

Chapter 12

Urbanization and Flood Vulnerability in a Peri-Urban Neighbourhood of Dakar, Senegal: How can Participatory GIS Contribute to Flood Management?

Audrey Maheu

Abstract Land and water are intricately connected and the inability to manage one component will necessarily impact the other. As urban sprawl grows out of control of authorities in developing countries, poor populations are forced to settle in hazard zones. Thus, comprehending the urbanization process is key in understanding flood vulnerability. This research uses the urbanization process as a starting point to understand the social and environmental dynamics behind floods in a peri-urban neighbourhood of Dakar, Senegal. Participatory GIS (PGIS), land use change analysis, interviews, transect walks and ethnographic observations were used to understand settlement in flood-prone areas. Limited access to risk knowledge was identified as a contributor to flood vulnerability. We argue that although risk awareness existed among peri-urban communities, an uneven access to knowledge led to settlement in risk-prone lowlands. We demonstrate risk awareness among the community by looking at the influence of three variables on the urbanization process: landforms, land availability and land price. This paper concludes with a critical analysis of PGIS regarding analytical and empowering outcomes of this methodological approach.

Keywords Participatory GIS • Participation • Flood • Vulnerability • Peri-urban • Urbanization

We argue that although risk awareness existed among peri-urban communities, an uneven access to knowledge led to settlement in risk-prone lowlands. We demonstrate risk awareness among the community by looking at the influence of three variables on the urbanization process: landforms, land availability and land price.

A. Maheu (✉)

International Development Research Centre (IDRC),
7 Des Frères, Vaudreuil-sur-le-lac, QC J7V 8P3, Canada
e-mail: amaheu@idrc.ca

More than half of the world's population is currently living in urban areas, and by 2050, the world urban population will have almost doubled that from now, reaching 6.4 billion (United Nations 2007). Urban areas in Africa and Asia are expected to absorb most of the anticipated population growth, with “full urbanization” already completed in Europe, North America, and most of Latin America. This widely recognized and expected increase in urban population hides another reality: the growth and transformation of peri-urban areas. Studies in Latin America and Asia show that peri-urban areas absorb nearly all “urban” population growth, a trend likely to continue in Africa (da Gama Torres 2008). This poses a particular challenge as peri-urban environments “suffer some of the worst consequences of urban growth, including pollution, rapid social change, poverty, land use changes and degradation of natural resources” (United Nations 2007).

More than a de-densifying periphery around the city, the peri-urban interface is characterized by a heterogeneous mosaic of natural, agricultural and urban ecosystems affected by the flows (material, energy, people) between the urban and rural systems (Allen 2003). Institutional fragmentation, rooted in the urban–rural dichotomy between space and inner-city, as well as rural migration movements, often lead to the uncontrolled sprawl of peri-urban areas. Peri-urban areas are typically characterized by the existence of informal economies, often based on illegal activities such as clandestine slaughterhouses, or the intensive use of agrochemicals in agriculture and mining (Allen 2003). In such environments, urbanization is devoted from conscious planning and settlement precedes the extension of basic services implying large public health concerns. In fact, the problems of peri-urban areas are similar to those of low-income urban settlements: limited access to water and sanitation, waste accumulation, concentration of poverty, etc. Land speculation and the private appropriation of land in peri-urban areas further exacerbate the marginalization of the poor within the city's suburbs.

Slums often form at cities' edges, where they have been shown to increase the risk of natural disasters for the entire city (ISDR 2009). More often than not, these informal settlements develop in hazardous areas, where land is inexpensive, leaving the slum inhabitants particularly vulnerable to natural disasters. Illustrating this are the chronic problems of fires, landslides and floods in informal settlements at the edge of cities (Aragón-Durand 2007; Murray 2009; O'Hare 2005).

The problem of Floods at the Peri-Urban Interface

Hydro-meteorological hazards pose the biggest challenge for both developed and developing countries in the face of climate change (Thomalla 2006). In developing countries, flooding has become a recurrent problem in numerous peri-urban areas as populations settle in flood-prone areas. Already in the 1970s, flooding was a persistent problem in squatter settlements in the suburbs of Kuala Lumpur (Aiken 1975). The Chalco Valley at the outskirts of Mexico City has been suffering from “chronic flooding” since the late 1980s (Aragón-Durand 2007). In Bamenda,

Cameroon, 20% of the population in informal settlements live in flood plains and urban expansion on hill slopes has triggered devastating flash floods (Acho-Chi 1998).

Flooding is not only the result of the occupation of hazard zones, it is also amplified by concurrent environmental degradation in peri-urban areas. For example, the loss of vegetation due to an increase in impervious surfaces was identified as an aggravating factor in the flood pattern in Dhaka, Bangladesh (Dewan 2008). Floods in Mumbai in 2005 led to a ban on plastic bags with garbage-clogged drains blamed for the magnitude of the disaster (Chatterjee 2005). Current flooding problems are likely to be exacerbated by both climate change and the booming urban growth in developing countries, making flooding an urgent issue to address in peri-urban areas, especially given the acute vulnerability of the poor populations concentrated in these areas.

GIS as a Diagnostic Tool

In the wake of the multiplication of flood events, urban planners and geographers have tapped the potential of Geographical Information Systems (GIS) to study flood events and to design solutions. GIS is thus a widely used diagnostic tool for understanding the causes behind the observed rise in flood events. A large number of studies have been produced on the dynamics of land use change and their relationships to floods. (Hara 2005) showed that land use changes following rural to urban transitions have reduced the volume of floodwater retention in peri-urban Bangkok, leaving both formal and informal settlements more vulnerable to flooding in this new landscape. The increase in impervious areas in suburban areas has been put forward as an explanation for flash floods (Romero 2004; Zhang 2008). In the Pearl river delta, China, for example, the filling of water bodies and the clearing of vegetation associated with urban sprawl impaired the buffering capacity of the ecosystem, thus triggering floods (Zhang 2008). These various GIS studies typically conclude that uncontrolled urban growth is the root cause behind the detrimental land use changes. Many have warned against the destruction of crucial ecological services when urban growth is not carefully planned (Romero 2004; Yu 2009).

While GIS has provided valuable insight in understanding the physical causes of flood events, it cannot *explain* the anthropogenic factors involved (Pelling 1999). Here, social sciences and political ecology can complement GIS analyses by investigating the social changes that triggered a modification of the physical landscape. Aragón-Durand (2007), for example, researched the socio-historical context behind flood risk generation at the outskirts of Mexico City. Texier (2008) showed that the marginalization of the poor by the municipal government was at the core of the 2007 flood disaster in Jakarta. These studies demonstrate that an understanding of the social construct of flood hazards is necessary in order to have a complete picture of the dynamics behind flood events. Unfortunately, GIS practitioners typically focus solely on the physical phenomena behind flooding, thereby providing only an incomplete picture of the problem.

