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Perspectives on the Role of Geo-Technologies for Addressing Contemporary Urban Issues: Implications for IDS

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Abstract Contemporary patterns of urbanization come with many challenges regarding the quality of urban life, especially with respect to the provision of urban infrastructures and housing, exposure to environmental risks and urban inequalities. In International Development Studies (IDS) it is understood that addressing these issues (both in terms of research and in practice) requires disaggregated and local spatial knowledge on the dynamics of urban populations, conditions, resources and flows. Geo-technologies such as remote sensing imagery or spatial simulation models have the capacity to provide this knowledge, but are endowed with certain risks and limitations. Using three illustrative examples this article discusses the potential and limitations of geo-technologies for addressing contemporary urban issues and how such technologies influence future development research. It shows that geo-technologies can produce disaggregated spatial and temporal knowledge, but should also include place and space specificities and cross-disciplinary boundaries in order to be useful. As IDS researchers have built-up considerable knowledge, expertise and networks on the ground, they can and should contribute to spatially contextualizing data- and technology-driven research.

Les modèles de urbanisation contemporains comportement plusieurs défis concernant la qualité de la vie urbaine, en particulier dans la provision d'infrastructures urbaines et de logement ; dans l'exposition aux risques environnementales ; et dans les inégalités urbaines. C'est bien compris dans le milieu des études en développement international que pour régler ces problèmes (soit en théorie que en pratique) on a besoin de connaissances désassemblés et spécifiques pour chaque localité sur les dynamiques des populations urbaines, et sur leurs conditions, ressources et flux. Les géo-technologies, tels que les images en télédétection, ou la simulation de modelés spatiales, peuvent fournir ces informations, mais comportent des risques et des limitations. Cet article utilise trois exemples pour illustrer le potentiel et les limitations des géo-technologies dans la résolution des problèmes contemporains urbains, et comment ces technologies influencent les études en matière de développement. Les géo-technologies peuvent fournir des informations désassemblés spatiales et temporelles, mais pour être vraiment utiles on doit aussi considérer les spécificités de chaque endroit et de chaque espace, aussi que de considérer d'autres disciplines. Les chercheurs en matière de développement ont des connaissances, de l'expertise, et des réseaux sur le terrain formidables, et ils peuvent et doivent contribuer à contextualiser spatialement les recherches impulsées par les données et la technologie.

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Introduction

Cities are nodes of economic development and social change as well as loci of power, poverty, exclusion and environmental risks. They are dynamic complex spaces shaped by forces of globalization and composed of multiple interacting layers of resources and flows, each having different characteristics, spatial properties and temporal dynamics (Gupta *et al*, 2015). Presently, more than 50 per cent of the world's population lives in cities, and it is expected that by 2050 about two thirds of the world's population will be urban (UN, 2014), driven by demographic processes, global capital investments, agglomerative forces and global governance networks and institutions (Seto *et al*, 2010). Urbanization and higher concentrations of people in cities can have positive effects for an economy of scale and provide opportunities for innovation (Bettencourt *et al*, 2007). However, they also raise many challenges regarding the quality of urban life. These include the provision and maintenance of adequate urban infrastructure and facilities (for example, water, energy, transport, ICT or health) and the increase in exposure to environmental risks and stresses, urban poverty, inequality and violence. Such issues are the topic of much current research in International Development Studies (IDS) in which both methods for understanding contemporary urban issues and relevant approaches to address these are debated and examined.

