People and the Planet 2013 Conference Proceedings

This article was first presented at the *People and the Planet 2013 Conference: Transforming the Future*, RMIT University, Melbourne, Australia, 2-4 July.

All articles published in this collection have been peer reviewed.

Title: Vulnerability and Change in the Global South: A Spatially Informed Approach

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Publisher: Global Cities Research Institute, RMIT University, Melbourne, Australia

Year: 2013

Editor(s): Paul James, Chris Hudson, Sam Carroll-Bell, Alyssa Taing

Series URL:
http://global-cities.info/news-events/conferences-forums/conferences-proceedings

Vulnerability and Change in the Global South: A Spatially Informed Approach

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Abstract: Urbanization, climate change, and population growth/ageing are three of the most important challenges facing human societies this century. The capacity of our systems to respond effectively is currently compromised not only by the limits of effective knowledge production and utilization, but also by our technical capacity to compile and analyze large-scale information from numerous interconnecting systems. The rush to 'big data' is one example among many of our current inability to deal with complex and highly dynamic problems effectively. This has to change if we are to address these challenges, especially in the vulnerable areas of the global south. One approach that has the potential to support our responses is the field of spatial science. This is a fast-changing, developmental and interdisciplinary field where many issues associated with complex natural-human system interactions are already being addressed. We outline how a spatial approach has the capacity to inform and support our responses to the challenges we all face in the coming decades. We also suggest that few other human technical scientific systems have the ability to address the complexity of problems we are already encountering and those that are yet to make their full effects felt.

Keywords: vulnerability, spatial, change, climate, population, complexity, urbanization

1. Introduction

Human beings have a conceptual and practical tendency to simplify the complex nature of external reality. This happens mostly by a process of exclusion, that is by either conscious or unconscious attempts to reduce the amount and type of information that we receive, perceive, analyze and/or incorporate into our cognitive domain (Fiske and Taylor 2013). As a result, humans have a significant problem with various forms of complexity. While approaches to reducing complexity have their (known) origins in Platonic and Aristotelian thought, it was the rise of positivism and 'modern' scientific thought that shaped approaches to human and natural systemic complexity through mechanisms such as categorization and taxonomic classification (Chute 2000, Pellegrin and Preus 1986). Consequently, many of our contemporary mechanisms for structuring knowledge are distinctly Victorian in their design and function, with a preference for simple linear heuristics that can circumvent the more complex responses required in the context of changing circumstances such as climate change (Richards 1993, Scoones *et al*. 2007). They tend to exclude rather than include, simplify and reduce the complexity that is the characteristic of reality. In other words, in both theory and practice, humans often respond to the world by ignoring, reducing or pretending external complexity with often inevitable consequences (Taleb 2007, Tenner 1997). In an age where digital information is both pervasive and expanding exponentially, analogue forms of analysis and thinking designed for this previous age persist. This situation produces in effect, a lag effect in the ability to cope with emerging situations and problems.

The recent fascination with 'big data' across public and professional fields represents an acknowledgement that many epistemologies, both social and scientific, lack the capacity to deal with information analysis and critique in an increasingly digital environment. While a variety of sciences are moving quickly to develop technologies, methods and conceptual schemata to enable the utilization of 'big data', many technical questions (Qin and Li 2013, Tien 2013, Wang *et al*. 2013, Wigan and Clarke 2013), social (González–Bailõn 2013, Oboler *et al*. 2012) and ethical (Boyd and Crawford 2012, Currie 2013, Davis and Patterson 2012, Ioannidis 2013, Oboler *et al*. 2012) remain to be resolved. In addition, with current rates of technological innovation and change, it is likely many variations on current questions and entirely new issues will emerge over time.

This paper attempts to address a number of the key problems that will potentially confound the ability to deal with growing complexity if new approaches to understanding complexity do not move beyond this current situation. The paper will identify a number of multi-scalar developmental, and challenging issues faced in increasingly interconnected environments, both natural and man-made. This is done by using spatial science as a broad inter-disciplinary field of activity as an example of how complexity can be addressed and how epistemic limitations are overcome; showing how some scientists are addressing the epistemic inheritances that limit the ability to respond to the rising complexity and associated risks; and then looking at a selection of these issues in the context of the 'global south', itself a reductive concept for a large proportion of the issues that currently face the majority of the human population. Lastly, suggestions will be made as to how the developmental spatial sciences and their efforts at systemic integration and knowledge exchange offer a useful example for other disciplines and policy arenas. This is not a call for more technology but rather an exploration of how casting off traditional knowledge paradigms can advance human knowledge and the potential capacity to address these varied problems, mostly of our own making.

2. Global challenges for this century

Human beings have a tendency to see history as representing both events and transformations. They define time and epochs against cultural and social criteria that are usually imposed long after the events they seek to define have occurred (eg. the Renaissance, *longue durée*, the Enlightenment [see Giddens 1990, Kaufman 2010, Kragh 1989, O'Brien and Roseberry 1991]). Humans are highly adapted to perceiving patterns, especially after events have occurred, but are not always as pattern sensitive prior to, or in the midst of unfolding events and we even combine such patterns with post hoc reasoning and affective biases to perceive patterns where none exist (apophenia) (Duncan and Barrett 2007, Gilbert 2002). In addition, humans can develop and lose knowledge over time as new information and technologies appear to supersede conventional or traditional systems. In this sense too, humans can lose track of things that they have already learned and fail to recognize patterns which they once possessed; local and cultural explanatory knowledge. A consequence of this is a process of both new knowledge development and the loss of older knowledge over time. This often means local and indigenous (but not only those) knowledge systems losing out to those of the dominant economic and scientific paradigms of contemporary society (eg. Mauro and Hardison 2000, Orlove *et al*. 2010).