GIS as a Prescriptive Tool

GIS in flood management has also been used to provide a “scientific input to planning” (Webster 1994). As such, hydrodynamic models have been integrated in GIS to map the behaviour of floods (Pradhan 2009; Vojinovic 2009). Along the same lines, multi-criteria analyses based on physical attributes of the landscape (elevation, slope, land cover, distance from channel, depth to groundwater table, etc.) were designed to determine hazard zones (Fernandez 2010; Yalcin 2004). These different applications do not focus explicitly on peri-urban areas and usually look at the city as a whole, although more comprehensive approaches coupling flood hazard maps and urban growth models are being developed (Correia 1999). GIS is also put to use to map social vulnerability by investigating the spatial distribution of socioeconomic conditions of populations (Morrow 1999). Of course, these social analyses are often combined with a physical vulnerability assessment in order to obtain a complete picture of the spatial distribution of vulnerability (Bizimana 2010; Chakraborty 2005). In a positivist approach, GIS is seen as a prescriptivist and prioritization tool, the main purpose of which is to answer the “where” question, e.g. “Where are floods likely to occur?” and “Where are flood prevention measures required?” This approach is fundamentally different from the first use of GIS in flood management described above, which applies GIS to understanding the root causes leading to flood events. This difference in GIS usage is not peculiar to flood management and the tendency to prioritize isolated problem-solving measures as opposed to investigating the root of a problem has been a cause of tension in GIS research for some time (Ramsey 2009).

The main problem behind the prescriptive approach lies possibly in the prescriptions themselves, which are often difficult to put in place logistically and which meet strong public opposition. The positivist approach to land use planning has in fact been criticized in the planning community (Hodge 1991). Cities in developed countries are learning the hard way that expert-led land use planning has its limits. GIS-based studies looking at new landfills’ location are perhaps the best example: although a location appears optimal according to a set of physical and social criteria, the failure of the siting process due to public opposition has become ubiquitous in North America (Lober 1995). GIS is a powerful tool for understanding the territory: however, it provides little help in the design of solutions and, most importantly, their acceptance by stakeholders.

Alternative GISs: PPGIS, PGIS, and CiGIS

Some may argue that GIS as a tool for flood management is inherently confined to the above-mentioned limits. However, the development of new fields in GIScience may be exactly what the doctor ordered. As GIS technologies rapidly spread to a variety of fields in the 1990s, a debate arose over the theoretical and societal aspects of GIS. In that context, GIS in relation to society became a field of research of its own—commonly referred to as the “GIS and Society” movement.

Of particular interest here is the criticism of GIS as an elitist system that reinforces top-down management. These critics condemned the technocratic avenue taken by GIS and argued for the recognition of spatially differentiated knowledge and the re-engagement of GIS with communities. As a result, new fields in GIScience emerged: Public Participation GIS (PPGIS), PGIS, and Community-integrated GIS (CiGIS).

Whereas the GIS and Society movement is generally concerned with theoretical and epistemological aspects of GIS (the whether and why questions), the just mentioned new fields are concerned with the “how” questions, e.g. “How can we put these new theories into practice?” (Sieber 2006). Thus, while alternative GISs all embrace the GIS and Society discourse, each has taken a slightly different avenue. Public participation GIS (PPGIS) aims at making GIS “available and accessible to all those with a stake in official decisions” (Schroeder 1996) and focuses on access to GIS technologies by grassroots organizations. PGIS has typically been critical of the overrepresentation of the privileged sectors of society and reaches out to marginalized populations. PGIS is strongly connected to the participatory movement in development, and the majority of applications labelled as PGIS take place in developing countries. Finally, in reaction to PPGIS, the goal of which is to develop applications controlled by the communities themselves, Community-integrated GIS (CiGIS) takes an alternative path: while fostering community participation in the GIS process, it also encourages expert-driven implementation in reaction to fundamental barriers in local capacity (Weiner 1999). Although these alternative GISs hold different values, they all share the common goal of working towards broader participation in GIS applications. To facilitate communication, this paper will adopt PGIS as an umbrella term for the different ways of implementing an interface between community and GIS.

PGIS: a Definition

The use of the PGIS label has been broad and inconsistent across applications (Schlossberg 2005), making it hard to produce a formal definition of this new field. By and large, PGIS has been understood as differing from traditional GIS in two aspects: (1) the type of information fed into the system and (2) the source of that information (Dunn 2007). With regard to the first aspect, the scope of the information feeding analysis in PGIS is much broader including narratives, fuzzy information, experiential knowledge and socially-differentiated information. The integration of qualitative information within a GIS framework has brought questions on two levels: GIS *with* qualitative methods and GIS *as* qualitative method. Discussions on GIS *with* qualitative methods look into the technical challenge of interpreting and representing different forms of spatial knowledge while research on PGIS *as* a qualitative method investigates the epistemologies of PGIS as a knowledge production strategy (Elwood 2006). As for the second aspect defining

PGIS, contrary to traditional GIS, PGIS necessarily involves citizen participation, with a special consideration of marginalized communities.

Participation in PGIS

A definition of PGIS cannot dodge the question of participation which has been at the core of discussions around PGIS. The notion of participation has been debated within the development community for a number of years and the requirements entailed by the participatory label have grown significantly over the years. In reaction to the utter failure of top-down projects, the mainstreaming of participatory approaches in the 1980s left a bitter taste for many in the development community. In particular, the wave of participatory rural appraisals (PRA) transformed participation into a technical fix to complex development problems (Hickey 2004). A radical change ensued that promoted commitment to the output of participation rather than to innovative ways of implementing it. Lengthy debates over the past decades have left many proposals on the table regarding the definition of participation. The definition gaining the most currency sees participation as a transformative process that strives for the achievement of full citizenship by disempowered populations (Hickey 2004). According to this vision, participation needs to be embedded in the broader political process rather than focusing on local initiatives (Williams 2004). However, setting such high standards for participation from the outset leaves little recognition of participatory approaches on the lower end of the spectrum and their potential as stepping stones towards a full transformation. The debate around participation remains wide open and although participation has been regarded as an imperative in development, “the ‘trendiest’ activity (at least among academics) is [still] the withering critique of participation” (Kesby 2007).

It is argued here that while mere tokenism is not an acceptable path for PGIS, the contribution of different levels of participation should be appreciated. Community-based GISs emerged in recognition of the limits of “overparticipation” (Weiner 1999). Kyem’s (2001) work in Ghana showed that granting overwhelming responsibilities to communities who are not ready for them can actually have a negative impact on social capacity. In fact, climbing on top of the participation ladder should not be the objective of PGIS. Instead, it should be recognized that some forms of participation are more suitable for certain environments than others. Hence, the definition of participation adopted here is not based on any “level” of participation but is understood as a process inclusive of all stakeholders and in which the stakeholders represent all individuals “who are affected by, bring knowledge or information to, and possess the power to influence a decision or program” (Schlossberg 2005). While inclusion of the public at large is not considered here, the potential for doing so should not be dismissed (see Schlossberg 2005 for a discussion on the topic).

The Benefits of Participation

Access to Differentiated Information

The benefits of participation in PGIS can be understood by looking at the two different (and some would argue conflicting) understandings of participation. On the one hand, participation has been understood as a means of obtaining differentiated information. With this approach, participation has been used for ground-truthing or as a source of new information (Koti 2006; Harris 2002; Sliuzas 2003). The core objective of these projects is the production of knowledge and the literature abounds with cases of PGIS applied to produce risk and vulnerability assessments (Kienberger 2007; Nethengwe 2007). One of the benefits of participation is thus a better understanding of a given issue by capturing new sources (e.g. experiential knowledge) and forms (e.g. qualitative) of information.