Smart city systems largely resting on (digital) information and communication technologies are increasingly seen as 'solutions' to contemporary and future urban challenges (Batty *et al*, 2012; Taylor and Richter, 2015). However, urban challenges differ across cities and regions, depending on the social, economic, demographic, political and geographic context (Gupta *et al*, 2015). Therefore technologies developed in Northern cities may not fit the development model of cities in the global South (Watson, 2013). In this article we highlight the potential of geo-technologies[1] for investigating urban issues in the global South to support urban planning and development processes (see also Pfeffer *et al*, 2015a). Key to geo-technologies are geo-spatial data situating places through their geographical coordinates and associated attributes (Goodchild, 2011) as well as the algorithm of geographic knowledge production, presentation and exchange. Our focus is on geo-technologies, because in current writings on smart cities and smart urbanism there is a lack of attention to place and space specificities. Rather, these writings present the smart city concept as a single technology, concealing the location-specific individual dimensions and processes and actors behind it. Furthermore, the smart city is largely a technology-driven discourse, and less attention is paid to the capacity of the technology to actually develop relevant knowledge on urban issues to feed strategic planning and long-term visioning processes. For instance, in cities in high-income countries, most attention is paid to real-time data collections to monitor operational and routine processes (particularly with respect to the functioning of physical urban infrastructures, such as transportation, water and sanitation, and energy) and the information needs of a modern individual. In this contribution we discuss the role of geo-technologies in investigating place and space.

In the following sections we briefly discuss contemporary patterns of urbanization and examine the potentials and limitations of geo-technologies in monitoring, analysing, planning and governing cities, using illustrative examples. We focus on what these technologies can do for urban development in Southern cities that have less resources to acquire and update geo-spatial data, and to develop and operate geo-technologies. This also includes a discussion of potential social implications (Pfeffer *et al*, 2015a; Martinez *et al*, 2016), uneven access to and use of these technologies and of the transferability of methodologies, tools and technologies rooted in high-income societies to less technologically developed urban locations, formulating a Southern perspective on the role of geo-technologies in addressing contemporary urban issues. It culminates in a reflection on what this means for research in IDS, in terms of topics, methods and ethics.

Contemporary Patterns of Urbanization

The most urbanized regions are currently in North America, Latin America, the Caribbean and Europe. Future urban growth will be concentrated in Asia and sub-Saharan Africa

(Seto *et al*, 2010; UN, 2014), putting considerable stress on the functioning of cities and their quality of urban life. For instance, in many urban areas, the provision of adequate housing and infrastructure cannot keep pace with the increasing migration of rural dwellers to urban areas, fuelling the growth and emergence of sub-standard settlements, often in sensitive environmental zones and at the fringe of cities, such as observed in the National Capital Territory of Delhi, India (Jain *et al*, 2015). In particular, in cities located in low elevation coastal zones, such as the city of Lima, increased establishment and growth of settlements in hazard-prone areas enhances exposure to natural hazards such as flooding, erosion or mudflows. As Lima is also a water-scarce area, population growth also influences availability of water and equal distribution of water (Miranda Sara *et al*, forthcoming). Increased exposure to environmental risks is often because of the tension between economic development and environmental vulnerability. In the Indian city of Chennai, for example, (global) capital investments in IT have led to city expansion towards the South, increasing environmental risks as the expansion occurred in an extremely vulnerable ecosystem (Kennedy *et al*, 2014; Jameson and Baud, 2016). The recent flooding of that area in December 2015, leading to the closing down of the operation of the IT hub and destroying several parts of the recently built express highway (NDTV, 2015), illustrates this tension. Moreover, higher densities and lack of green areas combined with increasing motorized transportation and industrial production have considerable negative effects on the environmental quality of a city and thus on the health and quality of life of city dwellers, exemplified by the recent smog alarms in Beijing, China. The urgency of urban problems is also recognized at the global policy level, as the UN has recently adopted sustainable development goals (UN, 2015) of which Goal 11 aims to 'Make cities and human settlements inclusive, safe, resilient and sustainable', directing the attention to the demographic, social, economic, environmental, infrastructure and political challenges cities face in the current era of urbanization. Current research on International Development stresses that, given that contemporary patterns of urbanization differ in scale, rate, form and function affecting the local, regional and global environment in different ways (Seto *et al*, 2010), a local translation of these goals is required, necessitating disaggregated insights into situated contexts and innovative governance tools to adapt to changing urban conditions (Robinson, 2006). Geo-technologies can potentially contribute to that.

Geo-Technologies for Addressing Contemporary Urban Issues

The field of geo-technologies is a rather technical field. For a long time it was the exclusive domain of geographic information scientists and experts who had the 'sole' expertise and control about how to acquire, manage and transform geo-spatial data and further process such data into information about people, conditions, resources and flows through computer algorithms. However, with the increasing penetration of graphical user interfaces, the internet, social media platforms, location-based mobile devices (GPS, mobile phones, camera) and easier access to geo-spatial data through open data platforms, geo-technologies not only crossed disciplinary boundaries but also became available for community groups and ordinary citizens, changing the landscape of urban knowledge production and consumption.