In the context of the global south this can mean that newer or introduced knowledge can displace local epistemologies creating a gap between what were once established and newly emerging paradigms. This has been a characteristic of what is thought of as modernity but it is not a given of that state. Many developmental technologies may impose a general outline to knowledge collection (eg. digitization) but they do not require or demand the loss of long-established knowledge about environments and cultures and the links between the two. In this paper the concept of the 'global south' is used as a way of exploring how preparation for, and coping with a range of rapidly developing phenomena can be addressed applying such technologies, while providing the capacity to address local and contingent understandings of change and adaptation in society and the natural environment. Use of spatial or geographic information science can be employed as a platform for understanding how the local and global can be gathered within one conceptual framework and utilized to develop local responses to change, and potential disruption. The three phenomena explored in order to do this are urbanization, climate change and population growth and ageing.

2.1 Urbanization

The current global population is currently between 6.8 and 7 billion people (Gonzalo *et al*. 2013) and has passed the point at which more than half of the global human population lives in cities (UN-Habitat 2010). By the middle of this century it is estimated that fully two-thirds of the global population will live in cities and that 80 per cent of these urban populations will be in countries, currently defined as developing (DESA 2012). This makes urbanization sound like a generalized, even uniform process but the nature of those urban environments in very broad both quantitatively and qualitatively. The cities of the global north tend more often to be affluent, well-resourced and well-regulated living environments. The same is less often true of the cities in the global south. The quality of life for people living in 'informal' and shanty town conditions is often complicated not only by a lack of resources including power, water and safety, but also by their lack of formal recognition within existing socio-political environments (UN-Habitat 2003). Dwellings which are not 'officially' recognized often receive few or no formal services (eg. water, power, waste collection and disposal) making them liminal locations of social marginalization and also the physical and mental health sequelae often associated with liminality (McGuire and Georges 2003). A similar pattern often exists in the cities of the global north where very different social classes may live in close proximity without sharing the same life chances or risks to health and wellbeing (Dorling and Thomas 2009). Social inequalities are just as readily urbanized as social opportunities. The vulnerability of differentiated social groups (including the poor, recent immigrants, those with disabilities etc.) can be quantified and qualified by applying a range of spatial research methods and visualization techniques.

A key issue for current continuing urban development is the quality of the fundamental resources required to support urban systems including air, water and soil quality. Associated human systems such as food production, power supply, waste management, transport and housing supply are evidently equally required. Clearly, cities do not exist in isolation from their surrounding areas, regions and states. They interact with them in a variety of ways including drawing in people and resources as well as exporting both positive and negative influences to their hinterlands including resource demand, payments for those and sometimes pollution and/or over-exploitation of water resources and the like (Gore and Fothergill 2007).

Contemporary megacities (now defined as 10 million people and over) are also proving to be a challenge for rational planning processes in that they need to address all of the previously mentioned issues as well as be livable, functional and at least to some extent, efficient in terms of their resource use (Kraas 2007). However, it has been noted that these are the easily identified aspects of rapid development and that many secondary urban areas are growing faster and often with less planning than those places formally designated as megacities (Linden 2000).

2.2 Climate change

Climate and weather are dynamic features of the environment. There is no scientific contention that climate (at various scales) does not change over time (McMichael *et al*. 2003). The political position that climate represents a static system or one uninfluenced by human activity cannot be sustained, as climate modelling requires highly dynamic methods to achieve even moderate accuracy (eg. McGuffie 2005, Robinson 2001). Even urban environments have been proven to influence local and regional climate and weather systems with important collates in terms of health and urban sustainability (Blake *et al*. 2011, Collier 2006). The major issue now is the *degree* to which human activity is contributing to global Climate change as evidenced by our current and projected circumstances and the potential impact of that change over some forecast period of time. In spite of these minor contentions, in areas such as disaster insurance and reinsurance, Climate change is accepted as real and significant work is being undertaken to track natural disasters and develop remediation and resilience plans for future impacts (eg. Ranger and Surminski 2013).

While climate change can be seen as a macro-scale process, it is also clear that regional climatic variations can and are occurring including the current rate of summer ice melt in the northern hemisphere (Blunden and Arndt 2013). Consequently, the world faces a significant alteration to past patterns of weather and disruptions to local and regional conditions that may have implications that exist in addition to the global-level changes we currently forecast. Climate changes of these dimensions have implications for urban development, as described above, and for population growth and ageing described in more detail below. This is because climate change effects will impact on urban systems many of which are concentrated in low-lying areas on or close to coastal zones. Many others are highly dependent on traditional water sources that may be affected by global patterns and regional climatic variations (Droogers *et al*. 2012). Populations in urban areas globally will experience dynamic and varying degrees of vulnerability (as they do now) based on these natural-social system interactions, with population ageing making for significant levels of increased vulnerability in many communities (eg. Loughnan *et al*. 2013, Olorunfemi *et al*. 2009). In this sense, climate change is a nexus issue linking urban patterns and social systems with wider natural system impacts.