The Potential for Empowerment

On the other hand, participation can be viewed as an end in itself in PGIS. While some projects aim at increasing citizen involvement (Al-Kodmany 2000), education, and communication (Mills 2008), others implement PGIS in order to promote empowerment (Bauer 2009; Stonich 2002). The common denominator here is that the GIS output is seen merely as an accessory to social change at large. In disaster management, PGIS has been used to impart a better perception and management of risk (Barclay 2008). Instead of using a top-down education approach where stakeholders are “taught” the elements of risks within a community, PGIS allows stakeholders to structure their relationship to the territory and gain a better understanding of the level of risk they are subject to. This process has empowering qualities as stakeholders reflect on their current standing and on how they can improve their conditions (D’Aquino 2004). PGIS can also help communities consolidate their message to be heard by authorities, building on the power of GIS as a communication tool. A number of cases exist in which PGIS has been used as an advocacy tool (Maantay 2002; Stonich 2002).

The PGIS process of producing spatial information has been acknowledged as empowering itself (D’Aquino 2004; Jordan 2002; Dunn 2007). Borrowing from Freire’s concept of conscientization (Freire 1970), PGIS encourages social and political action on a collective level by inducing reflection on living conditions and the development of a critical worldview. However, others have argued that “participation in the creation of knowledge does not necessarily give power to those involved in, and affected by decision-making” (Aitken 1995). This argument was made in reaction to sweeping claims on the potential of achieving empowerment through PGIS, claims which lacked empirical support (Corbett 2005).

Objectives

The above discussion on participation and PGIS provides an overview of this emerging field in addition to showing the potential of PGIS to complement GIS with regard to flood management. This research project investigated flood dynamics in Dakar's suburbs using a PGIS approach. The aim of this paper is to (1) discuss social and environmental dynamics behind floods in Dakar's suburbs, with a focus on understanding the settlement process in flood-prone areas and (2) explore new ways of doing GIS and critically analyse the contribution of participation to research and to participants.

Study Area

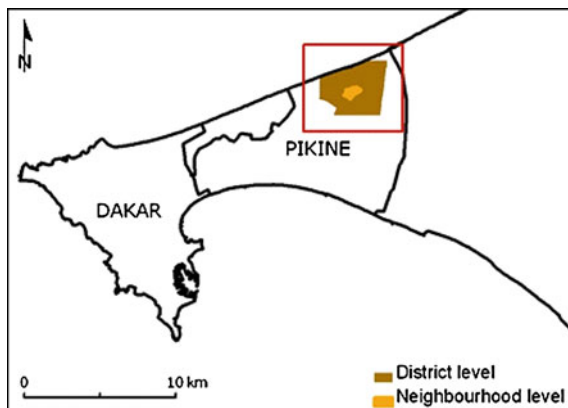
The suburbs of Dakar have suffered severe flooding over the last ten years, with the department of Pikine being the most severely hit. While the floods seemed to be exceptional events at first, they have since established themselves as a recurrent phenomenon with worsening consequences every year. The flood problem in Dakar's suburbs has its origins in the exponential population growth since the 1970s, when an enduring drought throughout the country triggered massive rural migration towards urban centres (Goldsmith 2004). This large influx of people resulted in an erratic occupation of land, especially in the suburbs of Dakar.

The geomorphology of Dakar's suburbs features highlands, composed of coastal dunes and Ogolian dunes, a set of inland dunes running parallel along the southwest–northeast axis and lowlands composed of interdunal depressions in between Ogolian dunes known as the Niayes region. The lowlands are humid environments where the water table comes to the surface. These areas were traditionally used for agriculture given their easy access to water. During the ongoing dry years, the lowlands dried up, thus freeing some urgently needed space that then was quickly occupied. Although these lowlands had dried out, the water table remained near the surface.

Recently, the Sahel region has seen a rise in precipitation (Ali 2009). Although portrayed as exceptional, this recent increase in rainfall is most likely a return to normal conditions after 40 years of drought (Sene 2002). Unlike many flood events across the world that are triggered by catastrophic amounts of water unleashed onto a city (through rain or storm surges), the flood problem in Dakar is the aftermath of a prolonged period of climate perturbation. Recent wetter years raised the water table closer to previous levels (<2 m below surface) and now little precipitation is required for lowlands to become saturated, leaving its occupants flooded (Mbow 2008).

Our research on these flood events was conducted in Diamalaye, an informal neighbourhood in the districts of Malika and Keur Massar located at the edge of the department of Pikine (Fig. 1). While districts are the smallest government units, neighbourhoods and their neighbourhood representatives are credible local authorities and, in fact serve as an interface between formal authorities and the population (Tall 1998). Thus, the neighbourhood provides an appropriate scale to

Fig. 1 Location of the study area at district and neighbourhood levels. The district level study area overlaps the districts of Malika and Keur Massar. The neighbourhood level study area corresponds to the neighbourhood of Diamalaye



understand social dynamics. A larger area was also considered to frame the flood problem within a wider context. Spatial analyses were conducted at both neighbourhood and district levels (Fig. 1).

This study area was selected for its landscape and for its peri-urban nature and the intense urbanization process currently underway there. Diamalaye displays the various physical features that are typical of Dakar's suburbs. Approximately half of the neighbourhood spreads across highlands and the other half across lowlands, providing subsets representative of the suburbs. Moreover, floods were late to come to the neighbourhood of Diamalaye. While the rest of the district began experiencing floods in 2005, floods only came to the neighbourhood of Diamalaye in 2009. Still, as the lowlands were being flooded in the surrounding neighbourhoods, people continued to settle in the lowlands in Diamalaye. Overall, the neighbourhood of Diamalaye provides the perfect setting for understanding the settlement process in lowlands (flood-prone areas) versus highlands.

The neighbourhood of Diamalaye is undergoing intense urbanization. Diamalaye is a young neighbourhood that emerged in the late 1970s and that truly exploded in the late 1990s. A 2007 survey shows that only 27% of the 2,000 inhabitants are native to the neighbourhood (Gaye 2008). The anticipated shutting down of the M'beubeuss landfill, which borders Diamalaye, also contributes to land speculation and intensifies urbanization pressure. On that account, Diamalaye presents the perfect conditions for studying how environmental and social dynamics of flood events unfold in the urbanization process. It will also offer useful information for managing urbanization in the context of city perimeter that is prone to flood problems.

Methodology

Similar to CiGIS studies (Koti 2006, 2010; Weiner 1999), this project used a variety of analytical methods to study the social and environmental dynamics underlying flood events in Diamalaye. The methodology comprised expert and participatory analyses that together formed the PGIS.

The participatory analysis took various forms. Four mapping workshops with an average of five participants were held in the summer of 2010. A local facilitator helped organize and conduct the workshops and served as an interpreter (French–Wolof). Each workshop targeted specific groups: young men, young women, farmers and neighbourhood representatives. Young people were targeted as they demonstrate an ease of communication with the researcher, which facilitated insight into social dynamics. The group of farmers was chosen due to the peculiar impact of floods on their livelihoods. During the three workshops with the above-mentioned groups, participants were asked to map flooded areas and flood risk within their neighbourhood and to describe flood impacts on their lives and adaptation strategies. Workshops were open-ended and included discussions on various aspects of neighbourhood life. The fourth workshop was held with neighbourhood representatives, including the chief neighbourhood representative and elders. During this workshop, the urbanization process was discussed along with the land acquisition process and land tenure issues. Interviews ($n = 6$) with key informants and local authorities were also conducted along key themes identified during the mapping workshops. Information gathered through workshops and interviews was then fed into the PGIS.