Elaborating the potential of geo-technologies for addressing contemporary urban issues in the global South requires some understanding of the different technologies and tools and how they are assembled for different purposes. In Table 1 we have provided a brief technical overview of the different genres that we consider important in the analysis and governance of cities.

Table 1: Geo-technologies genres

Definitions of geo-technological genres	*Examples of urban application*
Geographic information systems (GIS)	
A GIS is a system for producing, organizing, transforming, analysing, retrieving, representing and communicating geographical information about geographic phenomena (features, patterns and relationships) in the real world by applying a set of functions and decisions to geo-spatial data for a particular set of purposes while interacting with social and political structures (based on Burrough and McDonnell (1998) and Chrisman (1999))	Creating base layers of urban places and urban space, such as maps of urban infrastructure, administrative boundaries or urban facilities; mapping and analysing urban phenomena such as poverty, economic development or environmental hazard
RS technologies and analysis tools	
RS technology captures geographic information of the Earth's surface from a distance by means of a sensor, represented as a spatial image of absorption values[a] (see also Lillesand and Kiefer, 2000). Depending on the sensor, the images vary in spatial and temporal resolution and spectral characteristics. RS analysis tools help to convert absorption values into meaningful categories	Producing base layers of the physical elements of a city such as building footprints or transportation lines; monitoring temporal dynamics of environmental and physical properties or analysing land use changes
Spatial modelling and simulation tools	
Spatial modelling and simulation tools describe spatio-temporal behaviour of spatial processes and systems, based on a set of initial conditions, input parameters and a set of rules and (physical) laws (cf. O'Sullivan and Perry, 2013)	Simulating land use changes or predicting the likely occurrence of a natural hazard such as flooding, erosion or landslides
Planning and decision support systems (PSS/DSS)	
PSS and *DSS* draw on planning or decision-making theories and concepts, 'data, information, knowledge, methods, methods and instruments' to assist planning and decision-making processes, not necessarily spatial, but often supported by one or more geo-technologies such as GIS or spatial simulation modelling (Geertman and Stillwell, 2009, p. 3, Geertman *et al*, 2013)	Computing and visualizing relevant spatial information on the suitability of interventions, for example, in terms of siting urban facilities and infrastructure, upgrading or environmental protection
Location-based technologies	
GPS-enabled (mobile) devices, mobile phones and environmental sensors (for example, temperature, concentration of pollutants, noise levels) produce geocoded data of geographical locations for different moments in time, producing the input for mapping space-time trajectories, time series analysis and spatial interpolations	Measuring environmental issues such as air pollution, climate or acoustic environment; mapping migration or transportation flows or urban crowds; mapping or reporting urban issues
Network-based geo-technologies	
Network-based geo-technologie[b] combine the functionality of the internet, computer networks, database functionality, GIS functionality as well as social media tools. Hence, it can serve multiple goals including producing, storing, managing, sharing and	Using Google Earth, which offers access to high-resolution images from all over the whole world via the internet, or urban information systems to explore and monitor the urban space. A user can interact with different images or maps by applying typical GIS

Table 1 *continued*

Definitions of geo-technological genres	*Examples of urban application*
consuming of geo-spatial data and information by means of a server and a network (intra- and internet), often through a graphical user interface. There are a variety of modes and concepts, depending on the purpose, institutional embedding, degree of codification and standardization, interactivity, extent of (GIS) and database functionality and mode of participation	functions such as zooming, switching on and off different information layers or creating new geographic information
Smart city systems	
These are systems that integrate ICT and traditional infrastructure by means of new digital technologies such as digitally integrated sensors and sensor technology and human sensors capable of co-ordinately receiving, managing, analysing and producing new (location-based) information about the city (Batty *et al*, 2012)	Urban dashboards or control rooms that visualize real-time or near real-time information on different urban characteristics such as pollution, transportation flows or potential risks of natural hazards

[a]Absorption values represent the degree to which incoming energy (for example, from the sun) is absorbed by the earth surface or reflected. Land uses (water, vegetation types, built-up area) differ in their degree of absorption.
[b]Common examples are Management Information Systems, Spatial data infrastructures, GIS-based web applications, Geoweb, Volunteered Geographic Information, new spatial media (Goodchild, 2007; Scharl and Tochterman, 2007; Crampton, 2009; Elwood and Leszczynski, 2011; Elwood and Leszczynski, 2013).
Source: Adopted from Pfeffer *et al*, 2015a.

