Mapping out Responsibility

An Investigation of the Cartography of Slums

Master Thesis

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Introduction

In everyday practices, for many individuals making use of a map is usually an activity for navigating from place to place, via Google Maps, a GPS tool or an actual handheld map. Such an activity follows the authority of the map in an almost unquestioning way. In some cases involving Google Maps, this has led to disastrous situations where drivers end up in lakes or ditches by following the map instead of paying attention to the terrain itself. When such accidents happen, is it the fault of the driver or the app (and by extent the company in charge of the app)? In other cases, maps can be of use to gain more insight, especially on territories that one has never been to, or territories too remote to be physically accessed. But is it necessary for the map user to be critical of what they are shown, or should they have faith that the map (and the map maker) is representing what the user needs to know in an accurate manner? Such concerns over accuracy, use, and responsibility, will be the themes of this thesis. The investigation to follow, will be assessing maps as doing more than just guiding or showing a route. I shall be looking closely at the social, political and technological processes that orient the production of maps. The focus of this thesis will be to assess and make sense of maps that are being used to map a particular type of environment and its inhabitants, namely efforts being made to map what are called 'slums' and slum dwellers. This thesis will investigate the mapping of 'slums' in order to ask: *what does responsible mapping of 'slums' look like*? And to answer this, I will trace out where responsibility lies amongst the actors involved in the mapping process, the relations they share with these maps, along with the design and rationale when these maps are put to use.

Lining up the terms

Defining what a map is, and what a 'slum' is, is the challenge taken up in the first chapter of this thesis. To look at a map either digitally or in one's hands, at a surface level, is to be faced with icons, names of places, objects (e.g. forests, rivers or parks), a key, a grid, and a flat plane where these items are represented. But a broader conception of what maps are and what they do, can be revealed by looking at how and for what reasons a map is produced. As mentioned, the maps I shall be focusing on in this thesis, are maps of areas referred to as 'slums'. The term 'slum' was first used in nineteenth century Britain to describe 'low-quality working-class housing which was privately produced and administered under rental tenure' and slowly transformed into becoming a synonym for parts of the city with housing that had high occupancy of low income groups, with a lot of building deterioration and

health problems (Huchzermeyer, 2014: 86). I will address the issues involved in the use of the term 'slum' in the first chapter, and then move to considering how maps in general and maps of ‘slums’ in particular, are produced.

I will be taking as a starting point the discipline of critical geography, to answer the question of what a map is. Beginning with outlining two successive models of maps: i) the map communication model (MCM) that treats maps as instruments in a scientific manner, and ii) the geovisualization model that emphasises the interactivity of maps as a result of advances in computer software, that allows multiple users to work on the same map. The MCM treats maps as objects in-between map makers on one side and map users on the other, with the map maker having the authority of dictating what kinds of features, measurements and information to present on the map. Under this model, the focus in understanding maps and for the map maker becomes a self-reflective one, as cartography “in these terms is purely technical and develops by asking self-referential, procedural questions of itself that aim to refine and improve how maps are designed and communicate” (Kitchin et al, 2009: 11). Maps in this model are designed and used as scientific tools. In contrast, the geovisualization model places the map as the site of interaction and negotiation for map makers and map users, but also enables map users to make their own maps. These two models will help show that maps can either be considered as mere tools that communicate specific visual information, or as sites where individuals can encounter means for collaboration, negotiation and contestation of how to map out a specified territory.

But the analysis of critical geography also allows for opening the way to looking at how maps are situated, and the social relations that motivate the rationale and design choices behind their production. The maps I shall be analysing are maps specifically produced for extracting the boundaries, structures and sizes of ‘slums’ from satellite images of cities in the developing world. The literature that I will be using to make this analysis will be from the work of geospatial scientists, the majority of which is based on research from the International Institute for Geo-Information Science and Earth Observation (ITC) in Enschede (Netherlands), who develop what are called remote sensing maps. As the phrase ‘remote sensing’ suggests, these maps are made from a distance quite removed from the area being mapped. These maps are produced using geo-information systems and science (i.e. GIS) that utilise very high resolution (VHR) images of cities and computing architectures of varying complexity to identify and represent ‘slums’.

Additionally, I shall be using research from UN-Habitat, whose definition of 'slums' is the one in operational use in the remote sensing literature. The definition of the term 'slum' comes from a 2002 expert meeting between UN-Habitat, United Nation Statistics Division (UNSD) and Cities Alliance (UN-Habitat, 2018: 3). 'Slums' or 'slum households' are dwellings in which the inhabitants suffer from: i) lack of access to improved water services, ii) lack of access to improved sanitation facilities, iii) lack sufficient living area, iv) lack of housing durability, and v) lack of security of tenure (3). And a 'slum dweller' is an individual "living in a household that lacks any of the above attributes" (3). With there presently being approximately 1 billion people living in 'slums' or (one of the synonymous terms) 'informal settlements', these areas "remain very much a global urban sustainability challenge but also a development opportunity" (2). But the term 'slum' is not, as I will point out in the first chapter, a universal term or category, despite how the definition from UN-Habitat operates as a formal definition. The term 'slum' depends on different cultural, temporal, geographic and spatial characteristics, not just fitting the five criteria that defines a household as a 'slum', and its inhabitants as slum dwellers. Yet maps of slums in the remote sensing literature aim to capture these formal UN-Habitat determined aspects of what counts as a 'slum'. While the fact that the NGO Slum Dwellers International (SDI) also uses the term 'slum' in their literature and advocacy for slum dwellers' rights, means that the term is operational both at the international policy level, and at the local level of the 'ground' being mapped. Maps of 'slums' and the information they help produce on 'slums' are vital because they can help with measuring and monitoring their growth, in managing the development of cities. Looking towards the state and wellbeing of cities is a component of Sustainable Development Goal (SDG) 11 to make cities and human settlements inclusive, safe, resilient and sustainable. The first chapter will thus aim to address the following concerns: defining what a map is and its function, breaking down the definition and use of the term 'slum', and which actors are involved in this defining (of what a 'slum' is), and the activity of making maps of 'slums'. Along with using literature from ITC, assessing what the technological demands of remote sensing using GIS are, as the first of three mapping approaches I will be assessing.

In addition, it will be realised that the use and need for maps of 'slums' is not restricted to the work of geospatial scientists. Information about the size, structure and growth of 'slums' is vital for local and state-level governance bodies, international governance bodies (e.g. UN-Habitat and Cities Alliance), as well as non-government organisations (NGOs) such as Slum Dwellers International (SDI). In this way, maps operate as what Tim Ingold refers to as a 'parliament of lines' (Ingold, 2010: 4). This metaphor will be useful in highlighting how maps do not only reflect technical concerns, but also social and political

concerns that have to do with the interests of the actors involved, and how these interests are negotiated in the process of map production.