This research is also based on an ethnographic approach. For a period of four months, the researcher lived in an adjacent neighbourhood, undertook numerous walks across the neighbourhood and made observations. This data was also entered in the PGIS. While not participatory per se, this was part of a strategy to access differentiated information in keeping with basic PGIS principles.

The research project also included expert analyses going along traditional GIS methods. Land use changes were mapped at both neighbourhood and district levels through the manual classification and comparison of aerial photographs from 1954 (1:50,000), 1979 (1:60,000), 1997 (1:20,000), 2003 (1:10,000) as well as a 2009 SPOT image. Using this time series, conditions previous to (1954), during (1979), and after (2003 and 2009) the drought could be compared and analysed. A DEM of the region was also produced for the region using both surveying data from an ongoing project of Université Laval as well as contour maps (1:10,000) from the *Direction des travaux géographiques et cartographiques du Sénégal*.

Using the 1954 aerial photograph, a map of geomorphological features was also produced to delineate lowlands and highlands. The DEM was used to corroborate this map. Through manual classification, four features were mapped: coastal dunes, Ogolian dunes, the Niayes areas and water/lakebed. This latter category represents waterbodies from 1954 but given that water levels fluctuated during the drought, the category was named “water/lakebed”. Spatial analysis was conducted to compare urban development against geomorphology features (Fig. 2). This was a step towards understanding the settlement process in lowlands.

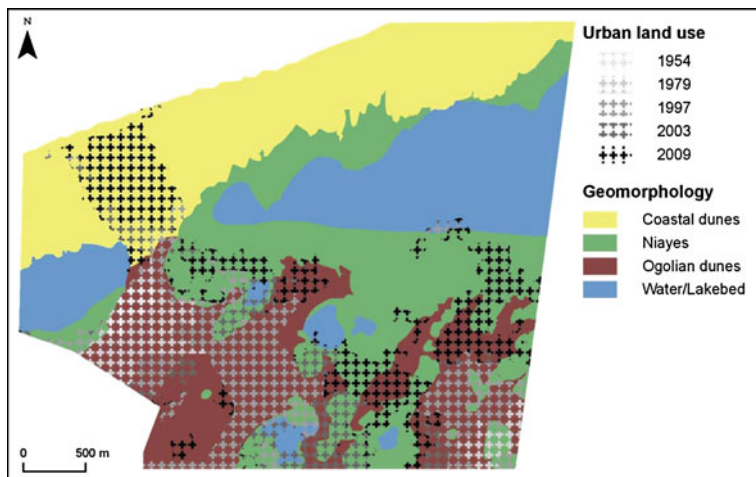


Fig. 2 Intersection between geomorphological features and urban development at the district level. Ogolian dunes correspond to highlands and Niayes correspond to lowlands

Results

The Urbanization Process

The flood hazard in Dakar's suburbs has its roots in the urbanization of lowlands. Land use changes between 1979 and 2003 show the steady invasion of lowlands during drought years (Fig. 3). During the same period, water levels and humid vegetation in lowlands receded, freeing up space for occupation. This goes along research by (Mbow 2008) on the adjacent district of Yeumbeul, where the land cover change induced by drought brought about urban development in lowlands.

Land cover change is only part of the reason behind occupation of lowlands. While physical processes allowed for the occupation of lowlands, land use and land cover changes are essentially driven by people's responses to opportunities (Lambin 2001). We argue that although risk awareness existed among peri-urban communities, an uneven access to knowledge led to settlement in risk-prone lowlands. We demonstrate risk awareness among the community by looking at the influence of three variables on the urbanization process: landforms, land availability and land price.

The Influence of Landforms

It is generally assumed that the drought modified the landscape significantly enough to blur the flood risk associated with lowlands, thus prompting the occupation of lowlands (Lo 2000; Mbow 2008). We hypothesized that if this

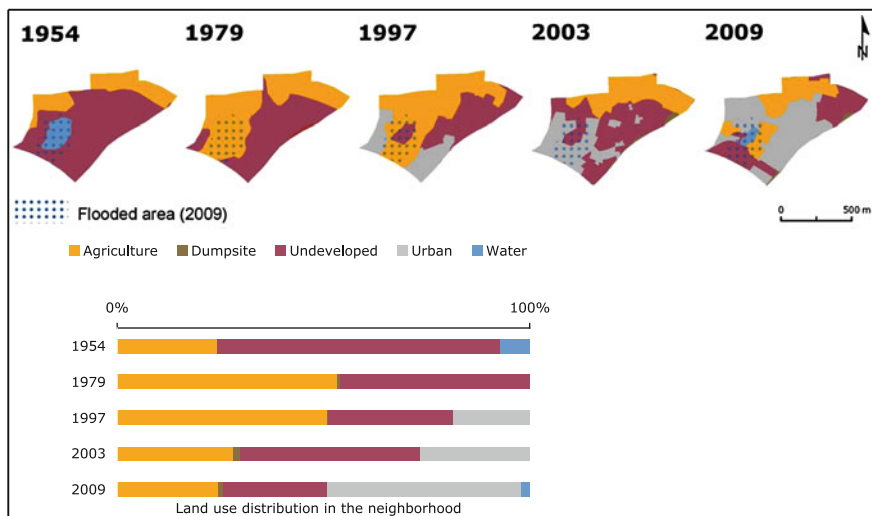


Fig. 3 Land use changes at the neighbourhood level

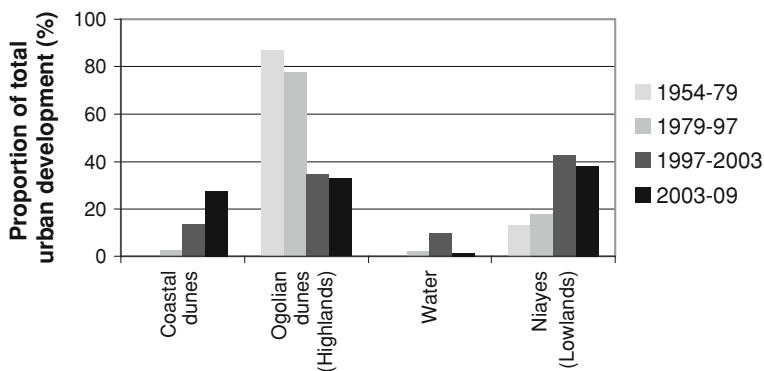


Fig. 4 Where urban development occurs: the geomorphological distribution of urban development for a given time period. Analysis at the district level

assumption holds true, urban development will then occur regardless of landforms during periods of drought, as water levels and vegetation then receded from lowlands, leaving little apparent differences between lowlands and highlands.

To verify this hypothesis, we identified which landforms were the sites of new urban development (Fig. 4). The drought period was set between 1960 and 2000, mainly for lack of more precise parameters. Most climatologists consider the Sahel drought as beginning between 1960 and 1970 and while the drought is still not over, climatic research has observed an increase in precipitation beginning in the early 2000 s which points toward the end of the drought (Aguiar 2009; L’Hôte 2002; Sené 2002).