One needs to note that a geo-technological genre is seldom applied as 'stand alone' product but always in combinations, as reflected in the definitions of planning and decision support, network-based geo-technologies and smart city systems. Key to geo-technologies is the availability of accurate and reliable geo-spatial data locating and measuring populations, urban conditions, resources and flows in the geographic space. Hence, in the current era of digitization, remote sensing (RS) and location-based technologies are indispensable for any analysis or information system as they provide the necessary input. Although querying and mapping individual geo-spatial data may already be interesting in itself and can lead to new knowledge and hypotheses about what the city looks like or how it functions, combining multiple data sets through meaningful (theoretical) concepts, rules and physically based equations goes beyond this and produces new insights into how different urban dimensions and processes interact with each other vertically, horizontally and (if applicable) through time. Thus geo-technologies have the potential to advance our existing knowledge on contemporary urban issues in manifold ways. Given their generic nature, we could produce a long list of different urban applications. In this article, we have selected three illustrative cases to elaborate their potential, while being reflective on the mapping processes and outcomes, requirements, transformational potential as well as feasibility of being transferred to different contexts. The examples were selected on the basis of their capacity for analysing city dynamics in space and through time and illustrating potential limitations for incorporating them into research on urban development issues.

We start with an example rooted in Earth observation, one of the most important scientific fields in the acquisition and processing of geo-spatial data through RS. For a long time RS has played a major role in land cover analysis, land use change detection and the creation of base data for further geographic analysis. However, with the increasing number of sensor launches in the

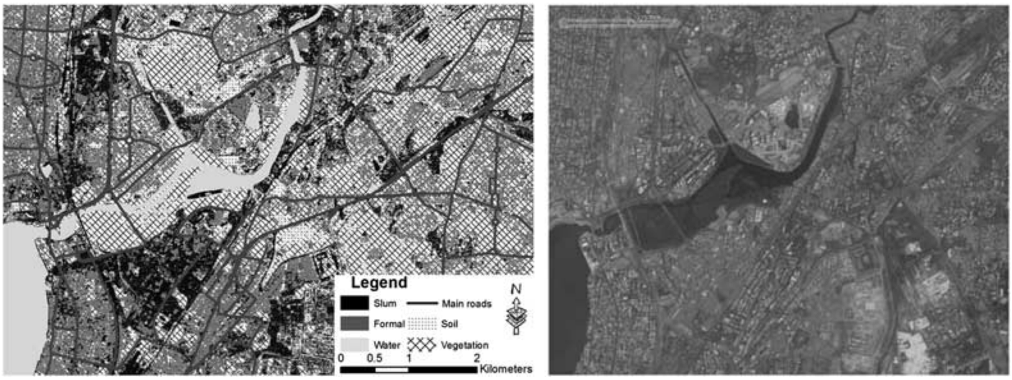

Figure 1: Identifying slum areas by means of remote sensing imagery. Left: extraction of sub-standard areas (slums) (distinguishable due to absence of vegetation and clustered roofs) and formal areas in Mumbai (Worldview-2 image, 2009; *Source*: DigitalGlobe) – Kuffer *et al*, in review. Right: Google Earth image; DigitalGlobe; Image Date 15 December 2009.

last decade, very-high-resolution (VHR) images became available providing a highly disaggregated view of the city. Through this rich data source with a high spatial and temporal granularity we can now explore how contemporary urbanization processes influence the urban morphology and spatial configuration of land use and physical patterns or determine the likelihood of the occurrence of natural hazards. We can, for instance, analyse urban sprawl, changes in urban densities and building layouts, the growth and emergence of sub-standard settlements at the urban fringe and even identify individual objects, such as slum houses. Figure 1 shows how VHR images have been used to identify sub-standard areas (slums) in the city of Mumbai (Kuffer *et al*, in review).

