Mapeo del conocimiento tradicional sobre las amenazas

para la investigación informada, prácticas y políticas en las Américas

Mapping local knowledge of hazards

to inform research, practice and policy in the Americas

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Abstract

Hazards are fundamentally understood and experienced spatially; therefore, it is not surprising that hazards research, management, communication, and policy have relied heavily on spatial representations using geomatics tools such as remote sensing and geographic information systems (GIS). As powerful and useful as these tools have been, they tend to privilege the collection and utilization of quantifiable data at the expense of qualitative data (e.g., experiential local knowledge). Local knowledge has been increasingly used both to challenge and to supplement mapping strategies, although less so in the realm of hazards than in other areas such as natural resource management. In this paper, we propose a unique framework for taking these approaches one- step further through the development of a knowledge management system that integrates local knowledge of hazards with spatial visualization tools. First, we discuss relevant literature related to current tools and practices for visualizing hazard information. Next we propose a methodology for mapping mental models of individuals. Finally, we discuss the potential applications of such a framework for hazards research, practice, and policy, as well as discuss the challenges associated with this framework.

Keywords: Hazards, local knowledge, mapping, mental models.

Resumen

Las amenazas fundamentalmente se entienden y experimentan espacialmente; por lo tanto no es sorprendente que la investigación de amenazas, gestión, comunicación y la política se han apoyado fuertemente en herramientas de la geomática como la teledetección y los sistemas de información geográfica. A pesar del poder de estas herramientas, ellas tienden a privilegiar la colecta y uso de datos cuantitativos en detrimento de otros tipos de investigación, como la cualitativa (por ejemplo el conocimiento tradicional empírico). El conocimiento tradicional está siendo utilizado cada vez con mayor frecuencia para retar y suplementar las estrategias de mapeo, aunque en menor medida en el ámbito de amenazas en comparación a otras áreas como la gestión de recursos naturales. En el presente documento, proponemos un marco único para abordar estas aproximaciones un paso más adelante a través del desarrollo de un sistema de gestión del conocimiento que integre el conocimiento tradicional de amenazas con las herramientas de visualización espacial. Primero, discutimos la literatura relacionada con las herramientas y prácticas para visualizar la información de amenazas. Luego, proponemos una metodología para mapear modelos mentales de individuos. Finalmente, discutimos el potencial de aplicación de este marco para la investigación sobre amenazas, prácticas y políticas; así como los retos asociados a este marco.

Palabras clave: Amenazas, conocimiento tradicional, mapeo, modelos mentales.

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1. INTRODUCTION

The challenges to tackle climate change are copious and profound (Garcia et al. 2010). A number of scholars acknowledge the need to assess and incorporate local hazards knowledge into geospatial technologies (Wilbanks and Kates, 1999; Lopez- Marrero and Yarnal, 2010). Specifically, a number of scientific communities have assessed cognitive and cultural understanding of geographic spatial characteristics including community- based GIS and participatory modeling (Knapp and Fernandez-Gimenez, 2009). These traditions are similar in the effort to incorporate local understanding into mapping and geographical assessment. These traditions differ, however, by asking participants to share their internal cognitive map or perception of external boundaries. For example, participants may draw maps of countries or describe their knowledge of impact zones from previous hazards. In this paper we respond to the need for systematic understanding of local issues by drawing upon and extending the analysis capabilities of remote sensing, geographic information systems and local knowledge. Specifically, we call for systematic mapping of local knowledge of hazards.

This article is the product of international and interdisciplinary collaboration that was part of a two- week seminar called "Integrating research on climate change and hazards in the Americas" (C2HEKE, 2010). Climate change is expected to produce a suite of new hazards and vulnerabilities the consequences of which are underscored by the dedication of the seminar and most participants' research trajectories to the topic. However, the data management system that we propose could easily be broad enough to include all hazards, including other natural hazards, technological or chemical hazards, or even violence. As a result, the authors have left the language general enough to cover a wide variety of hazards while drawing more heavily on previous work on climate change- related hazards.

2. Current tools and Practices for Visualizing Hazard Information

In the following section, we address current tools for assessing and visualizing hazard- related information. Selected tools include remote sensing, geographic information systems (GIS), and local knowledge through mental models.

2.1 Remote Sensing

Remote sensing, particularly satellite images of the earth, provides a suite of possibilities with respect to viewing earth system changes. For example, remote sensing is one of the only tools that can efficiently monitor large- scale land use changes, specifically in regard to loss of forests. In fact, this tool is critical in examining the effectiveness of land use management policies, which many countries in the Americas have implemented. However, the information provided by remote sensing does not automatically lead to sound land use management policies like the protection of the principal ecological structure (Van Der Hammen and Andrade, 2003) in national and regional parks, wetlands, and in vulnerable areas. Consulting firms will often provide remote sensing images to national governments, as the imagery often conveys powerful messages by itself. But, these images alone do not suggest the full environmental picture, as it can only address large- scale visual measures of environmental change and problematic indicators of human land- use pressures (Robbins, 2001; Turner, 2003). In other words, geomatics is a tool but by no means can it replace human ecology. Remote sensing does not include additional information on ecosystem health, environmental information, or community perceptions.

2.2 Geographic information systems (GIS)

GIS are software tools for the storage, management, and display of geographically referenced information. Research into hazards has widely applied GIS in its analysis, but the degree of integration with GIS has tended to vary depending on the type of analysis framework. The frameworks described herein include vulnerability impacts, adaptation, and composite indicators.