2.3 Population growth and ageing

Population and the management of population (governmentality), has been a major issue since the emergence of the modern nation state (Curtis 2002, Foucault 2009). Many of these issues centre upon deeply embedded processes of identity construction associated with nation-building and the mythologies that have developed around these processes. These mythologies relate to topics such as optimal population size and composition reflecting a twentieth century obsession with the 'science' of population and its dynamics (Hartman 1997, Hodgson 1991). Yet modern nations are, for the most part, little more than 200 years old and many are younger still. A characteristic of this often ideology-driven analysis was a very particular focus on the growth of populations in those countries referred to as third world or developing countries, reflecting the deeply ideological nature of the analysis. Concepts such as 'carrying capacity', introduced by the Club of Rome in 1972 and revisited regularly since, have been used to draw attention to the intimate relationship between the limited extent of our physical environment and the seemingly unlimited potential for human reproduction (eg. Hui 2006, Ryerson 2010, Sayre 2008, Turner 2008).

Population changes have been dramatic over the last century and particularly over the past half-century (eg. Bongaarts 2009). In that time, the total human population has more than doubled but also major changes have taken place in the composition of populations and these processes are ongoing. The majority of the 'developed' countries are now experiencing population ageing, and a number of developing countries have, or are fast approaching this 'demographic transition' (Madsen 2012). This means, descriptively, that their populations are no longer characterized by high fertility, morbidity and mortality, but instead now have low birth rates, often below replacement level, with rising life expectancies and significant growth in the absolute number and proportion of the population that is over 65 years of age (eg. Kinsella and He 2009). Most of the countries of Western Europe, North America and many others have reached or are reaching a point where this is the pattern that will dominate for the next generation or two. This situation is unique in human history and it has significant implications for how our societies develop into the future including ageing as a developmental goal that illustrates how previous patterns of high fertility and low life expectancy are being overcome (eg. Beard *et al*. 2012, Healy 2004).

Associated with this in many countries is a rise in the diseases associated with ageing including neurodegenerative conditions such as the dementias (eg. Prince *et al*. 2013). In addition, older people are more susceptible of comorbidities than younger people, including chronic conditions and dementia, meaning that the complexity of addressing this ageing situation requires a change to conventional health and medical systems (Rechel *et al*. 2009). The differing patterns and speed of population ageing mean that the global north is experiencing these issues earlier than the global south and, in doing so, making demands on labour from the global south, especially workers in the various health disciplines (eg. OECD 2008). However, the variable rates of population increase and rising life expectancies across much of the global south mean that ageing is and will continue to be an important part of the emergent demographic situations in those countries. This in turn will intersect with climate change and urban development to create differential patterns of vulnerability.

The intersections between climate change, urbanization and population ageing are increasingly being recognized as major factors for disaster planning (Foresight 2012). An important consideration in this linkage will be not only the physical vulnerability of older people in the global south but the numerous comorbidities associated with ageing including disabilities and neurodegenerative conditions such as the dementias. Ageing and health status form a complex nexus in terms of planning for and coping with disaster events. The global epidemiology of ageing needs to be added to the vulnerability equation even in the global south where outside planners tend to emphasize conditions associated with the Millennium Development Goals (MDGs) of the United Nations. Population characteristics are highly dynamic and population ageing will present unique challenges in the urban environments of the global south.

3. Risk and vulnerability

3.1 Defining risk and vulnerability

The concepts of risk (risk civilization, risk society, risk culture) and vulnerability may be seen as twins in developing a conceptual framework of safety and future-oriented planning and development (see Boudia and Jas 2007). The need for these conceptual twins can be seen in contemporary approaches to complexity and our need to plan for and anticipate a variety of potential future scenarios in which complex systems may confound current planning abilities. Beck has argued for more than two decades that the growing influence that the construction of risk has on the organization and operation of contemporary industrial society (modernity) has come to define that society to the extent that we now live in a 'risk society' (Beck 1992, 1996 and 1999). In this context, he suggests that those most 'at risk' are also increasingly those most marginalized from access to insurance and related risk-mediating practices resulting in a perverse risk-protection inversion (Beck 1991, Eliott 2002). But as well as this, this conceptualization and deployment of a risk-oriented approach characterizes the contemporary form of governance including state-based surveillance of and intervention in particular groups in our societies.

Giddens (1990) invokes spatiality as a construct for analyzing both abstract and experiential systems. In the context of abstract systems (which he defines as 'symbolic tokens and expert systems' [p. 80]) he suggests that access points are both points of vulnerability and opportunities for connection-building and trust development because we are, often, socially disconnected in very large societies where we cannot possibly know everyone. In this sense, vulnerability can lie in the space between those whom we know and actively trust and those 'experts' who represent abstract systems in which we are asked to trust but which cannot provide the psychological satisfaction we require of such encounters producing Gidden's 'unease' with the juggernaut of modernity. This analysis seems to elide the kind of systemic failures that regularly occur in complex expert systems, such as banking and medicine for example, where expertise can often manufacture vulnerable groups and individuals.