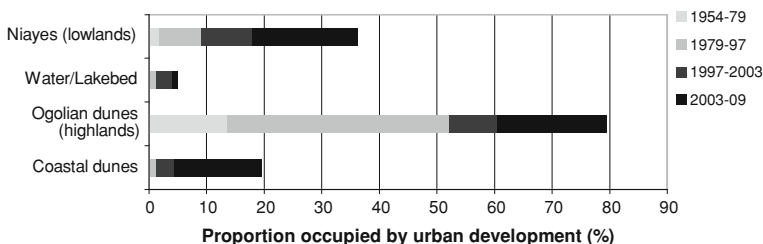


Fig. 5 Urban development as a proportion of total land available for a given geomorphology category. Analysis at the district level. Urban development corresponds to *new* urban land use that originated during the time period indicated. Ogolian dunes correspond to highlands and Niayes correspond to lowlands

Figure 4 shows that between 1954 and 1997, urban areas preferentially developed on highlands at the district level. Even during the drought, highlands were favoured over lowlands for urban development. The same trend is observed at the neighbourhood level. The neighbourhood of Diamalaye first developed on top of an Ogolian sand dune and only later did settlement spread over to lowlands. The preference of highlands for settlements, a phenomenon occurring worldwide, can be explained by various factors such as climate, diseases, defence mechanisms and agricultural diversity. While the preference for highlands is not necessarily a demonstration of more flood awareness per se, it does reflect how this landform is considered more suitable for settlement than lowlands. Interestingly, between 1997 and 2009, as precipitations slowly returned, highlands and lowlands hardly differed with regard to urban development. Then, as urban pressure built up during this period, land scarcity could have played a role in the gradual urbanization of lowlands. However, as it will be discussed below, land availability was not a strong determinant of the urbanization of lowlands.

The Influence of Land Availability

Dakar’s flood problem is usually framed within the rapid population growth of the city and it was suggested that the occupation of lowlands is the result of land scarcity (Mbow 2008). We tested these hypothesis by distinguishing the urban development per total land available for a given landform (Fig. 5). The hypothesis is that urban development in lowlands did not begin until highlands available for development became scarce. An important assumption here is that unoccupied land is available for acquisition, which usually holds true as land-owners tend to validate ownership by laying down at least crude foundations. Figure 5 shows that the occupation of lowlands started even as only 53% of highlands (Ogolian dunes) were occupied. Spatial evidence shows that the occupation of lowlands is not merely the result of land scarcity as the peri-urban district develops.

The Influence of Land Price

As land availability did not show to be a strong determinant of the occupation of lowlands, the influence of a third variable, land price, was investigated. Through interviews and workshops, cheaper land price was identified as the main motivation for settlement in the lowlands of Diamalaye. Similarly, participants in mapping workshops repeatedly associated lowlands with lower land value throughout the district. Land price impacts the urbanization process at two levels: it acts as a migration attractor and as a situational determinant.

The cheaper cost of living in the suburbs through subsidized services, an attractive fiscal system, and a lack of speculation bringing down land and property value have been identified as important drivers of urban sprawl in developed countries (Ewing 2008). Urban sprawl remains poorly researched in developing countries, even though urbanization has become a prominent force in the reconfiguration and economic development of these regions. While the literature on West African urbanization has focused mainly on rural-to-urban migration, the contribution of migrants as a driver of urban expansion is being revisited (Beauchemin 2004). In Ouagadougou, peri-urban neighbourhoods are teeming with young inner-city migrants who are attracted to these districts by government employment plans aiming to relieve the congested downtown area (Boyer 2010). Inner-city migration plays an important role in the demographics of the urban expansion of Dakar, with second or third generation rural migrants attracted towards the periphery in order to gain access to home ownership (Vernières 1973; Legros 2003). As land prices go up in the city and in the proximate suburbs, peri-urban locations are the only remaining option, as emphasized in workshops and interviews. Cheaper land prices drive urban sprawl to the periphery by attracting new migrants.

Cheaper land prices attract new migrants towards the periphery and this same driver influences the choice of location for a parcel of land within the peri-urban environment. At both neighbourhood and district levels, lowlands were associated with land prices that are lower, often less than half the price of parcels located on highlands. Land value reflects a large set of environmental variables, road development, proximity to amenities, provision of services, human as well as environmental risks. Even in informal land markets, prices are not set arbitrarily and typically follow economic principles (Adams 2004). The price difference not only explains the specific motivation for settlement in lowlands during drought years, but also shows that landowners recognized differences in environmental conditions significant enough to impact land value. Still, in the midst of the drought period, lowlands and highlands showed little distinct physical differences (water and vegetation had receded from lowlands) and both areas reached very similar development levels (e.g. proximity and availability of services). Just as urban development was privileged on highland landforms, the differential price treatment between lowlands and highlands suggests risk awareness among the community.

Risk Awareness and Marginalization

Spatial patterns of urban development point toward risk awareness among the local population. Interviews with key informants and local authorities corroborate this finding by acknowledging that most landowners knew about the land's unsuitability for residential development. However, this finding goes against repeated claims of flood victims stating that they were completely unaware of flood possibilities. In the neighbourhood of Diamalaye, many pointed to the pond that had turned into a soccer field during dry years as evidence that the flood risk was impossible to recognize. How can such different perspectives on flood risk arise? We argue that the problem did not lie within the presence of risk knowledge as demonstrated above but with the unequal access to that knowledge among the population.

Risk mapping exercises with the population showed that now that the hydro-meteorological conditions are turning back to normal, the relationship between flood risk and lowlands is well understood. Thus, at present, settlement in lowlands is not the result of a misconception of risk. The uneven distribution of knowledge is part and parcel of other disparities occurring in the Diamalaye. A distinct gap persists between the lowland and highland portions of the neighbourhood regarding access to services and political representation. Figure 6 shows the uneven electricity delivery within the neighbourhood leaving lowlands' dwellers to deploy cable extensions (up to 500 m) to hook up to power sources outside of the neighbourhood. Along the same trend, Fig. 6 also shows the uneven spatial distribution of neighbourhood representatives. Despite their informal status, the neighbourhood chief and his representatives play an important role in the daily activities of the neighbourhood. The current composition of local representatives meant little attention was given to issues arising in the lowlands' portion of the neighbourhood, including the issue of floods.

These disparities demonstrate the differential treatment of lowlands and highlands within a same neighbourhood, corroborating (Agrawal 1999) conceptualization of a community as a non-homogeneous entity. Limited access to knowledge is a key contributor to vulnerability among poor urban dwellers regarding natural hazards (Blaikie 1994). Environmental knowledge is thus a form of power, while conversely, the lack of access to knowledge exacerbates marginalization. Similarly, the uneven distribution of services and political power are also indicative of exclusionary practices and can be considered spatial manifestations of marginalization. Lowlands dwellers were typically found to lack relational qualities prior to their arrival in the neighbourhood. Most of them were introduced to the neighbourhood through outsiders of the community: friends from a neighbourhood adjacent to Diamalaye or word of mouth about available land. More importantly, lowlands dwellers lacked any kinship relationship with the main original landholding families. Nevertheless, although chaotic in appearance, the urbanization process in the informal neighbourhood of Diamalaye is controlled by social relationships and informal institutions thus transposing marginalization and exclusion throughout the spatial development of the neighbourhood.