A geography of participation

The overview of the actors and rationale involved in the mapping of 'slums' discussed in the first chapter, will be necessary for sketching out what I will call the geo-policy assemblage that orients what actors, technologies, forms of governance and decision making are involved in the map making process. I borrow the term assemblage from the work of Gilles Deleuze and Felix Guattari (1987). The term will be useful for my analysis because it will help to show that maps are caught up on the one hand by forms of content (the different actors and institutional bodies that are involved) and on the other hand forms of expression (the policies, definitions and measurement indicators that are used for identification and classification for managing 'slums'). The second chapter of this thesis will be aimed at revealing and analysing the interactions of this geo-policy assemblage, by beginning with Michel Foucault's (1991) analysis of governance, in order to draw more focus on the social and political aspects of mapping 'slums'. This analysis will start with the term governmentality (i.e. the rationality of governance) from Foucault, for thinking about how 'slums' are identified, classified and governed within the geo-policy assemblage. The consideration of remote sensing approaches in the first chapter, will show that advanced technologies used for the mapping of slums, may not be inclusive (i.e. accessible to the people on the 'ground') of all map users. Focusing on the social and political aspects of the mapping of 'slums', will thus require a closer investigation of a mapping approach contrasting remote sensing, namely, community-based mapping. I shall spend the majority of the second chapter on the NGO SDI, due to their extensive work in empowering slum dwellers through community based mapping, showing the capacity of maps to be used for advocating the protection of slum dweller rights. By putting slum dwellers at the front-line of mapping their own households, community-based mapping gives slum dwellers more solidarity and more of a voice. Especially when in a number of countries, 'slums' and slum dwellers are not acknowledged by state and municipality agencies in the gathering and representation of census data. This is an issue I shall go into more detail on in the second chapter, highlighting how the activity of mapping 'slums' can either contribute to enriching the lives of slum dwellers, or can be part of the process of unjust evictions.

Slum dwellers, I shall show, are either excluded when the technologies used are too complex and therefore require experts, or when specific governance bodies decide to not include certain 'slums' in

the census maps. Community-based mapping thus allows slum dwellers to work together to initiate mapping strategies, and NGOs such as SDI help in making these efforts actualised at local, national and global levels as part of what are called federations of collaborating slum dweller communities. Further, by taking the initiative in mapping their own living situations, the maps made by slum dwellers replace the technicalities of remote sensing with a focus on the social, cultural and historical aspects of slums that may not be picked up by VHR images or representable explicitly in remote sensing approaches. Community-based mapping therefore allows slum dwellers to collaborate and gain visibility, but more so, by putting themselves on the map slum dwellers can gain a voice that allows them to potentially work alongside municipalities in efforts to improve the living conditions of their 'slums'. In this way, slum dwellers can become involved in a process of what Elinor Ostrom (1997) refers to as co-production.

But is there perhaps a way of bridging remote sensing and community-based approaches to the mapping of 'slums'? In the third chapter of this thesis, I will look to the literature on participatory GIS (PGIS) as a way of formulating a middle ground between remote sensing and community based mapping. PGIS aims at combining 'participatory mapping visualisations, spatial information technologies (SIT), spatial learning, communication and advocacy' (Rambaldi et al, 2006: 106). PGIS would therefore allow for a greater geography of participation that brings together municipalities, remote sensing experts, NGOs and slum dweller communities. However, as shall be discussed throughout the chapter, such a collaboration of diverse actors has a number of challenges that need to be addressed in the formation of an effective PGIS. As will be demonstrated from the first and second chapter, while remote sensing approaches utilises technologies including drones and machine learning, community-based approaches are more low-tech, using handheld GPS devices and tablets. The first hurdle is therefore the selection of adequate technologies that will allow sufficient training without needing too much expertise and financial cost, but also satisfy the accuracy requirements so that the data gathered and maps produced can be used not just at the local household level but also at the city level for monitoring SDG 11. Another hurdle is what form the collaboration will take. An effective PGIS should allow multiple users to interact with the mapping data synchronously as well as asynchronously, but also allow all users to manipulate the data (especially in cases of errors or adding comments and queries). But the need for interactive collaboration and computational architecture, carries with it higher economic costs, the possibility that changes in governance leadership will shift funding and participation of important actors away from the PGIS, as well as the issue of time necessary to set up, test and get the system running. These are the issues that I will be addressing throughout the third chapter.

Mapping responsibility

Given the fact that there are a lot of moving parts in the formation as well as functioning of the geo-policy assemblage orienting the mapping of 'slums', it is necessary for the roles, tasks and responsibilities of each actor to be recognised. Thus the third chapter shall include what I call a matrix of responsibility, along with a code of GIS ethics as guidelines, that could be of use in the setting up of a PGIS for the mapping of 'slums'. With this matrix, I will attempt to provide a sufficient overview of the realms of responsibility and action that all the involved actors have, the dependencies between actors, but also the potential responsibility gaps that lower the potential success of setting up a PGIS. The matrix will provide a way of answering the main research question of this thesis, namely: *what does responsible mapping of 'slums' look like?*

Chapter 1 - Sensing at a distance: How remote sensors see slums

In this chapter, I will present the issues involved in defining what a map is (and what a map does), how the term 'slum' is geographically and context dependent, the varying remote sensing techniques that are used, and the national and international agendas that prompt the mapping of slums. The focus of this chapter is to show that maps and map-making are not neutral or purely objective ways of dealing with the world. What will be revealed is that there are specific choices that go into how maps are constructed, reflecting more than just technical concerns but also social and political influences that shape how maps are made.

1.1. **What is a map? What is a slum?**

In this section I will aim to unpack what maps are, by looking at how they have been conceptualised. Maps presuppose a territory that is being mapped. The territory that I will be focusing on in this thesis, are areas in cities referred to as 'slums'. I have been using quotation marks around the term 'slum' because it is a contestable term, and also because it is not a universal category, despite being used as though it were. The term originates in 19th century Britain to describe areas that have high rates of poverty, overcrowding of residents, housing with poor sanitation, and deteriorating housing structures (Huchzermeyer, 2014: 86). The term thus became synonymous with areas of cities that have become overpopulated and run-down, without the necessary financial investment to maintain them. It has resurfaced as an important word in global discourse on city management and development as per the 'Cities Without Slums' initiative that came from the joint collaboration between World Bank, UN-Habitat and the United Nations Environmental Programme, which formed Cities Alliance at the beginning of the 21st century (Huchzermeyer, 93; Gilbert, 2007: 697). This initiative turned the areas referred to as 'slums' into becoming seen as negative imprints on cities, especially for cities that wished to compete to become more modern. As pointed out from observing the language of the UN-Habitat, their "high level messaging on the need to reduce 'slums', move people out of 'slums' or help people escape 'slums' [resonated with] approaches of slum demolition and relocation to segregated developments on the urban periphery" (Huchzermeyer, 94). The term 'slum' therefore does more than refer to a section of cities, it also has an effect on how the inhabitants are to be treated and governed. I shall return to this

problem in the second section of this chapter, where I take more space to look at what the rationale is behind the mapping of 'slums'. For now, I will aim to address what it means to map them.