Next to 'raw' RS images, Google Earth (www.google.com/earth/) provides universal access (provided internet access exists) to detailed images everywhere in the world at different moments in time. The importance of visually monitoring urban trends through Google Earth is illustrated by Klaufus (2010) for a number of Latin American cities, where this is often the only source of spatial information on a city-wide scale. Although Google Earth provides a wealth of information that can be visually explored and interpreted, the free version does not allow for a systematic analysis in an automated manner. If the aim is to analyse a phenomenon in a systematic and automated manner, one needs to have access to cloud-free images covering the whole city (which can be very costly), other geo-spatial data (which are often not in place at the quality required), contextual information on the respective city (which requires local knowledge or collaboration with local experts), suitable RS software (which is also very costly if no open source option is available) and the necessary conceptual knowledge and technical expertise to process geo-spatial data into meaningful information on the respective aspects.

In the context of spatiality two things are important. First, the outcome of such an analysis is achieved through human interpretation and subjective choices; if the classification process is not done in a careful manner and if the algorithms are not adjusted to the local context, the outcome could have detrimental effects for certain population groups. For example, if an area is not captured, it may not receive funding, or, conversely, the outcome may assign labels to certain areas, which may induce certain disadvantages for these areas, possibly leading to lower land prices. Second, because of the sophistication and costs involved, this type of analysis is still very exclusionary, being available to those cities or actors working within cities that have the necessary resources in terms of skills, software and access to data. The development of the global human settlement layer[2] (Kemper *et al*, 2015 in Pfeffer *et al*, 2015a) was a first step to overcome the second issue, as it was meant to be an inclusive and dynamic concept to provide access to information about patterns of urbanization. Hence, for IDS, this technology requires attention for questions of inclusion and exclusion in RS, for the construction of codifications and interpretations and for policy implications of being (wrongly or rightfully) (dis-) qualified.

The second example is also rooted in physical sciences, in particular, in the field of environmental modelling (see also spatial and simulation modelling). Environmental models describe the spatial and temporal behaviour of processes in a landscape such as flooding, landslides, mudflows or air pollution on the basis of the model input (spatial and temporal characteristics, boundary conditions and parameter values) and a set of rules (conceptual or physically based) (Wainright and Mulligan, 2013). In cities such as Lima, Rio de Janeiro, Lagos, Kampala, Cape Town, Jakarta, Delhi, Mumbai and Chennai, large urban populations concentrate in low elevation coastal zones, along rivers, in mountainous terrain or bare areas. Because of their geographies, these cities experience considerable exposure to natural hazards, often affecting the poorer population groups settling in the hazard-prone areas. Rapid urbanization and much extreme weather events as a consequence of climate change exacerbate environmental risks, making it even more important to have knowledge on where and when a hazard is likely to occur. Environmental models can provide this kind of information and can assist in assessing different scenarios, as models can be executed for different sets of model inputs. The outcome of such models are a series of maps and graphs that not only illustrates the state and dynamics of certain landscape factors in support of understanding a particular system but also allow for the evaluation of the effects of certain interventions or changes in such natural systems. They thus have the potential of enriching a process of social knowledge construction on urgent urban issues, in support of strategic planning and visioning. However, just as in the case of RS applications, the output of such models depends largely on their inputs and therefore on the availability of local knowledge, context-specific parameter values, available data with considerable spatial and temporal detail, and technical expertise to build new or adjust existing models. Sliuzas *et al* (2013) have made an attempt to build a hydrological scenario support tool for the city of Kampala in collaboration with UN-HABITAT's Cities and Climate Change Initiative to simulate the places that would be affected by a flood in the case of an extreme rain event. The upper part of the Figure 2 illustrates the kind of data required to undertake such an endeavour, whereas the lower part is one of the possible outcomes (flood height) that could be used in a visioning process. They also demonstrate the challenges faced in a data-scarce environment as well as the importance of working with local experts. For IDS research, this example shows how such local knowledge can be integrated and how research can be done on data-scarce environments.