2.2.1 Vulnerability Impacts Framework

Within hazards, GIS has received the most use in the characterization of physical vulnerability impacts. Here, the focus has been on hazard exposure, with research questions revolving around what and who is vulnerable, where, and to what degree. Analyses typically follow a linear process beginning with current and future local manifestations of one or more specific hazard scenarios, evaluation of exposed biophysical and socioeconomic units, application of sensitivity or fragility functions that relate exposure to impacts, and assessment of impacts (Hewitt, 1983; Eakin and Luers, 2006). Impacts are generally described in terms of monetary losses, physical damage, agriculture losses, human health outcomes, or other adverse impacts. The analysis usually concludes with discussion of potential adaptations that feed back into future hazard and socioeconomic scenarios. Because the analysis begins with prescribed hazard scenarios, the vulnerability impacts framework is often described as top-down or deductive (UNFCCC, 2005), see for example the approach by the Colombian Ministry of the Environment (MAVDT, 2005). With the focus on describing the spatial variation in biophysical risk, the most vulnerable populations and built environment elements are often considered to coincide with areas of greatest exposure (Liverman, 1990). Geospatial analysis lends itself well to the analysis of impacts (Gravelle and Mimura, 2008; Liu *et al*., 2008; Torresan *et al*., 2008). Hazard scenarios, exposed elements, land use categories, and aggregated demographic data are frequently both inputs and outputs in the vulnerability impacts assessment process (Table 1).

Table 1. GIS Use in Vulnerability Impacts Assessment

GIS Representation	Hazard Analysis	Exposure	Impacts
Point	Stream gages, chemical releases	Homes, bridges, dams	Percent damage
Line	Shorelines, rivers, hurricane tracks, tornado tracks	Transportation networks, levees, energy transmission	Degree of functionality, monetary losses
Polygon / areas	Watersheds, flood zones, landslide areas, soil type, lakes, wildfire burn area	Administrative units, territorial boundaries, agricultural zones, ecosystem services	Mortality, morbidity, loss of function
Grid / lattice	Terrain/bathymetric elevation, storm surge, mean sea level, slope, wind field, soil saturation	Land use/cover types	Erosion, deforestation

2.2.2 Adaptation Framework

One of the conclusions reached in the third Assessment Report of the IPCC was that far too little is known about the vulnerabilities and potential adaptations in developing settings (AIACC, 2010). As a result, adaptation frameworks, the so- called second generation of vulnerability assessments, have grown in favor. Whereas vulnerability impacts approaches can be described as top down, adaptation frameworks apply a bottom up approach to assess vulnerability. The latter, understood not merely as taking the community into account but working with the community from the very genesis (Franco- Vidal *et al*., 2009). As opposed to the focus on prescribed hazard exposure scenarios, the starting point of the adaptation framework is the multiple and concurrent stresses facing people at the local level, of which specific hazards may be only one. The analysis then proceeds to work its way up through assessment of adaptive capacity to determine social vulnerability and potential adaptations (Dessai and Hulme, 2004). Other than study- area maps, geospatial analyses typically do not play even a cursory role in vulnerability assessments using adaptation frameworks. Part of this lack of GIS use stems from the political ecology/economy lens applied by much of this research that seeks to understand who is vulnerable and how, as opposed to where. There also exists strong epistemological avoidance of spatial analysis by some researchers who are at odds with its positivist, reductionist, and structuralist associations, but geospatial analysis and qualitative research need not be mutually exclusive (Schwanen and Kwan, 2009). As such, this paper seeks to advance the use of geospatial analysis and visualization within the adaptation framework.

2.2.3 Composite Indicators

Indicators are quantitative or binary variables that serve as proxies to represent complex systems. An indicator can consist of a single variable (e.g., education level) or a combination of variables (e.g., gross domestic product that aggregates yields of goods and services). Single and multiple indicators are often aggregated to produce composite indicators, or indices. Composite indicators have been employed at both global and local scales to inform decision making, measure progress toward goals, improve stakeholder participation, and as a tool to integrate development and vulnerability reduction strategies (Parris and Kates, 2003; Quest and Lauwe, 2006). They may also be applied to identify areas where a detailed vulnerability impacts or adaptation is warranted.

GIS and spatial analyses feature prominently in indicator development. Hazard, economic, social, and environmental input variables are aggregated into polygons and grids, while results are mapped into national boundaries or sub-national administrative units. Well known composite indicators such as the Social Vulnerability Index (Cutter *et al*., 2003) and Human Development Index (UNDP, 2006) seek to measure purely social conditions, while others such as the Disaster Risk Index (UNDP, 2004) and Environmental Sustainability Index (Esty *et al*., 2005) attempt to also include hazard exposure and environmental conditions. Primary criticisms of composite indicators are that their construction requires many subjective decisions, external validation is difficult, and they fail to reflect the capacities of people and places to absorb hazard effects.

2.3 Local Knowledge

As with other natural and human processes, knowledge about hazards has typically been divided into expert and non-expert or "local" knowledge. In hazards, expert knowledge tends to dominate decisions about how research will be conducted, how hazards will be managed, and how information will be communicated. Hazard management programs increasingly call for the inclusion of non- experts and non- expert knowledge into decision making (Mehta, 1998; Allen, 2006; Pelling, 2007; Mercer *et al*., 2008; López- Marrero and Yarnal, 2010), but the degree to which non- expert knowledge is incorporated varies from case to case because technical expertise remains privileged. However, there are factors that contribute to vulnerability that cannot be quantified and may not be apparent to technical experts. If those factors cannot be identified and addressed, vulnerability may be reinforced. The importance of integrating non-expert knowledge in hazards research, management, and communication therefore cannot be overstated.