A 'slum', much like a city, is a living environment (i.e. that is temporal and dynamic), and is captured in a computationally rendered map (that is interactive and accurate in relation to the software and hardware used to produce it). The way the map is constructed affects the living conditions of the 'slum', as will be pointed out throughout the thesis, by either helping to improve the infrastructure of the 'slum' or leading to the eviction of slum dwellers. This is because the map is responsible for what is made visible or invisible in the living environment, *and so the choices made by map-makers in what is represented on the map, speaks for the living environment*. Below are two maps (Fig. 1) of Kaylan (India) that displays an ordinary unmarked rendering of the city, and a rendering of the city where 'slums' can be identified.

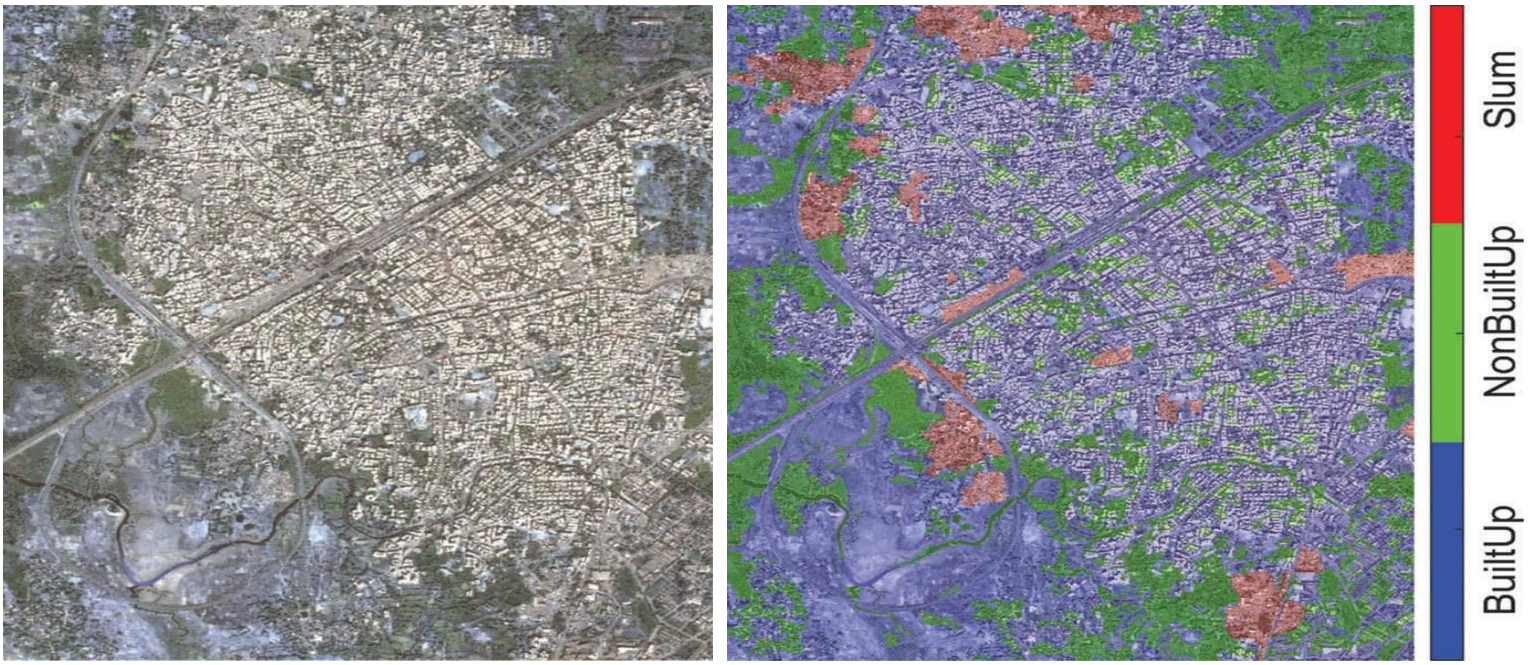


Fig 1: A map of Kaylan, India: on the left, image taken from Google Earth, on the right, image segmentation analysis shows areas identified (from expert interviews) as slums (red), built up areas (blue) and non-built up or vegetation areas (green). (Source: Ranguelova et al, 2018: 7)

But this supposition of a map as being only a means of representation to a territory, needs to be investigated. And such investigation is carried out in the discipline of critical geography, from which I shall begin this analysis of what maps are. The term 'critical' here refers to the growing concern presented in the work of geographers John Brian Harley, Denis Wood and Jeremy Crampton, who

brought to the forefront of the disciplines of cartography and geography the awareness that maps are not value-free objects. Maps may appear, at first glance, to be neutral representations, means of navigating and planning how to understand the territory that they represent. Looking at maps as means of representation necessitates assessing the activity of map-making, starting with the discipline of cartography. Harley (1989) defines cartography as "a body of theoretical and practical knowledge that map-makers employ to construct maps as a distinct mode of visual representation" (Harley, 1989: 3). In cartographic terms, maps are therefore tools of representing and communicating through visual means. Crampton (2001) points out that an early model and method of cartographic practice was the map communication model (MCM) which had the following schema:

Cartographer ---> Map ---> User[1]

Maps are seen and used, in the MCM, as tools of visual communication in a scientific manner, i.e. that need to be accurate, and their accuracy relies on the techniques used to design maps that are effective in their communicative ability. As Kitchin et al (2009) point out, cartographers focused on improving the design of maps by improving the capability of representing spatial variables (like location, direction and distance), selecting information and appropriate symbols for the data, and deciding what kind of maps are to be published (Kitchin et al, 2009: 5). The usefulness of a map in the MCM thus relies on how it is read, and by reading it users would be able to gain knowledge about the territory. But this also relies on the map user having sufficient knowledge of what spatial variables and symbols are rendered on the map, for the communication from map maker to map user to be successful. This interaction with the map and the MCM schema can be likened to another schema, namely Don Ihde's (1979) hermeneutic relations between humans, technology and the world. This type of relation is schematised as:

Human ------> (machine-world) (Ihde, 1979: 13)

And can be rewritten as:

Map user ------> (map-world)

The map is thus a tool designed to represent the world (depending on the scale this can indeed be the world or a specific territory) to the map user, as a result of what the map maker decides to have on the map. As Albert Borgmann (1999) states, maps are "instruments that render reality not just