Vulnerability is commonly defined as a composite measure of a selection of population-based characteristics (Dutta *et al*. 2010). Cutter and colleagues, for example, have developed several spatial modelling approaches to vulnerability. In these models, characteristics of vulnerability tend to include age characteristics (children and the elderly), socio-economic status (especially the poor), 'race' and ethnicity (more particularly minority status), gender (women) and often selected groups with special/specific needs such as the disabled, rural dwellers, the unwell and transient or liminal groups (Cutter *et al*. 2003). These social variables can be combined with natural hazard assessments to create a measure of exposure to particular events such as hurricanes, floods and so on, in ways that can then be mapped (Cutter and Finch 2008).

In addition, exposure to man-made factors can also be assessed following a similar approach including actual and potential exposure to air and water pollutants for example, and climate change more broadly (eg. Jackson *et al*. 2010, Xu *et al*. 2012). In the context of the global south, the same methods can be applied but using local information and knowledge to adjust variables such as key social characteristics and the identification of local risk factors, natural and man-made. The capacity exists to use an overarching scientific approach to develop and test locally-informed models of potential events and their consequences for local communities. This can be done within computer-based environments that can incorporate multiple scenarios over differing geographical scales including local, regional, national and even cross-border impacts.

One of the features of this risk-vulnerability engagement is that need for recognition of this as a dyadic process in that the administration of risk can produce or exaggerate vulnerability and specific states of vulnerability can lead to differential and heightened levels of risk. Social variables are, after all, secondary features of the analysis and governance of society leading to the characterization of population subsets as embodying specific characteristics. While environmental conditions may be seen as external to this process, it is clear that the framework of 'risk' analysis is a direct intervention in the way situations and groups are constituted and, accordingly, valued.

3.2 Risk and vulnerability in the global south

One of the issues with translating north understandings of vulnerability to the global south is the tendency for their implicit assumptions to fail partially or completely in the cross-cultural process involved. Northern models often assume a distinctly middle-class and highly rationalistic approach to all human motivations and circumstances that tend to be imposed in developed countries but may be far less conceptually stable in developing countries (Cannon 2008). This means that there is also a critique of the concept that disasters are socially constituted.

3.3 When things go wrong

One of the key issues with the concept of vulnerability is that it helps mediate the concept of 'risk' which often represents peoples' exposure to hazard events as uniform and stable even when significant local variations can be observed (Birkman 2007, Comfort *et al*. 1999, Cutter *et al*. 2002). While this is true for some types of hazard events, many other situations arise in which the social circumstances of categories of individuals or social groups may predispose them to greater or lesser exposure and severity thus mediating their overall risk profile. This is typically true of health cases, for example, where social status and other population characteristics are correlates for exposures to particular kinds of health conditions. In addition, risk profiles can mute vulnerability characteristics by the use of crude probabilities, which suggest health statistics explain rather than describe peoples' circumstances. The link between correlation and causality is readily confused through inadequate analytical rigour. Briggs and Mantini-Briggs (2004) provide a case-study of a cholera epidemic in Venezuela in the early 1990's and show how exposure to the disease was exacerbated, and the capacity of the formal health system to respond was heavily compromised by prevailing ideologies of race and indigeneity. Even public data collection and reporting were minimized and misrepresented because of a belief in the relative value of different social groups within Venezuela at that time. In other words, when things do go wrong the capacity of health systems to respond, usually represented in highly rational terms, can be heavily impacted by prevailing power structures, social beliefs and practices.

These kinds of situations mean that whatever the ontological reality of a situation and the scope of objectified risks, knowledge and beliefs (epistemologies) can have important effects in enhancing or limiting our systemic responses. The tendency of social relations to mediate vulnerability status can be seen in the way events can have differential effects in geographically defined areas. A city may be struck by heavy rains, for example, but the impact may differ based on who lives on the steepest slopes or how and where city councils have chosen to invest in flood control and remediation efforts. The same variations may also affect the ability, and even willingness, of emergency response teams (as in the aftermath of Hurricane Katrina). The consequences of a specific rate of rainfall may have differential social effects. These risk-vulnerability relationships can change under the same or similar conditions. For example, in many developed countries and urban centres the more affluent suburbs may be located close to water including rivers, lakes and the seashore making them vulnerable to shifts in weather patterns including tidal surges and shoreline erosion. The same weather patterns are more likely to impact on the poor in developing countries where low-lying land close to water is often where the poor live.

3.4 The production of vulnerability in a globalizing context

The three features we have focused here all have the capacity to produce their own distinct and intersecting forms of vulnerability. Given that vulnerability as we have described it here can be a product of the interactions between environments and individuals (or social groups), then it is clear that people with a vulnerable status can themselves be, highly mobile, and that, vulnerability can also be fluid. We propose also that vulnerability can be scalar in character as some events may be highly localized while others (such as the 2004 Indonesian earthquake and tsunami) may have effects far beyond their geographic point of origin.

4. Complexity and systems

4.1 Complexity in natural systems

We suggested above, that human cognitive capacities have a tendency to 1. reduce complexity in incoming perceptual information and 2. actively pattern seek, often by referencing and reproducing previously established cognitive-analytic patterns. We tend to see what we expect to see based on previous experience. We can also see how our perception and cognition are often constrained by group-based ideas and learning processes including social and cultural processes. Yet it seems clear that natural phenomena are often enormously complex involving ‘deep’ processes in space and time, and especially when these systems are, as is usual, closely coupled (Liu *et al*. 2007). Geological science is perhaps one easily understood example of a recent modern science that encapsulates dynamic spatial and temporal processes (geocomplexity) that run into the hundreds of millions of years and more (Turcotte 2006).