Non- expert knowledge includes that which is informally learned through a combination of common sense (Gramsci, 2008), social interactions (Douglas, 1992), and practical experience or *mētis* (Scott 1998). As a form of non- expert knowledge, local knowledge is typically understood as that which is universally attainable, but explicitly place- based and therefore not universally applicable. Although local knowledge has been discounted because it usually does not explicitly use the scientific method or require formal training, it has also been revered for contributing key pieces of information that are missed in scientific assessments. Although local knowledge may be restricted to a specific location, it is often open to analysis of a complex set of relations among innumerable variables. Thus, while the scope of expert knowledge is limited to a minimal number of relationships between isolated variables, local knowledge accounts for broad, systemic complexity that is understood in the context in which it is used (Scott, 1998). Indeed, some have attempted to reclaim the value of local knowledge by presenting it as just another variation of science, one that uses experience, reasoning, and locally appropriate rationality to discover patterns (Scott, 1998; Robbins, 2003). Ethnosciences have therefore become an important area of study, and in some cases local knowledges (indigenous knowledges in particular) have been privileged over expert (usually Western) knowledge by a number of academic scholars (Smith, 1999). However, all knowledge is partial, social, political and cultural. Therefore, there is a need to combine multiple ways of knowing in order to solve problems and to effectively manage resources and systems (Robbins, 2003).

Local knowledge has been frequently used to verify, challenge, and supplement scientifically-produced knowledge (Fairhead and Leach, 1996; Heiman, 1997; Robbins, 2003; Wainwright, 2008). Such efforts have often incorporated geospatial components using GIS, ranging in scope from the provision of supplemental information to indigenous countermapping. In participatory GIS, the knowledge is incorporated directly by the participants as the primary creators of the information system and mapping (Elwood, 2006). Most of these projects focus on the demarcation of territory and natural resource management. Within hazards, the incorporation of local knowledge and non- experts in the process occurs primarily within disaster response planning (e.g., Mercer *et al.*, 2010). Experience suggests that excluding non- experts in the prevention phase of hazard management has provided solutions to risk reduction that were incomplete at best by failing to address important needs, or even harmful by undermining self- determination, community cohesion, and individual capacity to reduce vulnerability (Cardona, 2011; Bedoya and Ruiz, 2008).

Yet, expert and local knowledge should not be considered mutually exclusive or contradictory. The point here is not to reinforce the stature of expert knowledge by folding diverse knowledges into a systemic methodology of spatial representation, but to facilitate the use of these different knowledge sets in hazards research, management, and communication.

2.3.1 Mental Models

One approach for assessing individual understanding and processing of new information that is often used in risk communication literature is the mental models approach. It posits that examining how individuals understand and view various phenomena is an important step in gauging how audiences organize and process information (Geuter and Stevens, 1983). A mental model is a dynamic mental representation of a situation, event, or object (van Dijk and Kintsch, 1983). This representation is case specific and is subject to change due to new life experiences, stigmatization, perception, and individual information processing strategies (Norman, 1983). Mental models can be used as a way to process, organize, and comprehend incoming information (Radvansky *et al*., 1998; Zwaan and Radvansky, 1998) make social judgments (Wyer and Radvansky, 1999), formulate predictions and inferences (Magliano *et al*., 1996), or generate descriptions and explanations of how a system operates (Rickheit and Sichelschmidt, 1999). For example, a picture of an exhaust pipe may trigger inferences about air pollution and respiratory illness. Even sounds or who communicates the message (the messenger) can contribute to how we think about an issue (Moser and Dilling, 2007).

People try to make sense of the world around them by integrating new information with existing beliefs (Karasz *et al*., 2003). Successful integration requires creating coherent mental models, allowing people to make sense of what they hear and make consistent inferences regarding the situations that they face. Affording people such mental models requires understanding the beliefs that they already hold in their intuitive formulations. Communication structured around such existing sets of beliefs attempts to build on and in some cases adjust those beliefs. A scientific examination of lay beliefs should focus on the topics most relevant to achieving the goals that matter most to people. The mental models approach seeks these ends by integrating decision theory and behavioral research (Morgan *et al*., 2002).

2.3.2 Spatial Mapping of Local Knowledge

There is considerable potential in integrating the technological and analytical capabilities of remote sensing, GIS, and local knowledge. What is necessary to advance our understanding of hazards at the local level is to simultaneously map both geomorphological and ecological attributes gathered using remote sensing and GIS with local knowledge gathered through mental model assessment. The need to spatially map mental models is significant because geographic characteristics generally, and hazards specifically are informed and constituted by local understanding and priorities (Battersby and Montello, 2009).

> "The residents' local knowledge concerning their living environment is often invisible, qualitative and vague, and thus difficult to collect. One way to improve its connection to planning is to find out the location of this knowledge, the precise nature of it, and also whether people are able to bring it forth accordingly. Spatially referenced information has usually been handled in a geographical information system (GIS) that faces new challenges when managing spatial data produced by the residents. There is a need for enhanced techniques in order to gather, handle, analyze and visualize behavioral and experiential knowledge" (Rantanen and Kahila, 2009: 1981).