[1] Kitchin et al, 2009: 6

perspicuous but surveyable from end to end" (Borgmann, 1999: 168). In the MCM, what the map maker decides to use and put on the surface of the map (e.g. grids, scales, colours and objects) will determine how the map user can not only understand the map but also how they will encounter and navigate the world through the map. This authority over the means of representation (i.e. the map and what is shown on it) reflects what Peter-Paul Verbeek refers to (in his reading of Ihde) as the amplification and reduction of aspects of reality, along with invitation and inhibition of behaviours and actions, that technologies can effect when in use (Verbeek, 2005: 171). Map makers can amplify certain aspects of the terrain being mapped (such as rivers or cultural sites) while reducing other aspects (such as areas that are not acknowledged by the state or not known about, and 'slums' fall into this domain). More so, given the way the map is treated in the MCM, it only invites those in the field of cartography to be able to make maps, and inhibits non-experts from being able to be involved in their production[2]. But this model of cartography and characterisation of maps as scientific communication tools, has been critiqued by critical geographers, as well as superseded by the ascent of the practice of geovisualization. This new model of what maps can be, has led to changes in the interaction between map makers and map users. The four principles of the MCM and how they are challenged by four corresponding principles of geovisualization can be illustrated as follows:

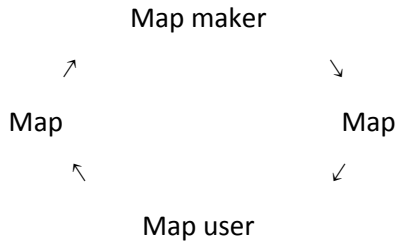
Table 1: How maps operate following two distinct models (Source: Crampton, 2001: 237-238)

Map Model	Model Characteristics/Principles
MCM	1. The map is an intermediary between cartographer and user (one-way communication) 2. There is a clear distinction between map-makers and map-users 3. The map is a communication tool between map-maker and map-user 4. The map-maker needs to know the map-user's ability to comprehend, learn and remember what is communicated
Geovisualization	1. Visualization environments provide multiple ways to present, animate and make data 2. There is a growing awareness that maps

[2] The notion that maps can invite and also inhibit the activities of certain actors, points towards an issue I will take up in the second and third chapter, namely whose voice or point of view is dictating how maps are produced.

	are situated in epistemic and power related discourses 3. Exploration of data is taking as more than just representation 4. The cartographer-user dichotomy is problematised by the fact that users can be their make their own maps

Geovisualization shifts the control and interpretability of maps from asymmetrically being in the hands of map makers to there being more symmetry between map makers and map users. In this way, the one directional arrow from map maker, to the map and the map user, instead becomes:



In the geovisualization model, the map becomes a site where map users can contest with map makers, as well as become map makers themselves with the right software tools. Thus there is a shift from reading the map as is presented to manipulating the map in digital visualization environments that allow for more alternative ways of representation. This results in the circular loop represented above, whereby map users can become map makers and the map is no longer something produced only from the perspective of an expert cartographer, allowing more perspectives to be invited to work on and produce maps. Along with this change in the way the map is treated, the work of critical geography also shows the importance of assessing the social and political relations maps and map makers are embedded in. As maps make aspects of the territory visible (or invisible) through their amplification and reduction of aspects of the territory (an issue I shall elaborate more on in the next section), their role goes beyond being merely tools of representation. Their construction and use, I will show, can affect the living conditions of those in the territory being mapped based on what they show or don't show. Harley (2009) points this out astutely, stating that:

"in the selectivity of their content and in their signs and styles of representation maps are a way of conceiving, articulating, and structuring the human world which is biased towards, promoted by, and exerts influence upon particular sets of social relations" (Harley, 2009: 129).

This reveals that maps not only point towards a territory, but they also point towards the choices made for technical (e.g. techniques for measuring and representing), underlying social (e.g. urban planning) and political (e.g. making areas and inhabitants visible/invisible) reasons. Maps, therefore, have a very active and creative capacity. This is captured by Corner (1999), who characterises map-making as having an operational structure consisting of three components: fields, extracts and plottings. Corner describes the field as "the continuous surface, the flat-bed, the paper or the table itself, schematically the analogical equivalent to the actual ground, albeit flat and scaled" (Corner, 1999: 229). This 'field' is what cartographers, urban planners, and government officials interact with, by deciding on how to measure, what to measure, and render from the territory onto the surface of the map. The creation of the field, for Corner, conditions what kinds of observations are made and presented. This conditioning is based on the layout of the map, as reducing the scale, enlarging the frame or how systems of representations are connected, "significantly affect what is seen and how these findings are organised" (230). Extracts are the things that are observed within the living environment and drawn onto the surface of the map. They are referred to as extracts as they are "always selected, isolated and pulled-out from their original seamlessness with other things; they are effectively 'de-territorialized'" (230). The term 'de-territorialized' here is taken from the work of Gilles Deleuze and Felix Guattari. The act of deterritorialization, summarily as I shall return to this notion in the last section of this chapter in more detail, is taking something out of its domain or area, in order to reterritorialize it in another area (Deleuze and Parnet, 1977: 18). This act, in the context of mapping 'slums', involves the use of techniques to actively render 'slums' from their living environment onto a graphical field that allows a better way to deal with, manage and draw information about the living environment. And the ability to have this selectivity and deterritorialization that allows capturing of extracts, presupposes an underlying understanding of how to capture objects in reality, i.e. an ontology of what is to be represented.

As geographic information scientists Kohli et al (2012) state, the ontology of a domain "consists of the domain vocabulary, all its essential concepts, their classification, taxonomy, relations and domain axioms" (Kohli et al, 2012: 155). The term 'ontology' here is distinct from how it is used and understood in philosophy, namely as the study of being. For geographic information scientists, ontologies are useful for "constructing useful representations - models - of a particular kind of real-world phenomena" (Couclelis, 2009: 13). In the context of the mapping of 'slums', a slum ontology is a useful guide in dealing with how to best render objects captured from the real world using specifically Earth Observation (EO) technologies for remote sensing applications (i.e. making maps from a literal top-down

view of the area). The ontology created by Kohli et al was initially conceived for operating with object-oriented image analysis (OOA) techniques, using very high resolution (VHR) aerial imagery to monitor and track the growth of 'slums' (Kohli et al, 156). This ontology therefore serves the technical demands of the geographic information scientist (i.e. map maker using EO), by providing a conceptual model of what information is to be read from the VHR images based on an understanding of 'slum' morphology. The slum ontology schematised by Kohli et al represents the diverse physical characteristics of 'slums' they assessed from expert interviews and literature reviews, at three spatial levels: object, settlement and environs. Each level has specific extracts as shown in the table below (Table 2).