4.2 Complexity in human systems

The interactions between human-developed phenomena such as agriculture and industrial processes are extremely complex as we are increasingly, finding to our cost. The example of climate change in this paper is one in which a variety of sub-processes have been investigated and theorized, which illustrate just how complex some of those interactions are. Human systems in their own right, including the development of phenomena such as language and culture, are highly complex.

4.3 Human-natural system interactions

At one level it is obvious that there is no concrete distinction between human and natural systems because humanity is deeply coupled to, or embedded in, and dependent upon the natural environment and natural systems (Alberti *et al*. 2011, Liu *et al.* 2007). However it is also clear that human beings have created, and continue to create, factors and sub-systems which operate (or are at least often designed and implemented as though they do) outside of natural systems, constraints and dynamics. By this, we do not mean that those are separate from nature, but rather, they tend to create their own effects which often have 'feedback effects' on natural systems with global climate change or even local micro-environmental changes being observable examples. In addition, there is evidence to suggest that these complex interconnections have reached a new stage and that we have entered a new era, defined as 'the anthropocene', in which human-derived effects outweigh or permanently unbalance long-term natural system stability (Steffen *et al*. 2007).

4.4 Beyond system-based approaches

Systems theory has proven popular during the post-war period with a significant boost provided by the development of computer-based modelling technologies. Spatial (geographic) information systems technologies also received a major boost in the 1980's with the development of personal computers meaning that geographic information systems (GIS) software could move from mainframe environments to desktops (Chrisman 2006, Goodchild 2008). Since then a variety of even more accessible spatial technologies have developed and become (almost) universally available including GPS units and GPS-enabled mobile telephones which permit volunteered spatially indexed (geocoded) information to be posted to the internet in ever increasing volumes (eg. Ratti *et al*. 2006). This technology also now extends to integrative environments, which can best be described as virtual geographies because researchers are able to produce simulations of the earth and specific places in a digital context for visualization, exploration and analysis, including data mining activities (Lin and Batty 2011).

What is proposed is essentially a spatio-temporal political ecology in which the techno-scientific elements of concern can be modelled alongside the political and socio-cultural dimensions. At this level, the spatial dimension becomes both the pivotal overarching design feature, because we are attempting to model external reality at varying levels of complexity, and that it functions as an integrative dimension for all of the various disciplinary and policy perspectives that come into play.

5. The spatial dimension

One of the key dimensions missing from much social and environmental policy discussion is the spatial dimension. While environmental science is developing rapidly in this area, it is clear that the spatial sciences are mostly absent from much of the public policy domain and the concept that spatial science has an important contribution to make to evidence-based policy development has some way to go (Wise and Craglia 2008). Recent developments in spatial technologies including geographic information systems, GP-enabled smart phones, real-time satellite imagery and virtual earth simulation software (such as Google Earth^{TM}) have greatly expanded the scope of contemporary mapping and analysis. Modern computerized maps are digital, meaning that they are mathematical and statistical well before they are visual images on the computer screen. This means that the ability to simulate, represent and analyze information in a spatial context is at the cutting edge of contemporary scientific practice and this has huge implications for policy development at a local and international level.

5.1 Emerging spatial technologies and concepts

Early computerized mapping systems were developed in the United States and the Soviet Union as part of Cold War planning and research (Barnes 2008, Cloud 2002, Kent and Davies 2013). A major problem with this was that analogue mapping techniques were insufficient for truly global warfare and the trigonometry and applied geophysics of our planet required greater, computerized sophistication. Google Earth™ was itself developed under similar circumstances. The result has been a branch of science where funding and associated speed of development have proven remarkable, especially in the continued absence of nuclear conflict. This technology has generally become available for a wide variety of civil purposes including GPS for traffic and off-road and remote navigation purposes (Parkinson 1994).

The development of geographic information systems technology, labelled 'giscience' by Goodchild (1992) just over two decades ago, and the integration of different spatial and temporal data sources within such systems have been both rapid and increasingly successful. Openshaw (1991) suggested that effective space-time integration *was* geography. Since then there has been a paradigm shift, not unusual in this field, as the scientific approach to geographic space becomes increasingly one of integration, and interdisciplinary (Koutsopoulos 2011). Space is not simply an ontological entity that is 'out there' but rather a medium through which we construct and engage with our knowledge-based perspectives about the external world. This makes it a dialectical process because there is no singular position from which to describe all the features of and processes involved in what we conceive of as our environment. More recently still, Google Earth Engine (http://earthengine.google.org/#intro) has brought 40 years of Landsat imagery together in one accessible data library helping a variety of scientists, researchers and others explore changes in landscape patterns over time.

Koutsopoulos (2005 and 2011) further suggests that this paradigmatic change requires a re-configuring of how we conceive of geographic and, more broadly, spatial inquiry. He proposes that what we require as the basis for these kinds of inquiry is a 'choroinformatics' approach as the foundation for this new geographic paradigm. In this approach, there would no longer be a need to rely on closed analytical systems accessible only to experts but rather develop open-ended forms of enquiry that go beyond current problem-solution modelling activities. This is both directly (the new skills-knowledge required by existing expert users) and indirectly (the skills-knowledge required by new users and critics) a call for a new kind of literacy, one which will make us all active participants in the production and critique of varied forms of geographic space and activities based on such space.