What is more, local knowledge of hazards among other concerns significantly impacts local capacity for adaptation and mitigation (Lopez- Marrero and Yarnal, 2010). Local understandings of hazards are not merely a matter of opinion that exists outside of geographical characteristics; these ideas are part of a dynamic relationship with biophysical aspects (Knapp and Fernandez- Gimenez, 2009). Approaching hazards in this coupled human-natural way shifts systemic analysis from a "hard," or causally- oriented assessment procedure, to a "soft" systems approach. Hard and soft systems orientations are not synonymous with 'hard' and 'soft' sciences (e.g., bio- physical and sociology, respectively). The distinction is more nuanced. A soft systems approach assumes that human-natural systems are complex and dynamic. As such, simple, causal models fail to explain such a system.

> "The key difference between them [hard and soft systems], little understood as of yet in the literature, is that the hard tradition assumes that systems exist in the world and can be engineered to achieve declared objectives. The soft tradition assumes that the world is problematical, always more complex than any of our account of it, but that the process of enquiry into the world can itself be engineered as a learning system, one in which soft systems thinkers have the option consciously to adopt the hard stance if they wish" (Checkland, 1999: 52).

As such, people "become both a source of information for reality and the reality itself" (Battersby and Montello, 2009: 274). Consequently, participant engagement must be iterative both to collect primary data on mental models and to inform the on- going analyses and mapping processes. Though the conditions that constitute a collaborative opportunity cannot be determined a priori, it would be difficult to reap the benefits of iterative procedures without at least (a) participants being able to truly define the problem definition and (b) several rounds of engagement including initial collection of mental model data, collective and individual interrogation of those results, informed reanalysis given participant feedback and, ultimately, various deliverables as appropriate for the local context (Daniels and Walker, 2001).

2.3.3 Current Applications of Local Knowledge GIS

A small, but expanding area of geographic research has emerged in recent years that attempts to embed GIS into qualitative studies (McLeman *et al*., 2010). Qualitative research can produce a number of outputs, such as interview transcripts, diaries, photographs, audio and video recordings, among others, that when analyzed, can shed light on the experiences and customs of often overlooked groups. Unfortunately, these data are not compatible with the numeric and string data formats used to attribute and symbolize geographic features in a GIS. Led by researchers such as Kwan and Elwood, the functionality and importance of qualitative GIS is on the rise. Efforts to build qualitative GIS databases have generally focused on fitting qualitative data to existing GIS formats, hyper- linking external qualitative data to GIS spatial objects, or adjusting the GIS itself to accommodate new types of data (Jung and Elwood, 2010). In one ethnographic study, diary and interview information describing residential mobility patterns, disability, and neighborhood attributes was collected for low- income and minority families in three U.S. cities. The data were then mapped and compared with available property, census, schools, crime, and road network GIS data (Matthews *et al*., 2005), creating so-called geo- ethnography. The authors found that the GIS coupling enhanced the ethnographic analysis by condensing into a single image many of the daily challenges faced by families and by identifying particular locations of social isolation.

In a more technically sophisticated analysis, the life paths of Muslim women in the months following the events of September 11, 2001, were modeled based on oral histories, audio clips, photos, and field notes (Kwan and Ding, 2008). The goal was to assess changes in the fear and perceived safety of the study subjects based on location, time, and particular geographic features. The end product, termed by the authors 'geo- narratives', effectively imported qualitative data excerpts from NVivo into a 3D GIS, in a way that allowed for the interactive geovisualization of location, chronology, and narrative. Some of the latest research provides a much tighter qualitative GIS coupling, enabling qualitative data to be stored in native GIS structures so that these data artifacts can be returned from spatial queries (Jung and Elwood, 2010). This computer- aided qualitative GIS allows for both qualitative data (e.g., audio and video files, textual information, and photographs) and GIS objects to be both stored and coded within the GIS. The technology is effectively a bridge, running the GIS and qualitative data analysis software in parallel. This gives the analyst access to the full functionality of each individual software package.

Judging from advancements like those described above, the theory and application of qualitative GIS have advanced to a stage where it has demonstrated its high potential. More work is needed to explore the use of more varied forms of qualitative data, methods to merge descriptive and geospatial data, integration of GIS and qualitative analysis software such as NVivo, MAXQDA, and ATLAS ti, and the use of internet mapping platforms to extend visualization beyond the primary researchers. The topic of adaptation is a perfect test bed for further study, as local vulnerability studies continue to increase in use.

3. BUILDING A KNOWLEDGE MANAGEMENT SYSTEM

Thus far, this article has outlined the importance of both local knowledge and geospatial information with respect to hazards research, practice, and policy. To date, this information is packaged separately with no way to integrate how individuals' mental models of hazards relate to the geospatial dimensions of that area, nor the actual environmental changes that can be seen through satellite imagery, for example. As such, there is a great need to synthesize and integrate local knowledge

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through mental modeling with geospatial dimensions using both GIS and remote sensing. To do this, we propose a knowledge management tool to show the relationships between local knowledge and geography to inform research, practice, and policy.

The term knowledge management is traditionally used in an organizational context to represent the need to gather explicit and implicit knowledge that employees in that organization hold (Alavi and Leidner, 2001). Although the research community is not an organization per se, the foundation of knowledge management to organize different types of knowledge with in a "community" still applies. Managing and integrating many different types of data (i.e., qualitative, quantitative, spatial, etc.) surrounding the issue of hazards is a challenge. Confounding this challenge is the need to visualize and map non-numerical data, such as mental models of hazards.