Table 2: Generic Slum Ontology (Source: Kohli et al, 158-159)

Spatial levels	Extracts captured
Object	Building structures (e.g. type of roof material) and access networks (e.g. roads)
Settlement	The form, shape and density of the 'slum'
Environs	The surroundings of the 'slum' (e.g. whether it is next to hazards or railways) and socio-economic opportunities (e.g. if close to employment facilities)

The aim of this generic slum ontology (GSO) is to allow robust measurement and representation of 'slums', by helping geographic information scientists understand the relationship between the VHR images used and actual slum characteristics. Due to the diversity of 'slums', the GSO would still need to be adapted to each specific local context it is implemented in (Kuffer et al, 2016: 11). This can be done by having local experts help with image interpretation (as was done in Fig. 2 below), especially when certain features cannot be captured by remote sensing methods (Friesen et al, 2018: 83). Although this need for adapting to the local 'slum' context may challenge the very idea of the GSO since it means that there is hardly a one-size-fits-all ontology covering all 'slums'. Even with the GSO, the accuracy of the methods used depends on a number of factors. For instance, being able to extract roofs or roads from the VHR imagery "works well when objects have clearly visible spacing and contrast in the imagery" (Kuffer et al, 14). But one of the difficulties of using VHR images as representations of slums, is the difference in scale as well as correspondence between these images and the actual objects in the living environment being observed through remote sensing methods. Thus the challenge is "to extract out of

the satellite image the correct set of pixels to build up the corresponding image objects, houses, roads, or even slums" (Sliuzas et al, 2008: 7).

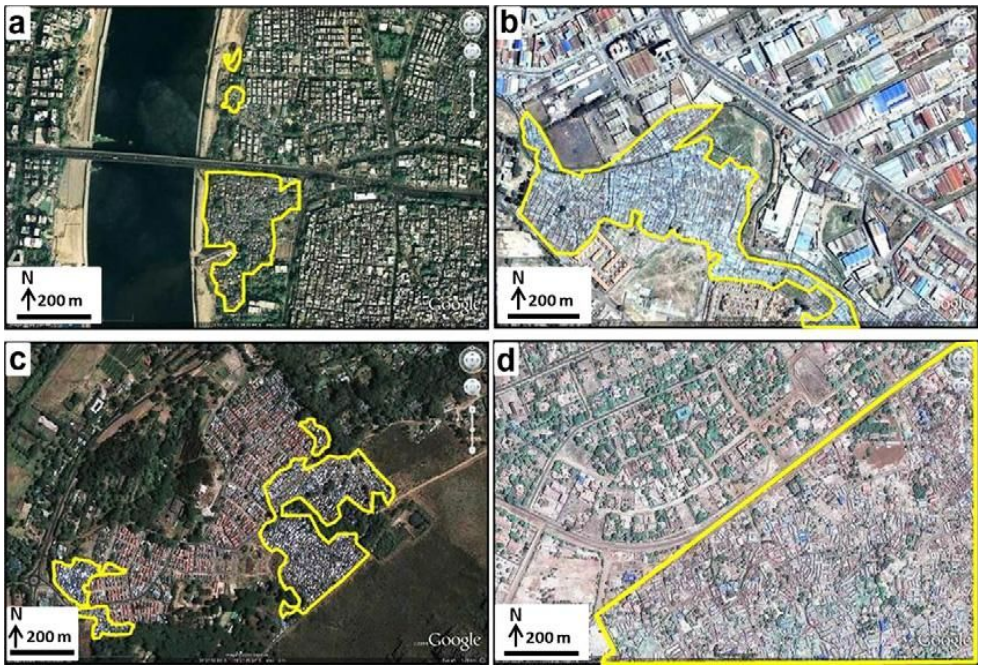


Fig. 2: Slum delineation in four different contexts by an Indian expert, using Google Earth images. Cities: a) Ahmedabad (India), b) Nairobi (Kenya), c) Cape Town (South Africa) and d) Kisumu (Kenya). (Source: Kohli et al, 2012: 157)

Such concerns over identification and classification can be better understood by considering the different levels of complexity of image interpretation elements (shown in Fig. 3 below). Pixels represent the most basic level of the image, while homogenous neighbouring pixels form segments, and homogeneous patches at higher resolutions can begin to have physical characteristics (such as street blocks) extracted using spatial characteristics such as density or texture (Kuffer et al, 2014: 141). Other issues include deciding what methods and indicators to decide upon, both of which affect the accuracy of the extraction of objects. The systematic review by Kuffer et al (2016) highlights these issues, for example, pointing out how mathematical morphology analysis has better performance than standard classification approaches, with machine learning along with texture and statistical-based approaches showing more promising results (Kuffer et al, 2016: 17). Whereas object-based image analysis (OBIA) showed more variance in effectiveness (variance being a result of diversity of slum morphology make it difficult for consistent object classification).

And concerning indicators of 'slum' growth, remote sensing map-makers can for instance look at entropy to monitor uncontrolled sprawl of roads and vegetation patch sizes. What Kuffer et al (2016) found is that while machine-learning methods "seem to be more successful when aiming at extracting slum areas at the city scale", OBIA works well in extraction of objects at the settlement level "when the urban morphology combined with a sufficient resolution image allowed their extraction" (Kuffer et al, 16). But no mapping techniques they reviewed had an accuracy of 100% with regards automatic identification and classification (16). These are some of the technical demands that need to be considered and struggled with in finding the right remote sensing mapping technologies and techniques.

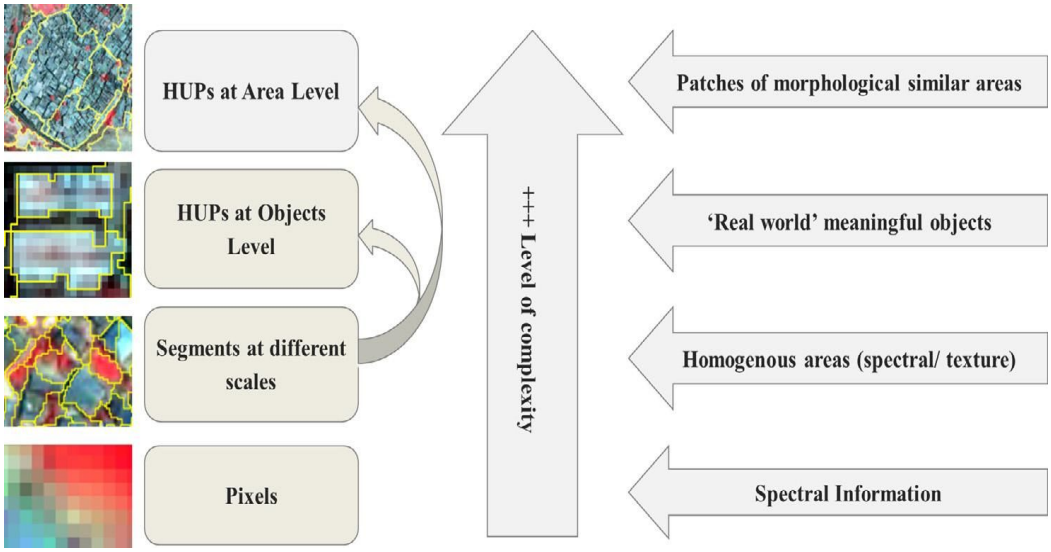


Fig. 3: Complexity of image interpretation elements (Source: Kuffer et al, 2014: 143)