5.2 Spatial literacy as key to better outcomes

Berry (2013) suggests that while the expansion of GIS as a technical solution has been hugely successful, the use of GIS as an analytical tool has lagged far behind, with a failure to appreciate the radical nature of digital mapping and its capabilities. One of the issues here is that much of the emerging spatial technology relies on a rising level of mathematical and spatial statistical reasoning and skill for its application and analysis. Many of the basic concepts in spatial reasoning are not taught, or even acknowledged in most of our existing education and technical training systems. Geographic knowledge has lost ground in many places over the last half century as the emphasis has shifted to 'quantitative' knowledge, often statistical, that functions in decontextualized analytical environment. This is to say, most data analysis is taught 'non-spatially' and as though the associated analyses and results do not vary over space—even if space is even acknowledged as an organizing principle. This means that mainly specialists and dedicated enthusiasts develop these skills. This situation will need to change as scientific and policy simulations become more amenable to spatial simulation and testing. Virtualization, already seen in the gaming industry, will increasingly shape the nature of our qualitative and quantitative analyses and people will require the conceptual knowledge and practical skills to participate in this kind of work and in the arguments such analyses will inevitably give rise to.

5.3 Spatial skills for and in the global south

In the context of the three problems addressed here, spatial literacy has the potential to expand the ability of countries in the current global south to prepare and plan for a wide variety of variables. As noted elsewhere in this paper, a variety of spatial information sources are becoming available for free, meaning that the potential exists for independent researcher advocates and others to access and utilize this kind of information in developing their agendas. This includes, with some caveats, those in the global south. The key issues will be access to the technology (eg. computing access, reliable power sources etc.) and training and education in the skills to utilize such options. Here too the growing availability and reductions in the cost of technology are likely to assist. The integration of spatial technology in mobile phones and related products is also enhancing these opportunities including the rise of the spatial crowd-sourcing movement for crisis response (eg. http://crisismappers.net/). The rise of open-source mapping software and applications mean that the hardware, software and skill issues will begin to converge very soon. This will be driven in part, by the variety of potential applications for this technology.

5.4 Knowledge, integration and a spatial perspective

In this context, spatial science represents both an epistemic technology for understanding complexity and wicked problems as well as being an ontological tool for planning, delivering and evaluating interventions in real environments. The advantage of a spatial perspective and spatial technology, we suggest, is the ability to model and simulate change processes in a virtual environment—effectively creating a spatial scientific laboratory workbench prior to project implementation. Being able to undertake these kinds of modelling activities in a simulated three-dimensional software environment has added benefits in terms of visualizing potential outcomes and sharing that information with a broad audience of people who may lack the spatial literacy skills we discussed above. Given that colour highlighting and similar techniques can be used to visually 'grade' variables within such environments, it means technical mathematical and statistical information can be highlighted in meaningful ways to support understanding of and inquiries on such modelling. The result is an accessible and highly visual experimental policy and planning environment. In addition, because simulation models of these types can easily be required to explicitly state their underlying assumptions (eg. population increase rates, economic impacts, estimates for sea level rises etc.), they do not have to carry over the many problems associated with conventional paper-based mapping

(Monmonier and de Blij 1996). Moreover, when errors are identified, re-running these types of analysis are much quicker than producing a conventional paper map.

In several countries, the value and utility of various kinds of geographic information have been acknowledged as a public good. The governments of Denmark, Finland, New Zealand and more recently Norway have begun to release topographic data sets on those countries as free resources for public access and use. As a consequence, it has been recognized, that certain kinds of knowledge and information operate at both a pragmatic and a philosophical level, in that ethically they have the potential to benefit society as a whole and that it is just and democratic to make that information available. A growing sub-field within spatial science is professional and disciplinary ethics reflecting this nuanced understanding of the wider implications of this rapidly developing field (Obermeyer 2009, Rimbaldi *et al*. 2006). Given what has been discussed about paradigm changes in geography and the emerging 'choreographic' perspective as one in which holism, interdisciplinarity and integration are key characteristics, it is both interesting and encouraging to see spatial science taking a lead in this area. The concepts of spatially-indexed information available through open access, open source and, increasingly the crowd-sourcing methods associated with *neogeography*, have implications for developments in the global south and the global north. While there are limitations to these outcomes, it is an interesting trend in the democratization of spatial science knowledge.

6. Building a virtual response for the global south and all of us

6.1 The utility and potential of a virtual system

While it has to be acknowledged that virtual environments are not and cannot be (quite) as complex as the external world, they also have some advantages over 'real life'. To begin with, mistakes made in virtual environments can be remediated, if identified and acted on, far more readily than in the external world. Our active mistakes and passive errors of judgement in evaluating potential risks, for example, tend to have significant consequences outside of digital test environments. *In silico*, we can safely model mistakes deliberately in virtual environments and study their effects within that system as a way of better understanding their potential impacts. This is something that tends to be avoided in reality because the costs, social and financial, tend to be so great. There is no suggestion that these do not occur and do so frequently, but rather that the point is to emphasize rationality means that many such mistakes have been represented at their optimum in terms of the problems they seek to address often in spite of their ideological underpinnings.