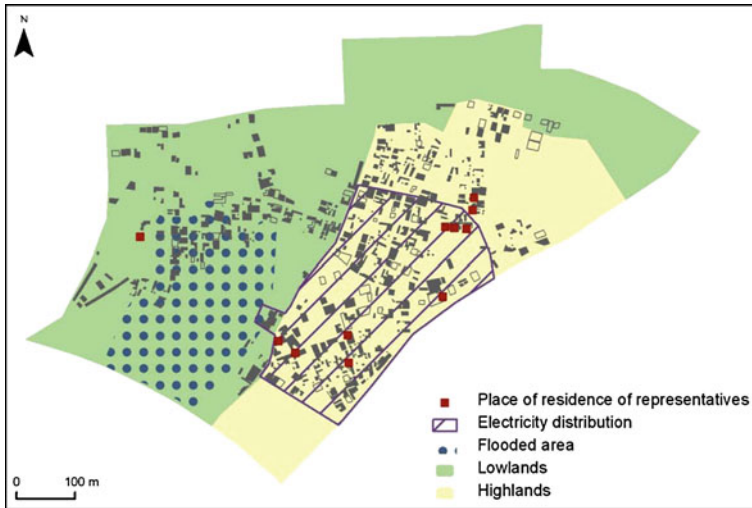


Fig. 6 Uneven distribution of political representation and service distribution at the neighbourhood level

The disconnection between a heterogeneous community and its homogeneous leaders often results in the exclusion of the most vulnerable regarding development goals of a community. For example, flood mitigation or adaptation was not identified as a priority by the population in a participatory development project currently underway in the neighbourhood. As Pelling (1998) observed in Guyana, vulnerability differentials and the perceived non-inclusiveness of the political space “encourage individuals to withdraw from the participatory system and concentrate on the lower efficiency but greater control to be found in investing in household or family-based coping mechanisms.” When investigating adaptation strategies, individual structural measures such as sand filling in houses, localized road raising and informal diversion works were the most common coping mechanisms, along with family relocation during flood periods. The perceived non-inclusiveness of political space has downstream repercussions on the neighbourhood’s development and is translated into neighbourhood-dwellers investing in individual strategies rather than relying on community-based action. This then prevents the building of social capital between lowlands and highlands groups, a shortcoming that is at the heart of flood vulnerability as it impedes the flow of information on risk.

PGIS: The Intersection between Intervention and Research

The use of participation within this research required the negotiation of participation as an intervention (linked to empowerment) and as an analytical method (as a source of information in a perspective of fundamental research).

The following section discusses how PGIS shapes and contributes to research on flood management as these two levels within the urbanization context.

Participation and Empowerment

The perceived lack of openness of the political space in the neighbourhood prevents the building of social capital between the two social groups in the lowlands and highlands. Building social capital would facilitate the flow of risk knowledge, which would promote the empowerment of marginalized groups at the same time. Social capital has been identified as a key element of adaptive capacity in the face of natural hazards and climate change (Adger 2003). While its importance has been recognized in the field of natural resources management, developing pathways to supplement social capital has proven difficult (Pelling 2008). As discussed above, PGIS can help develop collective ownership of an environmental problem, thus suggesting its potential for social capital building.

The success in building social capital varies depending on the way in which a PGIS is implemented. In this project, we set up the mapping workshops according to already established association regarding age, gender and occupation. We also sought to facilitate communication by creating a comfortable setting conducive for discussion. Furthermore, the workshops mainly targeted flood victims given the topic of this research. Overall, we concluded that the implementation of the PGIS reinforced social bonds within existing groups, as participants shared common experiences and a common fate. However, results demonstrated that the lack of social bridges between the lowlands and highlands impeded the flow of risk knowledge. We suspect that the PGIS could have contributed more to empowerment had it been implemented to develop social bridges between the lowlands and highlands, as opposed to only reinforcing social bonds between flood victims, as was the case in this project. Therefore, experience from this research shows that the design of PGIS implementation can have a significant influence on the building of social capital, and by extension on empowerment outcomes.

Participation and an Improved Access to Knowledge

One of the alleged benefits of a PGIS is to allow access to local knowledge, which is difficult to achieve through a conventional GIS approach given the source and form of local knowledge. This claim is based on numerous assumptions.

First, local knowledge in PGIS is often framed as a collective resource and assumed to be evenly distributed within the community. Such an assumption is the remnant of the conceptualization of the community as a homogeneous unit. Research by Agrawal and Gibson (1999) in natural resources management criticized the concept of community as “small, integrated groups using locally evolved

norms to manage resources sustainably and equitably.” Instead, they proposed a new framework where the community is understood through local politics and institutions. Their research triggered a series of articles framing communities within a political space, mainly focused on the distribution of power (Agarwal 2001; Klooster 2000; Nygren 2000). At the same time, concepts of local knowledge and indigenous technical knowledge (ITK) were being implemented in natural resources management (Agrawal 1995; Gadgil 1993). Despite the enthusiasm for these new concepts and the political focus following research by Agrawal and Gibson, certain aspects, such as the question of knowledge and its distribution remained unscrutinized. In this research, we showed that knowledge deserves to be meticulously investigated when trying to understand hazard vulnerability. Access to knowledge, in this case risk knowledge, is at the roots of flood vulnerability in the neighbourhood of Diamalaye. A PGIS can be an efficient tool to access local knowledge; however, the distribution and modalities of access to this knowledge must be carefully considered within the PGIS framework. As this research demonstrates, knowledge is not always evenly distributed and while a PGIS enables the mapping of knowledge distribution, it still requires a conscientious and targeted approach in order to obtain a comprehensive picture.

Second, many people assume that relevant authorities or institutions will make use of local knowledge, given the beneficial aspects. The knowledge flow (or lack thereof) is considered to be at the heart of the problem. In this sense, a PGIS is often interpreted as a way to instil or restore communication between the local population and authorities. However, in a context of development where weak institutions often prevail, no assumptions can be made regarding the outcomes this information will actually bring. In this project, the production of spatial information was beneficial as it helped bring attention to the flood problem and power asymmetries in this specific neighbourhood. Therefore, the translation of this knowledge into action by local authorities remains uncertain as a PGIS is subject to the same struggle of bringing research to policy-making.

Third, the central assumption of a PGIS in accessing local knowledge is that sustainability had been impeded by a lack of information. This project shows that it is not the lack of information that prevented sustainable urban planning but rather its uneven distribution among the population coupled with inefficient planning authorities. Access and distribution of information played a central role in creating the flood hazard in the study area. A PGIS can be used to target this specific problem and be used as a means to distribute this information by establishing channels to share geographical and environmental knowledge. However, more information is not a panacea for reaching sustainability; it only informs policy-makers during the actual policy-making process. Instead of concentrating on establishing vertical communication (between local population and authorities), a PGIS could be used to stimulate horizontal communication (between community members). In the context of weak institutions, such an investment in the knowledge flow within civil society is of utmost importance.

Conclusion

Spatial patterns unveiled by traditional GIS were used as an entry point to understand urban expansion. A PGIS implemented through mapping workshops as well as interviews and ethnographic observations revealed a geography of exclusion that exacerbates flood vulnerability. Therefore, any initiative tackling the flood hazard will need to acknowledge the heterogeneity of the community and exclusionary processes at play. Assistance and mitigation plans will need to expand actions beyond current institutional structures, even traditional informal ones, to successfully engage with marginalized and vulnerable flood victims. For example, surveys of flood victims and compensation distribution carried out by the state should try establishing direct communication channels with flood victims rather than going through indirect channels (e.g. informal institutions) as is currently the case.