Beyond technical demands, reaching the necessary accuracy when deciding upon which technology is most appropriate, is not just necessary for the remote sensing community but also for municipality and state agencies. As Kohli et al state, the knowledge base that would be generated from the implementation of the GSO will be "important for addressing problems related to monitoring slum growth but perhaps more importantly in supporting slum upgrading and improvement" (Kohli et al, 2012: 162). And it is in this implementation of the geoinformation scientist's ontology onto the living environment being mapped, that the third aspect of Corner's mapping schema comes out, namely the process of plotting. Plotting entails "the 'drawing out' of new and latent relationships that can be seen amongst the various extracts within the field" which "reveal, construct and engender latent sets of possibility" (Corner, 1999: 230). The tools used by map makers, especially with the interactivity of mapping software, means that insights and relationships drawn out from maps reflect what criteria

map-makers and map-users focus on. For instance Heesen et al.'s (2014) analysis of mapping resilience and vulnerability illustrates how professional and non-professionals perceive/experience vulnerability and from this map areas of vulnerability, showing congruence in some areas and incongruence in others as shown in Fig. 4 below.

And as also pointed out by Kuffer et al (2018), there is a tradeoff between the representational methods used and the level of accuracy reached. In the case study of mapping the 'deprived areas' (i.e. 'slums') in Mumbai, the use of standard machine learning algorithms (e.g. random forest) and a combination of spectral and image textures had an accuracy of 90% correspondence, while more complex algorithmic techniques could capture more of the diversity of slums, but at an accuracy of 75% correspondence. This lower accuracy was a result of inaccurate representation, e.g. "several mapped deprived areas [were not actually] deprived, while, in particular, very small deprived areas are omitted or the boundary" not properly extracted (Kuffer et al, 2018: 19). Thus if these maps are not treated carefully, they may be accepted as making claims about which are in fact false (e.g. identifying and classifying a part of a city as a 'slum' when it in fact isn't). Although in some cases, it may be that only large 'slums' are recognised while smaller 'slums' are not (due to not being easily identifiable). Criteria (e.g. selection of textures to identify), perspectives (along with subjective experience) and representational techniques each play a role in how accurately maps represent the area they are used to cover.

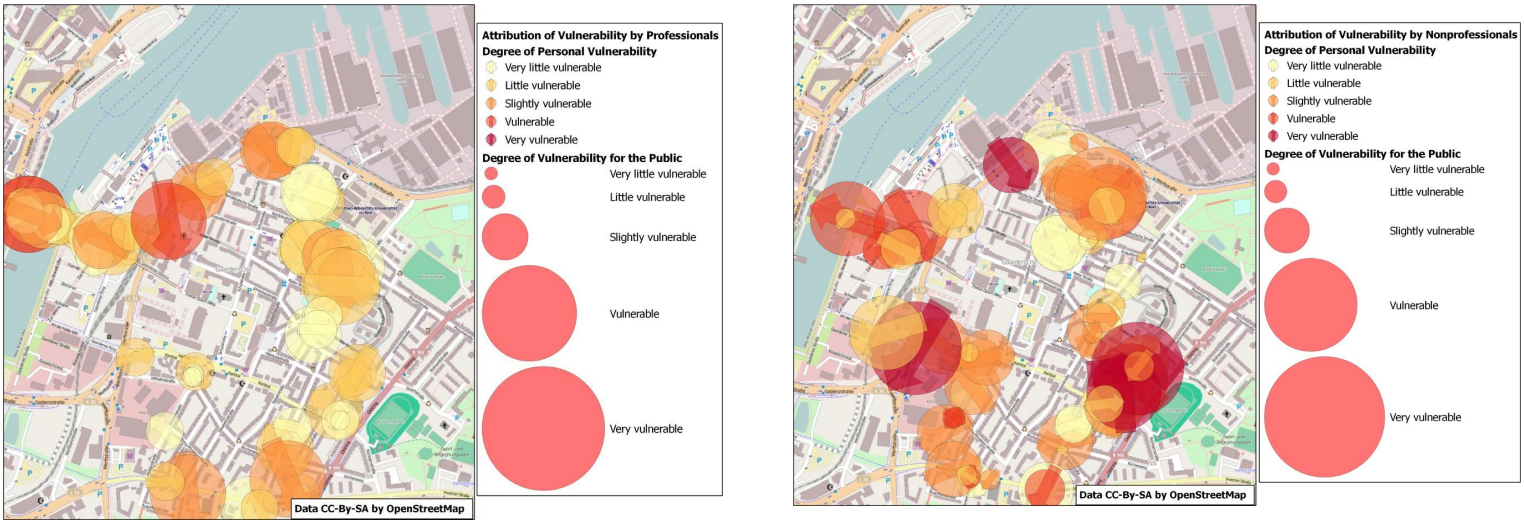


Fig 4. Map of Kiel, Germany: on the left, vulnerability as perceived by professionals and on the right, vulnerability as perceived by nonprofessionals. (Source: Heesen et al, 2014: 81-82).

Additionally, there is also the issue of how much detail the map, when represented as a final product, should have considering that individuals and groups become disclosed the more detailed the map is rendered. The features that are left open to map users by the techniques used by map makers such as using point locations to roughly show where slum areas are distributed (20), can help lower concerns of individual and group privacy and also security[3] (21). At the same time, if the mapping of 'slums' exclusively employs machine learning algorithms to capture specified and locational characteristics (e.g. by following the GSO) these algorithms can suffer from a path dependency that lowers their ability to capture areas of people living in areas that do not have these well defined characteristics (21). Maps therefore display extracts, and the techniques used to plot these extracts in a particular way (i.e. spatial level/type of detail). As Corner states, to "plot is to track, to trace, to set-in-relation, to find and to found" (Corner, 1999: 230). Map makers making maps of 'slums' therefore must be able to have a sufficient knowledge base of the 'slum' characteristics, through the development of a GSO that integrates local knowledge. To look at a remote sensing map of slums is to be pointed at a territory, *and the GIS practices that constructed that map, and the potential relationships to be found in the territory remote sensing mapping practices draw out*.

1.2. **Why make maps of slums?**

As map-making is an activity that entails making choices about what to display and what not to display (Hessen et al, 2014: 75), the immediate question then for the purposes of this thesis is *why is it necessary to make maps of slums*? The task of making maps of slums was initiated as part of the Millenium Development Goal (MDG) 7, target 11 which aims to improve the lives of millions of slum dwellers (Sliuzas et al., 2008: 1). As well as the UN's Sustainable Development Goal (SDG) 11 which aims at "inclusive, safe, resilient and sustainable cities and human settlements" (Kuffer et al, 2018: 1). The need to construct these maps as per the MDG and SDG stems from concerns with managing the development of cities, and specifically cities that have a growing number of 'slums' and slum dwellers. As Mahabir et al (2016) contend, the number of slum dwellers is estimated to increase to 2 billion by 2030 (in predominantly developing countries). And the growing prevalence of 'slums' has "regional and global implications, impacting areas such as education, health and child mortality, and political and social exclusion" (Mahabir et al, 2016: 400). There are thus societal, political and economic issues that

[3] I will go into further detail about the impact that mapping methods have on slum dwellers in the second and third chapter.

prompt international attention regarding the growth of 'slums', and the need for seeking means of dealing with their growth.