One risk associated with virtual environments is our tendency to attribute excessive validity to such systems. In the same way we model other complex systems (eg. in economics) we can make the serious error of substituting the virtual for the external. This is part of a wider problem with human cognition and especially so in scenarios driven by probabilistic measures and estimations (see Taleb 2007). Part of the problem with these attributional errors lie in the limitations of our perception and perhaps also our growing infatuation with technology as offering solutions to the problems we have tended to create with previous iterations of technology. Consequently, it is worth emphasizing that 'virtualizing' problem-based scenarios has important limitations that need to be considered in analyzing the outputs of such models. On the positive side, if we exercise some degree of epistemic modesty, we can incorporate our own cognitive and affective failings into such scenarios reducing our potential to act authoritatively on erroneous results.

6.2 The 'global south' is fluid

The language of development (eg. the Three World model) has conventionally been geopolitical in nature. This is especially true of the post-war period, when ideology drove humanity close to the brink of nuclear war and extinction—scenarios that were all actively modelled as potential 'wins'. While there is a tendency to visualize the 'global south' as a fixed category of dependent and vulnerable states, this is both unfair and inaccurate. Change is inherent in any dualistic categorization or dichotomy of this type. Significant population transitions have occurred faster in the so-called developing countries than they did in Western Europe with Japan and now China, for example, producing ageing societies in far less time than early theorizing suggested (Chen and Liu 2009). The emergence of the BRICS (Brazil, Russia, India, China, South Africa) countries as dynamic economies suggests that significant social change is likely to follow economic change in equally rapid succession (ISSA 2013). In Africa, some countries such as Ghana and Angola are readily challenging the economic paradigm of Africa as a dependent continent (IMF 2013). Angola has even begun to invest in the old colonial countries of Portugal and elsewhere (Conchiglia 2012). Constructing and normalizing a fixed picture of the capacity of countries for rapid transitional change is unwise and inaccurate.

At the same time, it is clear that many of the countries in the global south may lack the capacity for sustainable responses to the nature of the problems we discuss in this paper. There is no absolute guarantee that countries like Haiti, for example, will overcome current problems and match a 'global north' capacity to address vulnerability, crises or remediation efforts in the wake of major demographic, climatic and urbanization shifts. The problems faced in Haiti, a very small country, are an example of how remediation and recovery are not guaranteed and also how the imposition of highly rational system approaches, often from outside, do not necessarily produce the results they plan to produce or may even produce their own negative feedback effects.

6.3 Virtual does not mean 'not real'

One of our inherited epistemic confusions is the problem of differentiating between different kinds of entities as 'real' or not (see Chakravartty 2007, Longino 1990). Indeed this is both a major branch of western philosophical analysis and a problematic feature of knowledge production in late modernity. 'Real' entities are often presented as those which are tangible in some form, such as the concrete objects of daily experience including people, animals, built or manufactured objects, experiential phenomena and the like. To some extent a variety of other acceptable things are also given the status of 'real', including 'facts'. Usually meaningful data associated with various phenomena and some analytical systems such as statistics are attributed to the status of being 'real', even when few people understand what branch of statistics they are derived from or the limitations of statistical knowledge production (eg. the frequentist versus Bayesian paradigms). Risk factors are a typical example of statistical knowledge that has been attributed the status of being real even when they remain highly contentious (Desrosières 2006, Dorling 2010**).**

The divide between objectivity and subjectivity (Daston and Galison 2007, Nagel 1989), reflected in the quantitative-qualitative divide, are two further examples of the ideological foundations which constitutes acceptable knowledge in late modernity (eg. Shah and Corley 2006). These are forms of knowing and knowledge production predicated on a belief in very finite types of the 'real' which have the key characteristic of reducing individual and collective experience, particularly in the affective domain. Yet, psychological theory has made considerable advances in the exploration of human experiential knowledge production since the triumph of early positivism and quantification—itself a process that often claims numbers are more real than the phenomena they seek to quantify.

In the context of digitally archived data and associated (and emerging) analytical methods, a problem that arises is in analyzing what is 'real' or not. This is closely related to the confusion in the wider 'Western' epistemology with the problem of differentiating between 'theories' and 'facts'. In strictly philosophical terms, this is less of an issue but in scientific and public discourse, the limits of education about and political analysis of how knowledge is produced become evident much more quickly. Scientists and social scientists generally, but not universally, know that theories represent an aggregate approach to knowledge explanations that are often highly conditional, especially in developmental and fast-moving knowledge domains where data production and analysis leads to quite rapid changes in our understanding of phenomena. They are 'true' but less in the absolute sense that many people think of as representing 'truth' and more in a constrained and/or conditional sense in that they represent reality as we are currently best able to understand, analyze and represent it, but where this situation is mutable and may change at some future point. It may even be completely overturned by new knowledge, new theories or a proven inability to support what was believed to be true under changed conditions.