The third example concerns the introduction of networked geo-technologies to provide access to spatial information (for example, through Google Maps/Earth) and to support information flows between different actors – for instance, between government and citizens. This potentially democratizes access to spatial information and can provide means for more inclusive urban development as more attention is paid to participatory processes with the aim to include citizens in planning and decision-making processes. As elaborated in Table 1, networked geo-technologies are, for instance, online platforms through which people with little or no technical expertise can query, create, use and share geo-spatial data and information. Within the technology-driven smart city discourse, these show up, for example, as city-dashboards through which users can explore spatial and non-spatial representations of urban indicators such as population distributions or air pollution concentrations (Kitchin, 2014). However, users have influence neither on the choice of indicators and categorization of representations nor on the data

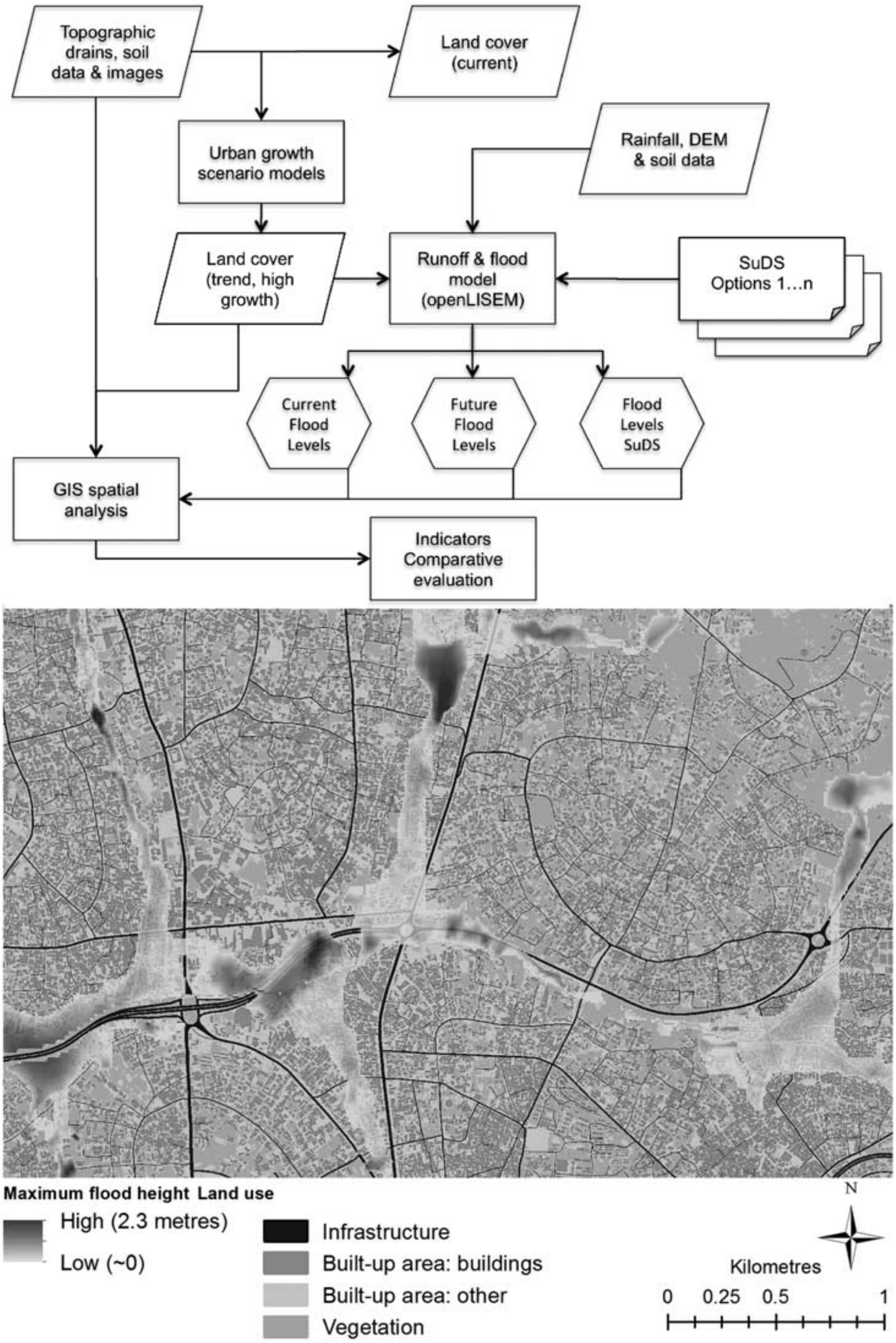

Figure 2: Scenario support tool. Top: DEM = digital elevation model; SuDS = different scenarios and Bottom: outcome of the flood model (Sliuzas *et al*, 2013).

Figure 3: SoftGIS system, Helsinki, Finland (Kyttä *et al*, 2013).
Source: Screenshot captured from pehmogis.aalto.fi/pehmogis/en/helsinki.html.

used. Online platforms that do enable active contributions from citizens include policy-support tools or e-grievance redressal systems. Examples are the Finnish easy-to-use GIS-based information system encouraging city residents to contribute their own local knowledge on urban planning and policy issues (Kyttä *et al*, 2013) or e-grievance redressal systems in several Indian cities such as Kalyan–Dombivili and Hubli–Dhaward (Martinez *et al*, 2011; Van Teeffelen and Baud, 2011). While the Finnish system focusses on long-term strategic issues in the city (Figure 3), the e-grievance systems target daily issues and operational processes such as complaints regarding public space or basic services.

However, although these systems potentially enable active contributions from citizens and non-technical experts, their success depends largely on the extent to which users have the means and skills to use the platform and to what extent the platforms consider issues relevant in a particular context. Hence, they also may have uneven representation of citizens, as residents who are unaware of the platform or who may not have the necessary means and skills or financial resources or who feel that the platform does not address relevant issues are excluded (Martinez *et al*, 2011; Haklay, 2013; Kyttä *et al*, 2013). In addition, if these platforms are not embedded in existing governance or knowledge building processes, their long-term existence remains precarious (Pfeffer *et al*, 2013). Although network-based technologies can support the production, use and exchange of spatial knowledge, more empirical evidence is needed on their actual capacity on the ground (Kitchin, 2015; Luque-Ayala and Marvin, 2015).

