiti removal in urban environments. His current research is focussed on the role of volunteered geographic information in natural disaster management. He currently holds a Bushfire and Natural Hazards CRC scholarship and is examining volunteered geographic information for bushfire preparation and community engagement in Tasmania. Billy holds a Bachelor of Science and a Master of Applied Science, specialising in spatial information science, from the University of Sydney.

Eleanor Bruce is a Senior Lecturer in the School of Geosciences, University of Sydney, and coordinates the Marine Science and Management Masters program. Her research examines processes of habitat loss in coastal environments, the use of GIS and remote sensing in vegetation change detection, marine zone planning, and the use of geographic citizen science in coastal management.

Note

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