A final element in this 'virtual versus real' discussion is the recent and rapid development of simulation environments for exploring many of the issues discussed here. The software platform Google Earth™ (GE) has only existed for a little over a decade (first released as keyhole in 2001 and GE in 2005). Al Gore (1998) proposed the concept of a digital earth environment a few short years prior to that, and the GE virtual environment is now in its seventh major release version and functioning across a number of operating systems. This product has become so pervasive that most GIS software producers now release their products with at least some degree of GE integration capacity. This both reinforces GE's position as the major virtual earth product and promotes a varied set of spatial literacy skills to a rapidly expanding user audience. Even though the underlying technology is highly complex, this is a virtual version of our planet after all, the useability factor is very high and requires limited technical skills for elementary use with amateurs and professionals able to utilize it for a growing range of applications.

7. Spatial knowledge and skills for the future

With the range of issues identified in this paper, what we are suggesting is that a degree of spatial literacy would be both a benefit for most practitioners in the various fields associated with urbanization, climate change, population growth and their interconnectedness. Our own experience in the health sciences illustrates the paucity of spatial knowledge, skills and even familiarity even when faced growing systemic complexity, interconnectedness and the growth of 'wicked problems' (Balint *et al*. 2011, Rittel and Weber 1973).

While not everyone can be expected to be, or even aspire to, spatial expertise, we propose that the integration of spatial knowledge, skills and concepts more broadly across the social sciences, and elsewhere, would have a range of potential benefits. The artificial boundaries of both modern academic disciplines and bureaucratic specialisms are increasingly a constraint on our capacity to respond to complex problems. There is a need for integrative knowledge that cuts across internally generated vocabularies and epistemic technologies. In this paper, we have proposed that part of the solution to this is available now through the avenue of spatial science.

In the same way that some knowledge of basic physics or statistics are seen as the mark of educational attainment, scientific literacy and 'higher' knowledge, so too is it that basic spatial scientific knowledge is an increasingly necessary addition to, expansion of and developmental pathway for 'expert' understanding about complexity, vulnerability and our efforts to successfully respond to wicked problems. Key to this capacity is the development of understanding and skills in the wider geographic information science arena. Goodchild (2006) has referred to this as the need for the 'fourth R' in rethinking geographic information systems (GIS) education as a step in producing an adequate level of spatial literacy within our education systems. Logan (2012) has recently proposed that there is a growing interest in spatial analysis amongst sociologists due to the emergence of new technologies and the growth of multilevel data sets incorporating spatial identifiers. Amongst the conceptual and practical skills he identifies are mapping, distance, social networks, spatial clustering, boundaries, spatial dependence and neighbour effects, and spatial scale including its application in multilevel models.

Conclusion

This paper has in brief exploration of one possible approach for expanding the understanding and application of spatial science skills and knowledge for dealing with a variety of wicked problems. This has been done in the context of three very specific but still large and highly complex concerns: rapid urbanization; climate change; and population growth and ageing. Each of these is a substantial issue in its own right and they are also interconnected at a number of levels. The proposal is not that spatial science on its own will 'solve' these problems as they are both dynamic and complex in addition to which the spatial dimension does not represent the full scope of these concerns but, rather, one which we suggest is currently missing in many discussions. There is no single technology or proposed technical fix that has the capacity to resolve these issues or, given our current behaviours, that a complete solution is necessarily possible. However, what is suggested is that without expanded spatial science literacy in the various fields identified, it is highly unlikely we will ever begin to deal with these problems effectively.

More than that, the authors would like to advance the idea that spatial literacy has a contribution to make towards enhanced scientific understanding and interventions within and between the natural and social sciences as well as in policy and advocacy domains. Spatiality has gone in and out of fashion in geography, for example, but remains a key conceptual issue within and beyond the discipline (Koutsopoulos 2011, Logan 2012). It also has significant implications beyond the theoretical domain in that any actions taken in the world have a spatial dimension to them and the three issues dealt with here all possess important spatial components. To act in the world is to act in a spatial way—both implicitly and explicitly.

The focus on the global south is not presented in an uncritical fashion, as we understand the limitations of socio-political taxonomies of the human experience and their very finite limitations in characterizing the varied and dynamic societies which such terms are used to cluster together. Instead, it can be seen as a stepping off point for addressing and expanding upon the issues of vulnerability we have presented here and additionally, as a way of crossing over the north-south divide as it is often characterized. Each of the three problem areas presented is in no way limited to the global south in their effects. Instead, they illustrate how things that will have particular kind of impacts in the global south will have similar or at least corresponding effects in the global north because the systems on which we all depend are global in their scope and dynamics. While the degree of those effects may and probably will vary, we show how spatial science applications can support our capacity to respond at levels ranging from the global to the local.

Lastly, the paper has tried to explain how the developmental processes of knowledge production in late modernity would benefit from a more widespread understanding of spatial science fundamentals and the many activities being undertaken within those sciences to deal with long-standing data integration management and analysis issues, including the distribution of such techniques and knowledge for the benefit of all. One of the reasons for this is that knowledge is conditional and often cultural in that particular aspects of some cultures can set the standard for what is accepted as useful knowledge. This is obviously problematic in the global south where the imposition of external knowledge, values and ideals have had serious impacts on the capacity of local epistemologies to influence self-determination as well as developmental plans and processes with inevitable consequences for health and wellbeing (eg. Stephens *et al*. 2006). In closing, the authors would suggest that some aspects of emerging spatial science also provide a platform for the engagement of these differing perspectives in ways that will benefit future outcomes. To not utilize viable and proven science and technologies in the face of the complex and wicked problems is not simply passivity, a mistake or error; it is a substantive and active failure of governance.

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