Mahabir et al list four factors that contribute to the persistent growth of 'slums': locational choice factors, rural-to-urban migration, poor urban governance, and ill-designed policies. Locational choice factors include access to local public goods, preferences for the composition of a community, and social ties such as sharing a common culture, language and similar income-generating activities (403). And while rural-to-urban migration may typically be considered a leading cause for the growth of cities in developing countries, this is also a cause for the growth of 'slums'. This happens in situations where the net migration from rural areas to urban areas is met by a lack of economic growth and sustainability (the perception of which drives the migration), which leads to large numbers of people not having their basic needs supported (404). More so, the lack of basic facilities may also be a product of insufficient urban governance policies and resource management. As Mahabir et al point out, governments in developing countries may fail to incorporate slum dwellers in planning schemes, or "refuse to provide urban services to slum dwellers in fear that this will only escalate the issue of slums" (404).

The fact that slums appear (in a literal sense) as an issue for governments with regards how cities are composed and urbanisation strategies developed, requires returning to another point of concern, namely how 'slums' get defined. According to UN-Habitat's (2018) definition, there are five indicators at the household level which distinguish an area to be considered as a 'slum'. These indicators are: security of tenure, adequate water, access to sanitation, structural quality of housing and location and overcrowding (UN-Habitat, 2018: 3) and the measurements used are illustrated in the table below (Table 3). Whereas what are referred to as 'informal settlements' are defined by three criteria: inhabitants having no security of tenure (in housing conditions ranging from squatting to informal rental housing), neighbourhoods are cut off from formal basic services and city infrastructure, and housing does not comply with city planning and building regulations (as well as being built nearby environmental hazards) (5).

Table 3: Indicators used by UN-Habitat in categorising 'slums' (Source: UN-Habitat, 2018: 8)

Indicator	Measurement
Security of tenure	● Proportion of households with formal title deeds or tenure arrangement to either land and/or residence.

Adequate water	● Settlements are considered to have an inadequate water supply if less than 50% of households have a household connection, public stand pipe or less than 20 litres/person/day available.
Access to sanitation	● Settlements are considered to have inadequate sanitation if less than 50% of households have public sewers, septic tanks, pour-flush latrine or ventilated improved pit latrines.
Structural quality of housing and location	● Settlements are considered lacking adequate location if they are located next to geological hazardous zones, around high-industrial pollution areas, or other unprotected high-risk zones (e.g. railroads and energy transmission lines). ● Settlements are considered lacking in structural quality of housing based on the quality of construction materials and compliance with local building codes, standards and bylaws.
Overcrowding	● Settlements are considered overcrowded if households have more than two persons allocated in a room.

Defining what 'slums' are is therefore tied to monitoring and measuring the quality of life for the households in specific areas of cities, by measuring the state of the five aforementioned indicators. But there are problems with these indicators, as for instance there are many cities in the West with housing complexes and suburbs near railroad crossings (these areas not being considered 'slums'), as well as the notion of overcrowding being based on more than two persons sharing a room might be problematic for smaller households but not an issue for larger households. Further, what is taken as 'overcrowding' as a measure of deprivation may not take into consideration specific cultural differences where certain households may have many people sharing a room as a reflection of their custom not as a sign of impoverishment. This is also the case with the additional indicator affordability as a measure of informal housing, which measures inadequate affordability if the net monthly expenditure exceeds 30% of the total income of the household which does not necessarily reflect on the other five indicators (8). But where does the data for measuring these indicators come from? The data is collected and computed from censuses and national household surveys, but also from collaborations such as WHO/UNICEF Joint

Monitoring Programme on Water Supply and Sanitation (JMP), demographic health surveys (DHS), and Multiple Indicator Cluster Survey (MICS) (Sliuzas et al, 2). Additional institutions providing the data include UN-Habitat, UNEP, Cities Alliance, Slum Dwellers International and the World Bank (UN-Habitat, 10). There are therefore international humanitarian bodies as well as governmental bodies that rely on gathering accurate data, in order to make maps that can capture and represent 'slums'. And this gathering process begins with defining what 'slums' are. The act of defining what is and isn't a 'slum' using the five mentioned indicators makes it appear as though there is a clear cut binary separation. Yet reliance on the five indicators to speak for what is going on in the living environment, leads to the need to assess the accuracy of representation, specifically how the data gathered may or may not match up to what is happening in the living environment the 'slums' are classified in.

The relationship between what data gathering processes say about the 'slum', and what is happening within the 'slum', has a range of problems for the mapping of slums. Firstly, census data may not match up with the actual number of 'slums' in a city. This is highlighted by Kuffer et al (2018) who point out that there may be inconsistencies in the data collected, because "data on locations and growth dynamics of deprived areas [of cities] are commonly unavailable, outdated, inconsistent, or exclude specific areas" (Kuffer et al, 2018: 2). For instance in Bangalore (India), Kuffer et al state that while the Karnataka Slum Development Board officially recognised 597 slums, a local survey by the Association for Promoting Social Action made a map that surveyed over 1,500 slums (2). Such a disparity reveals that while the availability and accuracy of data is a pivotal technical concern, an additional concern is whether or not specific government administrative bodies are willing to acknowledge the presence of 'slums' within a city (and therefore include them in official statistical data). For instance, again in India, "official slum maps covering notified and recognized slums commonly exclude a large number of slums, e.g. areas below a minimum size" and some cities "have stopped notifications because they do not have the resources for upgrading (notified slums are entitled to basic upgrading)" (2). This further problematizes efforts to map slums because: a) slums that are purposefully ignored will not show up via census data, and b) the actual growth rate of slums are not accurately measured and therefore managing their growth in cities cannot be done properly. This first point, on the purposeful ignoring of those living in slums, is taken up by Annie Beukes (2016). Beukes highlights how despite the fact that the conditions of poverty in underdeveloped areas of Nairobi (Kenya) were in plain sight in the 1970s to 1990s, the increasing numbers of people living in these conditions "remained unrecognised and unacknowledged by [the] government on the maps of the city and planning policies" (Beukes, 2016: 9). There is therefore an important relationship (to be explored in the next section) between what a map

makes visible, and what is left off a map and may appear to not be in the territory. *Thus maps are able to make claims over the territory they survey*, and an important concern in the next chapter will be to bring to light how these claims gain their weight.