A subset of knowledge management includes knowledge mapping defined as "a consciously designed communication medium using graphical presentation of text, stories, models, numbers or abstract symbols between map makers and map users" (Wexler, 2001: 250). It is not simply a database of information, but relevant information that empowers the user to explore relationships between the data. Taken individually, mental models of local knowledge and spatial information about hazards provide critical data points to make informed decisions. Combining the two empowers not only decision makers, but also scientists and practitioners, to understand the relatedness between perceptions of hazards relative to their spatial locations. As the definition outlines, a variety of information types are required to make a knowledge management system successful. Below are the individual components of the proposed knowledge management tool:

- *Text*: a compilation of a community's mental model through the use of words, ideas, or phrases.
- *Stories*: a database of quotes providing context to the ideas expressed above.
- *Models*: a compilation of the community's mental models through an idea map made of nodes and varying size lines to denote connections of ideas and the number of times the ideas were connected.
- *Numbers and Abstract Systems*: the association of space between the community's ideas and the physical hazards in their changing environment. Additionally, the system will store the node frequency and demographic data such as age, gender, socioeconomic status, etc.

Figure 1 outlines the components of this knowledge management tool. The elements are described in the following sections.

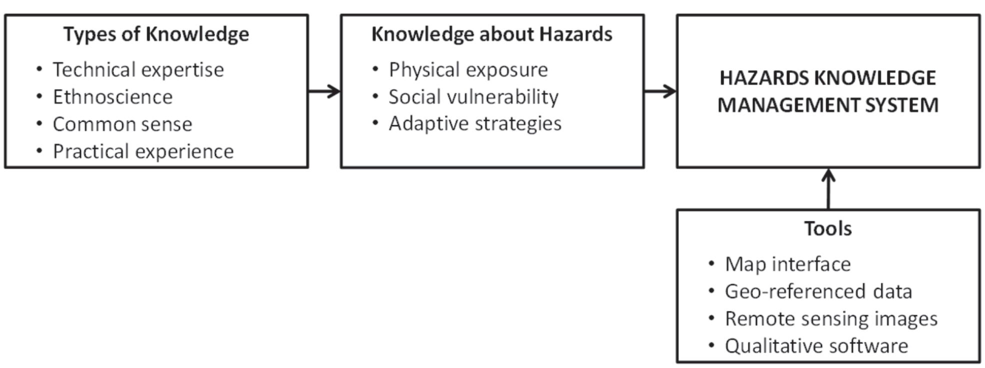

Figure 1. Knowledge Management System

3.1 Local Knowledge

A Network of Mental Models

The system should allow for the archiving of *all* research conducted on mental models as it relates to hazards across the Americas. Each community will have its own mental model map consisting of both nodes and lines connecting them. The nodes vary in size depending on how many individuals in a community mention this idea. The lines vary in weight depending on how many individuals in the community link the two ideas. The system must have a way to show this network of mental models.

Characteristics

The system must also enable the archiving of stories/quotes or research analysis associated with each node and link to maintain the context of each idea and relationship presented. Although a node may say, “flood,” the corresponding quotes may reveal that there are multiple bodies of water of concern to that community. Additionally, the system should maintain a database of demographic information including, but not limited to, age, gender, education, and income.

3.2 Tool Box

Map Interface

The system must have a map interface, such as found in GIS software. Alternatively, web browser-enabled technology such as Google Maps or Google Earth could suffice. Regardless, it is important for the map interface to be tied to the mental model network of that area. The main point of this system is to show the spatial characteristics of ideas in reference to different geographic and hazard areas such as rivers, lakes, and so on. To do this, the map will have many features using GIS and satellite imagery to provide the physical geography dimension. The system should allow for a GIS-enabled mapping system allowing the user to toggle layers on and off. These layers might include social vulnerability maps, locations of bodies of water, locations of other environmental risks (volcanoes, earthquake zones, areas prone to flooding, etc.) The benefit of using GIS is that it allows you to map not only physical characteristics of the environment, but also the social characteristics of the environment.

Remote Sensing Imagery

The system should also allow for the archives of satellite imagery that has documented drastic physical changes in the environment. Books such as the UNEP (2005) Atlas showing satellite images of how the environment has changed have proven to be desired tools by high-level decision makers. Showing where these changes have occurred in combination with the location of the mental model nodes and linkages will help to identify whether these satellite changes are also detected by the local community. Further, it will help to identify gaps in knowledge about the physical changes that are occurring.

3.3 Link between Mental Models and Spatial Dimensions

In addition to the physical and social characteristics of the environment that both GIS and satellite imagery allow, the system could have a coding scheme to show how the community ideas about hazards vary according to physical dimensions of their environment. Qualitative software such and NVivo or Atlas.ti could be used to maintain the quotes discussed in the characteristics section from above. The system could utilize these current tools or create a new tool specifically for this management system.

3.4 Perceived Challenges of a Knowledge Management System

Qualitative analysis of mental models by many researchers may identify varying ideas and linkages. Each individual researcher may use similar, but different words to describe the ideas based on culturally sensitive terminology. A challenge emerges when trying to conduct cross-cultural studies or when aggregating the data to a larger geographic area, for example, when aggregating from many county studies to a state level in the United States. Although qualitative software, such as Atlas.ti, allows the researcher to combine codes (or nodes), how does a large knowledge management tool combine ideas or nodes without the researcher present?