Geo-Technologies for Addressing Contemporary Urban Issues

In this article we have suggested that it is not enough to collect and query individual digital data sets but we need to recognize the importance of place and space and move towards use of more advanced geo-technologies such as RS tools, environmental models and (governance) support tools. They have the capacity to produce knowledge on urban dynamics, in particular to assess and monitor the extent of pressing urban issues, govern urban population, resources and flows, facilitate and manage data and information flows and to design urban plans, policies and strategic visions.

We consider this strategic because globalization has led not only to new patterns of urbanization and organizations of cities through capital investment, policy mobility and circulation of knowledge flows but also to an increasing informatisation, digitalisation and spatialisation worldwide (Baud *et al*, 2014). The use of geo-technologies in the analysis and governance of cities of the global South can change the landscape of IDS, in particular the production of urban knowledge and how (spatial) knowledge is constructed and influences contemporary urban issues, and how governments interact with citizens and businesses and vice versa.

However, although geo-technologies have become accessible to a wider range of users, the design and operation of the technical system itself still requires considerable expert knowledge, and, with the move towards more reliance on digital technologies and wired systems, systems that include the actors involved in designing them become even more powerful. Moreover, in order to produce meaningful knowledge about the city, they require social and contextual-embedded knowledge about the city and life in the city. Hence, crossing boundaries is extremely important, both between different disciplines and between academia and professionals, to combine forces and benefit from 'economies of scale'.

One needs to keep in mind, though, that geo-technologies not only provide interactive platforms for community groups and ordinary citizens to access different types of information and knowledge and to contribute their local knowledge but may exclude those who do not have access to the information infrastructure or do not know how to handle it. Furthermore, as these technologies still require considerable expert knowledge in the set-up, operation and modification, they increase the dependency of urban authorities on private sector firms that may become more powerful in the framing and prioritization of issues and the access to geo-spatial data and knowledge products. Hence, the high costs, technical requirements and expert knowledge (re-) produce urban inequalities in terms of who has access to the technologies and what they produce.