At the methodological level, a PGIS constitutes an excellent tool for gaining access to local knowledge. However, assumptions regarding knowledge distribution and the practical benefits this additional information brings should be carefully considered. A PGIS helped to unveil the geography of exclusion within the neighbourhood of Diamalaye. (Schmitt 1996) already raised the question of “systems for prospective exploration” rather than “systems for control” for GISs. In that spirit, participation contributes an added value by allowing a broader framing of land and water management problems and by supporting a freer investigation of spatial and non-spatial processes.

The use of a PGIS showed that the tool could contribute to empowerment through building social capital. However, the way in which a PGIS is implemented plays a significant role in its efficacy. PGISs should target specific social bonds and/or bridges to ensure empowerment outcomes rather than building social capital in general.

References

- Acho-Chi (1998) Human interference and environmental instability: addressing the environmental consequences of rapid urban growth in Bamenda Cameroon. *Environ Urban* 10(2):161–174
- Adams J, Antwi A (2004) Urban myth vs. economic explanation: An empirical analysis of land purchasing decisions in Accra. *World Rev Sci Technol Sustain Dev* 1(2):192–208
- Adger WN (2003) Social capital, collective action, and adaptation to climate change. *Econ Geogr* 79(4):387–404
- Agarwal B (2001) Participatory exclusions, community forestry, and gender: An analysis for South Asia and a conceptual framework. *World Dev* 29(10):1623–1648
- Agrawal A (1995) Dismantling the divide between indigenous and scientific knowledge. *Dev Change* 26(3):314–439
- Agrawal A, Gibson C (1999) Enchantment and Disenchantment: The Role of Community in Natural Resource Conservation. *World Dev* 27(4):629–649
- Aguiar LA (2009) Impact de la variabilité climatique récente sur les écosystèmes des niayes du Sénégal entre 1950 et 2004, unpublished PhD thesis, Université du Québec à Montréal

- Aiken SR, Leigh CH (1975) Malaysia's emerging conurbation. *Ann Assoc Am Geogr* 65(4):546–563
- Aitken SC, Michel SM (1995) Who contrives the 'real' in GIS? Geographic information, planning and critical theory. *Cartogr Geogr Inf Sci* 22(1):17–29
- Ali A, Lebel T (2009) The Sahelian standardized rainfall index revisited. *Int J Climatol* 29(12):1705–1714
- Al-Kodmany K (2000) GIS in the Urban Landscape: reconfiguring neighborhood planning and design processes. *Landscape Res* 1:5–28
- Allen A (2003) Environmental planning and management of the peri-urban interface: Perspectives on an emerging field. *Environ Urban* 15(1):135–148
- Aragón-Durand F (2007) Urbanisation and flood vulnerability in the peri-urban interface of Mexico City. *Disasters* 31(4):477–494
- Barclay J, Haynes K, Mitchell T, Solnana C, Teeuw R, Darnell A, Crowweller HS, Cole P, Pyle D, Lowe C, Fearnley C, Kelman I (2008) Framing volcanic risk communication within disaster risk reduction: finding ways for the social and physical sciences to work together. *Geol Soc Lond Special Publ* 305:163–177
- Bauer K (2009) On the politics and the possibilities of participatory mapping and GIS: using spatial technologies to study common property and land use change among pastoralists in Central Tibet. *C Geographies* 16:229–252
- Beauchemin C, Bocquier P (2004) Migration and urbanization in francophone West Africa: an overview of the recent empirical evidence. *Urban Stud* 41(11):2245–2272
- Bizimana JP, Schilling M (2010) Geo-information technology for infrastructural flood risk analysis in unplanned settlements: A case study of informal settlement flood risk in the Nyabugogo flood plain, Kigali City, Rwanda In: Showalter PS, Lu Y (eds) *Geospatial techniques in urban hazard and disaster analysis*, Springer Netherlands, London, pp 99–124
- Blaikie P, Cannon T, Davis I, Wisner B (1994) *At risk: natural hazards, people's vulnerability, and disasters*. Routledge, London
- Boyer F (2010) Croissance urbaine, staut migratoire et choix résidentiels des ouagalais. Vers un insertion urbaine ségréguée. *Revue Tiers Monde* 1(201):47–64
- Chakraborty J, Tobin GA, Montz BE (2005) Population evacuation: Assessing spatial variability in geophysical risk and social vulnerability to natural hazards. *Nat Hazards Rev* 6(1):23–33
- Chatterjee P (2005) Mopping up in Mumbai. *Lancet* 366(9488):795
- Corbett JM, Keller CP (2005) An analytical framework to examine empowerment associated with participatory geographic information systems. *Cartographica* 40(4):91–102
- Correia FN, Saraiva MDG, Da Silva FN, Ramos I (1999) Floodplain management in urban developing areas, Part II. GIS-based flood analysis and urban growth modelling. *Water Resour Manag* 13:23–37
- da Gama Torres H (2008) Social and environmental aspects of peri-urban growth in latin American Megacities United Nations Expert Group Meeting on Population Distribution, Urbanization, Internal Migration and Development
- D'Aquino P (2004) Pour une expertise participative qui accompagne l'émergence de territoire citoyens du local vers le global. CIRAD, available at http://hal.archives-ouvertes.fr/hal-00157746_v1/
- Dewan AM, Yamaguchi Y (2008) Effect of Land Cover Changes on Flooding: Example from Greater Dhaka of Bangladesh. *Int J Geoinformatics* 4(1):11–20
- Dunn CE (2007) Participatory GIS: a people's GIS? *Prog Hum Geogr* 31(5):616–637
- Elwood S (2006) Critical issues in participatory GIS: deconstructions, reconstructions, and new research directions. *Trans GIS* 10(5):693–708
- Ewing RH (2008) Characteristics, causes, and effects of sprawl: a literature review. *Urban Ecol* 5:519–535
- Fernandez DS, Lutz MA (2010) Urban flood hazard zoning in tucuman province, argentina, using GIS and multicriteria decision analysis. *Eng Geol* 111:90–98
- Freire P (1970) *Pedagogy of the oppressed*. Seabury, New York
- Gadgil M, Berkes F, Folke C (1993) Indigenous Knowl Biodiversity Conserv 22(2–3):151–156