A second concern is that although preferred as the best way to capture the voice of local communities, qualitative approaches to mental models do not collect widespread data in a timely fashion. The concern with quantitative methodology is that it loses aspects of the local context when limited to researcher-suggested terms and only certain specific linkages through survey methodology. The future challenge of such a system includes finding mixed methods approaches to collecting mental models data.

A third concern includes the maintenance of such a system. The goal of this project is to integrate local knowledge from all over the Americas, and as such, a multi- institutional, intercultural collaboration should maintain this system. This does not preclude the involvement of outside companies such as ESRI or Google, for example, or government agencies that have a stake in this information. The main challenge is creating a collaboration of institutions that will maintain the integrity and purpose of such a system. Georeferenced data has the potential to create privacy risks for research subjects and should therefore be managed carefully.

4. RESEARCH RECOMMENDATIONS

This article suggests a knowledge management tool to map local knowledge. But, before the development of such a system can occur, additional research steps must be taken. A list of research areas has been identified below as they relate to the system.

- Conduct more mental model studies of hazards in the Americas.
- Explore mixed methods approaches to conduct mental model studies.
- Develop methods to aggregate mental model studies.
- Research the best approach to archive mental models data and the nodes' corresponding quotes in an information management system.
- Determine the best approach to maintain the spatial components of the mental models map. Since spatial locations will vary within the context of each study, there should be a standard scaling system for comparative analyses between locations.

5. FUTURE APPLICATIONS

In the following section we briefly describe how the research trajectory of the knowledge management system could manifest and integrate hazards and communication research.

5.1 Testing the Iterative Process

The proposed knowledge management system provides an excellent opportunity to test the potential of and limitation of iterative learning and engagement among scientists and local stakeholders. Hazards research based on the vulnerability impacts framework often uses a hazards or vulnerability map as the starting point to engage people within exposed areas to better understand their challenges and capacities. Yet an emerging literature assumes a grounded approach that encourages people to express their concerns generally and then works with those stakeholders to connect their concerns to hazards. Both approaches have the potential to be applied in an iterative fashion.

We propose using an iterative engagement process to perform a cross-case comparison. In one locale, scholars could spatially map mental models in a completely grounded way. In another, comparable locale, scholars could begin by showing local participants a hazards or vulnerability map and build mental maps from those sites of engagement. In both cases, the iterative process facilitates multiple platforms of knowledge claims, definitions of problems and solutions, principal components, and dynamics. Given this generative insight and learning, the knowledge management system provides the opportunity to understand what, if any, difference it makes to begin with a hazards map or using a fully grounded method.

5.2 Mapping Local Knowledge to Inform Education and Outreach Campaigns

Emergency managers, land use managers, public health officials, and many other practitioners are in constant communication with their respective publics, whether it is through public service announcements, brochures, or primary and secondary educational programs. The challenge is that these practitioners often do not have the funds, expertise, or the time to conduct mental model studies to understand their publics' local knowledge and understanding of hazards. Thus, their outreach and educational information may not necessarily resonate with their community.

With the proposed knowledge management tool, practitioners will have the opportunity to see how their community thinks about hazards in their area. Mental models can use local knowledge to shed light on what features of hazards are salient to members of a community, which can help practitioners form more effective educational and outreach campaigns.

5.3 Using Local Knowledge to Improve Hazard Management

Local knowledge can also be used to facilitate a multidirectional exchange between experts and non- experts, which has the potential to broaden and deepen our general understanding of hazards and vulnerability. Non- experts could provide essential information regarding their experience of hazards and vulnerability that might otherwise go unrecognized by experts. The proposed data management system could help practitioners collect and store information about how people experience and understand hazards in myriad ways. Since hazards are fundamentally experienced spatially, the mapping component of this system will be especially useful.

While the specific experience of hazards will vary from place to place, there may be advantages to comparative studies across contexts. Systematic collection and organization of data can facilitate information and idea sharing. Researchers and practitioners can exchange methods, learn from previous successes and failures, and draw from and contribute to an overall improved understanding of hazards. The ability to share local knowledge and how it can be used in hazard management is critical. Generally such information is not spread through the same mediums as typical hazards research findings and management strategies – namely periodicals, reports, and specialists' conferences. The proposed data management system would therefore facilitate the exchange of information rarely observed in these professional channels.

6. CONCLUSIONS

Both local knowledge and spatial experience are important to understand hazards and to identify areas for policy intervention. Key challenges remain, including how to ensure privacy of research participants while managing a large and complex database. It is our hope that spatially mapping local knowledge through a management system will enable researchers, policy makers, and practitioners to improve their understanding and communication of hazards in order to create a better prepared Americas.

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REFERENCES

AIACC, 2010. About AIACC. Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors Retrieved June 20, 2010, from http://www.aiaccproject.org/about/about.html.

Alavi, M. and D. E. Leidner, 2001. Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. MIS quarterly: pp. 107- 136.

Allen, K. M., 2006. Community-based disaster preparedness and climate adaptation: local capacity-building in the Philippines. Disasters 30(1): pp. 81- 101.

Battersby, S. E. and D. R. Montello, 2009. Area estimation of world regions and the projection of the global-scale cognitive map. Annals of the Association of American Geographers 99(2): pp. 273- 291.

Bedoya , A. and J. Ruiz, 2008. Forma de gobernanza frente a la gestión del riesgo. Estudio de caso sector de Nueva Esperanza, Bogotá, D.C., Colombia. Perspectiva Geográfica 13: pp. 143- 164.