At the moment, there is little empirical evidence of the actual capacities of existing geo-technologies, for instance, whether a poverty map actually improved the quality of life in a particular area that was highlighted on a map, or whether the knowledge on the growth and emergence of slums mapped through RS images has led to effective policies. Moreover, there is little empirical evidence on the capacity of smart city systems to enhance urban governance and sustainable and inclusive development (Kitchin, 2015; Luque-Ayala and Marvin, 2015). In some cases counter-mapping activities have influenced environmental policy formulation and in other cases they have been 'ignored' (Pfeiffer *et al*, 2008; Scott and Barnett, 2009; Jameson and Baud, 2016). Nevertheless, we need a better understanding of the social implications of geo-technologies in Southern cities, especially a better grasp of their capacity for achieving sustainability goals and producing more equal conditions. It still needs to be seen who will benefit the most.

What Does it Mean for Development Research?

Geo-technologies will no doubt influence future research on IDS, both as topic of (critical) enquiry and analysis, and as a methodological tool to examine issues and questions relevant to the broad field of IDS. The above examples highlight urban domains (for example, planning, governance and environmental risks) where geo-technologies and smart city applications are prevalent (and their presence will increase even further). This raises critical and analytical questions within development research related to accessibility, processes of in/and exclusion, inequality and privacy with regard to both the tool itself – the ways it is used in processes of policy implementation – and the potential outcomes. These are by definition topics of research within IDS. We already see these questions being raised in the work of Kitchin (2014), Pfeffer *et al* (2015b), Taylor (2015) and Taylor and Richter (2015). However, also in terms of methodology, geo-technologies bring potential changes for IDS.

IDS is an interdisciplinary field, informed by various disciplines such as geography, anthropology, economics, psychology and political sciences. It also deploys a wide range of methods of data collection and analysis and often a mixed-methods research design drawing on surveys, ethnography, GIS, participatory methods and so forth. Despite this variation, a few generalizations can be drawn out. First and foremost, the large majority of IDS are fieldwork-based, involving interactions between researchers on the one hand and communities of residents, policy makers or representatives of NGOs, private sector and so on, on the other. The arrival of geo-technologies creates opportunities to 'do' development research without actually being in the field. There are both potential risks and benefits to this. The major risks are the lack of embedding of findings and understanding of the local context (see also Taylor and Richter, 2015) and a reduced role of local research communities in doing development research. These risks may outweigh benefits such as possibly reduced costs of doing research. As such, IDS researchers can and should contribute to spatially contextualizing data- and technology-driven research.

Geo-technologies provide a world of data and information that allows to carry out research questions and analyses that were previously hard or impossible. Confronted with a lack of (reliable and up to data) large data sets, development researchers would find themselves with limited opportunities to answer certain research questions, or depend on collecting their own data (costly in terms of finances and time). Geo-technologies provide new sets of data that allow new questions to be asked, new methods of triangulation to be applied and new cases to be explored.

These new technologies also challenge research ethics. Given the interest of the private sector in the development and application of geo-technologies, as well as in the information produced, they may become a more important client of research or potential user of findings. A thorough *ex ante* assessment of potentially interested users, possible applications and the consequences of these on the outcomes is required. These then need to be weighed against – and may find themselves in conflict with – the classic ethical principles of 'do no harm' and 'privacy'.

Notes

1. *Geo-technologies* encompass an array of technologies and computer tools to capture, analyse, monitor, predict and present geographic features, patterns and relationships in space and time. The most common technologies and tools are GIS, RS technologies and analysis tools, location-based technologies such as global positioning systems (GPS) or mobile phone signals, spatial modelling and simulation models, network-based geo-technologies and entirely integrated smart city systems (Table 1).
2. The global human settlement layer maps the spatial extent of urbanization of different cities across the world since 1975 using satellite Imagery; for a more detailed description visit ghslsys.jrc.ec.europa.eu.

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