- Gaye A (2008) Enquête socio-économique de Diamalaye de 2007: rapport d'analyse, Institut Africain de Gestion Urbaine
- Goldsmith PD, Gunjal K, Ndarishilanye B (2004) Rural-urban migration and agricultural productivity: the case of senegal. *Agric Econ* 31:33–45
- Hara Y, Takeuchi K, Okubo S (2005) Urbanization linked with past agricultural landuse patterns in the urban fringe of a deltaic Asian mega-city: A case study in Bangkok. *Landscape Urban Plan* 73(1):16–28
- Harris T, Weiner D (2002) Implementing a community-integrated GIS: perspectives from south african fieldwork. In: Craig W, Harris T, Weiner D (eds) *Community participation and geographic information systems*. Taylor & Francis, London, pp 246–258
- Hickey S, Mohan G (2004) Toward participation as transformation: critical themes and challenges. In: Hickey S, Mohan G (eds) *Participation: From tyranny to transformation?*. Zed Books, London, pp 3–24
- Hodge G (1991) *Planning Canadian Communities*. Nelson Canada, Scarborough
- ISDR (2009) *Global Assessment Report on Disaster Risk Reduction*. United Nations, Geneva
- Jordan G (2002) GIS for community forestry user groups in Nepal: Putting people before technology. In: Craig W, Harris T, Weiner D (eds) *Community participation and geographic information systems*. Taylor & Francis, London, pp 232–245
- Kesby M (2007) Spatialiasing participatory approaches: the contribution of geography to a mature debate. *Environ Plan A* 39(12):2813–2831
- Kienberger S (2007) Assessing the vulnerability to natural hazards on the provincial/community level in Mozambique: the contribution of GIScience and remote sensing In: *The 3rd international symposium on geo-information for disaster management*, Toronto: Canada
- Klooster D (2000) Institutional choices, community and struggle: A case study of forest co-management in Mexico. *World Dev* 28(1):1–20
- Koti F, Weiner D (2006) (Re)Defining Peri-urban Residential Space Using Participatory GIS in Kenya. *Electron J Inf Sys Dev Ctries* 25(8):1–12
- Koti FT (2010) Confronting sociospatial exclusion on the fringe of Africa's cities using participatory GIS: Lessons from Athi River town, Kenya. *Afr Today* 56(3):63–82
- Kyem PAK (2001) Power, participation, and inflexible institutions: an examination of the challenges to community empowerment in participatory GIS applications. *Cartographica* 38(3):5–17
- Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW et al (2001) The causes of land-use and land-cover change: moving beyond the myths. *Glob Environ Change* 11:261–269
- L'Hôte Y, Mahé G, Somé B, Triboulet JP (2002) Analysis of a Sahelian annual rainfall index from 1896 to 2000; the drought continues. *J Hydrol Sci* 47(4):563–572
- Legros O (2003) *Le gouvernement des quartiers populaires: production de l'espace et regulation politique dans les quartiers non réglementaires de Dakar (Sénégal) et de Tunis (Tunisie)*, unpublished PhD thesis, Université François-Rabelais de Tours
- Lo PG, Diop MB (2000) Problems associated with flooding in Dakar, western senegal: influence of geological setting and town management. *Bulletin Eng Geol Environ* 58:145–149
- Lober DJ (1995) Resolving the siting impasse: modeling social and environmental location criteria with a geographic information system. *APA J* 61(4):482–495
- Maantay J (2002) Mapping environmental injustices: pitfalls and potential of geographic information systems in assessing environmental health and equity. *Environ Health Perspect* 110(2):161–171
- Mbow C, Diop A, Diaw AT, Niang CI (2008) Urban sprawl development and flooding at yeumbeul suburb (Dakar-Senegal). *Afr J Environ Sci Technol* 2(4):75–88
- Mills JW, Curtis A (2008) Geospatial approaches for disease risk communication in marginalized communities. *Prog Community Health Partnersh Res Educ Act* 2(1):61–72
- Morrow BH (1999) Identifying and mapping community vulnerability. *Disasters* 23(1):1–18
- Murray MJ (2009) Fire and ice: unnatural disasters and the disposable urban poor in post-apartheid johannesburg. *Int J Urban Reg Res* 33(1):165–192

- Nethengwe NS (2007) Integrating participatory GIS and political ecology to study flood vulnerability in the limpopo province of south africa, PhD edn, West Virginia University, Morgantown
- Nygren A (2000) Development discourses and peasant-forest relations: natural resource utilization as a social process. *Dev Change* 31(1):11–34
- O'Hare G, Rivas S (2005) The landslide hazard and human vulnerability in La Paz City Bolivia. *Geogr J* 171(3):239–258
- Pelling M (1998) Participation, social capital and vulnerability to urban flooding. *J Int Dev* 10(4):469–486
- Pelling M (1999) The political ecology of flood hazard in urban guyana. *Geoforum* 30:249–261
- Pelling M (2008) Shadow spaces for social learning: a relational understanding of adaptive capacity to climate change within organisations. *Environ Plan A* 40(4):867–884
- Pradhan B, Shafiee M, Pirasteh S (2009) Maximum flood prone area mapping using RADARSAT images and GIS: kelantan river basin. *Int J Geoinformatics* 5(2):11–23
- Ramsey K (2009) GIS, modeling, and politics: on the tensions of collaborative decision support. *J Environ Manag* 90:1972–1980
- Romero H, Ordenes F (2004) Emerging urbanization in the southern andes: environmental impacts of urban sprawl in santiago de chile on the andean piedmont. *Mt Res Dev* 24(3):197–201
- Schlossberg M, Shuford E (2005) Delineating 'Public' and 'Participation' in PPGIS. *J Urban Reg Inf Sys Assoc* 16(15):26–28
- Schmitt E, Brassel K (1996) From GIS for control to GIS for creative exploration GIS and Society workshop, specialist meeting report, South Haven
- Schroeder P (1996) Criteria for the design of a GIS/2 specialists' meeting for NCGIA initiative 19: GIS and society
- Sene S, Ozer P (2002) Évolution pluviométrique et relation inondations-événements pluvieux au sénégal. *Bulletin de la Société géographique de Liège* 42:27–33
- Sieber R (2006) Public participation geographic information systems: a literature review and framework. *Ann Assoc Am Geogr* 96(3):491–507
- Sliuzas R (2003) Opportunities for enhancing communication in settlement upgrading with geographic information technology-based support tools. *Habitat Int* 27:613–628
- Stonich SC (2002) Information technologies, PPGIS, and advocacy: globalization of resistance to industrial shrimp farming. In: Craig W, Harris T, Weiner D (eds) *Community participation and geographic information systems*. Taylor & Francis, London, pp 259–269
- Tall SM (1998) La decentralization et le destin des délégués de quartier à Dakar (Sénégal). In: *Bulletin de l'Association Euro-Africaine pour l'Anthropologie du Changement Social et du Développement*, 15, <http://apad.revues.org/567>
- Texier P (2008) Floods in Jakarta: when the extreme reveals daily structural constraints and mismanagement. *Disaster Prev Manag* 17(3):358–372
- Thomalla F, Downing T, Spanger-Siegfried E, Han G, Rockstrom J (2006) Reducing hazard vulnerability: toward a common approach between disaster risk reduction and climate adaptation. *Disasters* 30(1):39–48
- United Nations Population Fund (2007) *State of the world population 2007: unleashing the potential of urban growth*
- Vernières M (1973) Campagne, ville, bidonville, banlieue: migrations intra-urbaines vers dagoudane pikine, ville nouvelle de dakar (Sénégal). *Cahiers ORSTROM, série Sciences Humaines* 10(2/3):217–243
- Vojinovic Z (2009) Supporting flood disaster management with numerical modelling and spatial mapping tools. *Int J Geoinformatics* 5(4):33–40
- Webster CJ (1994) GIS and the scientific inputs to planning. part 2: prediction and prescription. *Environ Plan B: Plan Des* 21(2):145–157
- Weiner D, Harris T (1999) *Community-integrated GIS for land reform in south africa*
- Williams G (2004) Toward a repoliticization of participatory development: political capabilities and spaces of empowerment. In: Hickey S, Mohan G (eds) *Participation: from tyranny to transformation?*. Zed Books, London, pp 92–109

- Yalcin G, Akyurek Z (2004) Analysing flood vulnerable areas with multicriteria evaluation. XXth ISPRS Congress Istanbul, Turkey
- Yu K, Wang S, Li D, Li C (2009) The function of ecological security patterns as an urban growth framework in beijing. *Shengtai Xuebao/Acta Ecologica Sinica* 29(3):1189–1204
- Zhang H, Ma W, Wang X (2008) Rapid urbanization and implications for flood risk management in hinterland of the pearl river delta, China: the foshan study. *Sensors* 8:2223–2239