Cardona, O.D., 2011. Sistema Nacional para la Prevención y Atención de Desastres en Colombia. Retreived June 17, 2011 from http://www.manizales.unal.edu.co/gestion_riesgos/descargas/gestion/SistemaNacionalODCardonaOFDA-IDEA.pdf

C2HEKE, 2010. Climate Change and Hazards Education Knowledge Environment. Retrieved May 19, 2011, from https://sites.google.com/a/aag.org/c2heke/home.

Checkland, P., 1999. Systems Thinking. Rethinking management information systems: An interdisciplinary perspective. W. Currie and R. Galliers. Oxford, Oxford University Press.

Cutter, S. L., B. J. Boruff and W. L. Shirley, 2003. Social Vulnerability to Environmental Hazards. Social Science Quarterly 84(2): pp. 242- 261.

Daniels, S. E. and G. B. Walker, 2001. Working through environmental conflict: The collaborative learning approach. Westport CT, Praeger Publishers.

Dessai, S. and M. Hulme, 2004. Does climate adaptation policy need probabilities. Climate Policy 4(2): pp. 107- 128.

Douglas, M., 1992. Risk and blame, Routledge New York.

Eakin, H. and A. L. Luers, 2006. Assessing the vulnerability of social-environmental systems." Annual Review of Environment and Resources 31: pp. 365- 394.

Elwood, S., 2006. Critical issues in participatory GIS: deconstructions, reconstructions, and new research directions. Transactions in GIS 10(5): pp. 693- 708.

Esty, D. C., M. Levy, T. Srebotnjak and A. de Sherbinin, 2005. Environmental Sustainability Index: Benchmarking National Environmental Stewardship. New Haven, Yale Center for Environmental Law & Policy.

Fairhead, J. and M. Leach, 1996. Misreading the African landscape: society and ecology in a forest-savanna mosaic. Cambridge, Cambridge University Press.

Franco-Vidal, C.L., A. M. Muñoz, G.I. Andrade y L.G. Naranjo. (Eds.), 2010. Experiencias de adaptación al cambio climático en ecosistemas de montaña (páramos y bosques de niebla) en los Andes del Norte. Memorias del Taller Regional. Bogotá, D.C. Febrero 19 y 20 de 2009. WWF, MAVDT, IDEAM y Fundación Humedales.

Garcia, J. Osorio, L. C. and R. Contreras, 2010. Articulando las agendas verde y marrón en un contexto de cambio climático. Guía para la formulación de agendas ambientales locales en Colombia. Bogotá: ONU-Habitat.

Geuter, G. and A. L. Stevens, 1983. Mental Models, Hillsdale, NJ: Lawrence Erlbaum Associates.

Gramsci, A., 2008. The Prison Notebooks. New York, International Publishers.

Gravelle, G. and N. Mimura, 2008. Vulnerability assessment of sea-level rise in Viti Levu, Fiji Islands. Sustainability Science 3(2): pp. 171- 180.

Heiman, M. K., 1997. Science by the people: Grassroots environmental monitoring and the debate over scientific expertise. Journal of Planning Education and Research 16(4): pp. 291- 299.

Hewitt, K., 1983. The Idea of Calamity in a Technocratic Age. Interpretations of Calamity from the

Viewpoint of Human Ecology. K. Hewitt. Boston, MA, Allen & Unwin Inc.: pp. 3- 32.

Jung, J. K. and S. Elwood, 2010. Extending the Qualitative Capabilities of GIS: Computer- Aided Qualitative GIS. Transactions in GIS 14(1): pp. 63- 87.

Karasz, A., M. D. McKee and K. Roybal, 2003. Women's experiences of abnormal cervical cytology: illness representations, care processes, and outcomes. Annals of Family Medicine 1(4): pp. 196- 202.

Knapp, C. N. and M. E. Fernandez- Gimenez, 2009. Knowledge in Practice: Documenting Rancher Local Knowledge in Northwest Colorado. Rangeland Ecology & Management 62(6): pp. 500- 509.

Kwan, M. P. and G. Ding, 2008. Geo- narrative: Extending geographic information systems for narrative analysis in qualitative and mixed-method research. The Professional Geographer 60(4): pp. 443- 465.

Liu, J., S. Fritz, C. F. A. Van Wesenbeeck, M. Fuchs, L. You, M. Obersteiner and H. Yang, 2008. "A spatially explicit assessment of current and future hotspots of hunger in Sub-Saharan Africa in the context of global change." Global and Planetary Change 64(3-4): 222- 235.

Liverman, D. M., 1990. Vulnerability to Global Environmental Change. Understanding Global Environmental Change: The Contributions of Risk Analysis and Management. R. E. Kasperson, K. Dow, D. Golding and J. X. Kasperson. Worcester, MA, Clark University: 27- 44.

Lopez-Marrero, T. and B. Yarnal, 2010. "Putting adaptive capacity into the context of people's lives: a case study of two flood-prone communities in Puerto Rico." Natural hazards 52(2): 277- 297.

Magliano, J. P., K. Dijkstra and R. A. Zwaan, 1996. "Generating predictive inferences while viewing a movie." Discourse Processes 22(3): 199- 22.

Ministerio de Ambiente, Vivienda y Desarrollo Territorial (MAVDT), 2005. Incorporación de la Prevención y la Reducción de Riesgos en los Procesos de Ordenamiento Territorial. Bogotá: MAVDT.

Matthews, S. A., J. E. Detwiler and L. M. Burton, 2005. "Geo- ethnography: coupling geographic information analysis techniques with ethnographic methods in urban research." Cartographica: The International Journal for Geographic Information and Geovisualization 40(4): 75- 90.

McLeman, R., S. Herold, Z. Reljic, M. Sawada and D. McKenney, 2010. "GIS-based modeling of drought and historical population change on the Canadian Prairies." Journal of Historical Geography 36(1): 43- 56.

Mehta, M. D., 1998. "Risk and decision-making: A theoretical approach to public participation in techno-scientific conflict situations." Technology in Society 20(1): 87- 98.

Mercer, J., I. Kelman, K. Lloyd and S. Suchet- Pearson, 2008. "Reflections on use of participatory research for disaster risk reduction." Area 40(2): 172- 183.

Mercer, J., I. Kelman, L. Taranis and S. Suchet- Pearson, 2010. "Framework for integrating indigenous and scientific knowledge for disaster risk reduction." Disasters 34(1): 214- 239.

Morgan, M. G., B. Fischhoff, A. Bostrom and C. Atman, 2002. Risk communication: A mental models approach. New York, Cambridge University Press.

Moser, S. C. and L. Dilling, 2007. Toward the social tipping point: creating a climate for change. Creating a climate for change: Communicating climate change and facilitating social change. S. C. Moser and L. Dilling. New York, Cambridge University Press: 491- 516.

Norman, D. A., 1983. Some Observations on Mental Models. Mental models. D. Gentner and A. L. Stevens. Hillsdale, NJ, Lawrence Erlbaum: 99- 129.

Parris, T. M. and R. W. Kates, 2003. "Characterizing and measuring sustainable development." Annual Review of environment and resources 28(1): 559- 586.

Pelling, M., 2007. "Learning from others: the scope and challenges for participatory disaster risk assessment." Disasters 31(4): 373- 385.

Quest, A. and P. Lauwe, 2006. User Needs: Why We Need Indicators. Measuring Vulnerability to

Natural Hazards: Towards Disaster Resilient Societies. J. Birkmann. Tokyo, United Nations University Press: 103- 114.

Radvansky, G. A., R. A. Zwaan, T. Federico and N. Franklin, 1998. "Retrieval from temporally organized situation models." Journal of Experimental Psychology: Learning, Memory, and Cognition 24(5): 1224- 1237.

Rantanen, H. and M. Kahila, 2009. "The SoftGIS approach to local knowledge." Journal of environmental management 90(6): 1981- 1990.

Rickheit, G. and L. Sichelschmidt, 1999. Mental models: Some answers, some questions, some suggestions Mental models in discourse processing and reasoning. G. Rickheit and C. Habel. Amsterdam, Elsevier Science: 9- 40.

Robbins, P., 2001. "Fixed categories in a portable landscape: the causes and consequences of land-cover categorization." Environment and Planning A 33(1): 161- 179.

Robbins, P., 2003. "Beyond ground truth: GIS and the environmental knowledge of herders, professional foresters, and other traditional communities." Human Ecology 31(2): 233- 253.

Schwanen, T. and M. P. Kwan, 2009. ""Doing" Critical Geographies with Numbers." The Professional Geographer 61(4): 459- 464.

Scott, J. C., 1998. Seeing like a state. New Haven, Yale University Press.

Smith, L. T., 1999. Decolonizing methodologies, Zed Books.

Torresan, S., A. Critto, M. Dalla Valle, N. Harvey and A. Marcomini, 2008. "Assessing coastal vulnerability to climate change: comparing segmentation at global and regional scales." Sustainability Science 3(1): 45- 65.

Turner, M. D., 2003. "Methodological reflections on the use of remote sensing and geographic information science in human ecological research." Human Ecology 31(2): 255- 279.

UNDP, 2004. Reducing disaster risk: a challenge for development. M. Pelling, A. Maskrev, P. Ruiz and L. Hall. New York, United Nations Development Programme, Bureau for Crisis Prevention and Recovery.

UNDP, 2006. Beyond scarcity: power, poverty and the global water crisis. Human Development Report 2006. K. Watkins. New York, United Nations Development Programme.

UNFCCC, 2005. Handbook on Vulnerability and Adaptation Assessment. Consultative Group of Experts on National Communications from Parties not Included in Annex I to the Convention (CGE). Bonn, United Nations Framework Convention on Climate Change.

Van Der Hammen, T. and G. Andrade, 2003. Estructura Ecológica principal de Colombia Primera aproximación. Bogotá, IDEAM.

van Dijk, T. A. and W. Kintsch, 1983. Strategies of discourse comprehension. New York, Academic Press.

Wainwright, J., 2008. Decolonizing development: colonial power and the Maya. Malden, Blackwell Publishing.

Wexler, M. N., 2001. "The who, what and why of knowledge mapping." Journal of knowledge management 5(3): 249- 264.

Wilbanks, T. J. and R. W. Kates, 1999. "Global change in local places: how scale matters." Climatic Change 43(3): 601- 628.

Wyer, R. S. and G. A. Radvansky, 1999. "The comprehension and validation of social information." Psychological Review 106(1): 89- 118.

Zwaan, R. A. and G. A. Radvansky, 1998. "Situation models in language comprehension and memory." Psychological Bulletin 123(2): 162- 185.