A second challenge in the mapping of 'slums' is that they appear in varying morphological compositions. As Kuffer et al (2016) point out, physical characteristics of slums "are often an expression of the slum-development processes; i.e., from low-density at their infancy stage to high-density mature slums, sometimes also including increasing building size and height" (Kuffer et al, 2016: 5). Such dynamic and temporal aspects of slum development is why I refer to them as living environments, since they are not static entities, and instead exhibit changes based not only on who lives in them but also where they are. Taubenbock and Kraff (2014) point out that 'slums' appear with different names depending on where they are found. For instance, there are "favelas" in Brazil, "bidonvilles" in francophone countries, "townships" in South Africa, as well as "zodpatpatties", and "patra chawls" in Mumbai and Ahmedabad (Taubenbock and Kraff, 2014: 17). 'Slum' is therefore not a universal category, and they not only differ in where they are found and what name they have, but also the history and culture within a given 'slum' differs from another, as well as economic capacity, social mobilization and public perception (18). These morphological and contextual factors mean that 'slum' is a category that should be treated and conceptualized only in relative terms. But does this then suggest that the term 'slum' should no longer be used? The fact that the UN uses the term 'slum' and the five indicators mentioned as the operational definition in dealing with managing cities in its official documentation, and that it is also used in remote sensing literature as well as SDI literature, means that the term is somewhat fixed in the discourse of city management and development discourse.

And a third issue that follows from issues of data gathering and differing morphological and contextual composition of 'slums', is deciding on what methods and techniques to use for mapping them. The method chosen means accepting certain advantages and disadvantages in the effectiveness and completeness of the maps to be constructed. An expert meeting on slum mapping and identification was held in 2008 in the Netherlands (Sliuzas et al, 2008), and from this meeting (following discussions of the difficulties of identifying slums mentioned above) three mapping strategies were highlighted: object oriented approaches to image analysis, lacunarity and field data collection coupled with community based approaches (Sliuzas et al, 7-10) which use remote sensing technologies for the mapping of slums. Lacunarity and OOA are now very dated approaches, and as mentioned in the first section, machine learning based methods along with field data and community based collection are the more current

mapping approaches. Community based approaches entail the leveraging of VHR images by organisations and NGOs to be used as tools for programs such as poverty mapping at the city level which can be used for city planning. Such mapping approaches can be used to 're-assess migration trends into cities' to compel governments to acknowledge the status of migrants as well as to 'start city planning, where road widening, flood protection, development of new infrastructure would affect slum settlements' (9). And it is with this socially oriented role in mind, that in the second chapter I shall focus on the work of Slum Dwellers International (SDI). SDI is an organisation that works to ensure that the global network of slum dwellers they represent are not only made visible on maps, but that they are made part of the process of mapping, along with collaborating with governing authorities in improving resource management and distribution. The work of organisations such as SDI along with the shift from the MCM model to the geovisualization model of map making, point towards the need to address the asymmetry that exists between map makers and map users (Kuffer et al, 2018: 22). How the data is gathered, what tools and techniques are used for displaying information, and accessibility for those 'on the ground', are concerns that I will take up in the second and third chapter of this thesis.

The role of maps as a means used for surveying, documenting, planning and collaboration, reveals that maps display the strategies as well as choices made by those who use and construct them with regards: what is being mapped, what can be represented and what cannot be represented (or should not be represented). This last point is astutely observed by Kuffer et al, who state that "consistency problems [of data collection in slums] arise from variations with data collection methods, as well as political and operational decisions of including deprived areas into these official statistics" (Kuffer et al, 2018: 4). This reveals that the *agendas behind mapmaking projects* are as important as the technological and social concerns that prompt the mapping of 'slums'. But regarding further technical concerns, the 2008 meeting also described indicators that would need to be met by whatever strategy was chosen. Qualitative indicators of 'slums' included the following: "Haphazard, high density building pattern; durability of housing/material for roofing (corrugated tin, plastic sheeting/tarps, cloth/grass); proximity to natural and technological hazards" (Sliuzas et al, 6) along with the composition of road networks and access to basic public services. And for automated approaches, indicators included: "Proportions of land cover (% area covered by structures, % area of open spaces, % of vegetation); Spatial metrics (lacunarity, textural contrast, variability of building size & orientation); morphology of building heights (derived from shadows or lidar); characteristic scale (relative size of housing units, relative size of road networks, Plot Ratio, Floor Area Ratio)" (6-7). These indicators are meant to allow for accurate mapping of slums, although the more sophisticated mapping techniques are also the most costly on one hand, and it also

matters what scale is used. For instance, the use of Unmanned Aerial Vehicles (UAVs) with a spatial resolution of 3-5 cm can help map makers delineate building outlines and building counts with highly accurate roof area estimation, as well as if a drainage is covered by waste (though these images are difficult to acquire for larger cities)(Kuffer et al, 2018: 6-7). Whereas VHR images with a resolution of up to 30 cm can allow for details on urban area morphology as well as building outlines (6). *But the greater the level of detail captured, the more likely that the privacy as well as security of slum dwellers may become infringed*, meaning there is a trade off between the level of accuracy and ethical concerns (to be explored in greater detail in the third chapter). The consideration of these indicators and attention to the specific technological devices used in remote sensing approaches to mapping slums, shows the many technical demands that must be met in deciding which approach to use. The effectiveness of the maps produced, therefore relies on how well these approaches can be used to deliver accurate maps of slums given the location, context, textures, morphology and objects that can be measured, computed and displayed.

But beyond such technical demands, there are also social and political issues when mapping strategies are used to spearhead not only what is to be said about a slum, but what is to be done about a slum. As Kuffer et al point out, "the person producing the final mapping product *has the power to decide what gets recorded on the map without consulting the mapped communities*" because it appears as though "there is no strict technical need to involve the inhabitants of the researched areas in the acquisition, analysis, and visualization of the data" (17, italics added). This implies that an issue with remote sensing approaches is that those on the 'ground' may not be consulted at all in the process and final out of the mapping, excluding them from having any influence on what the map shows. Such maps therefore effectively silence those being mapped. And the choice of what techniques but also how to gather the data, shows that geoinformation scientists are responsible for whether or not they exclude slum dwellers and silence them, or invite their perspective.

1.3. What maps do

Maps that are constructed with EO technologies and modern map-making software are neither just tools of measurement, or intermediaries that communicate what the cartographer dictates or inscribes onto the map for the user to follow. What is revealed from the analysis of critical geography is that maps point towards the practices used in their construction, and the social and political relations that dictate the choices made for what to represent on the map, to speak for the territory being mapped. Maps are

constructed to make claims about the territory and individuals and groups found therein (e.g. by making them visible/invisible). But these claims can be rejected or contested by both map makers and map users depending on the representational power of these maps (e.g. a map's authority should be questioned if it represents an area as a 'slum' when it isn't actually a 'slum'). For these reasons, maps need to be considered as more than just mere objects. Tim Ingold (2010) makes a distinction between objects and things, that bears importance in conceptualising what maps of 'slums' do. As he states, while the object is closed off, 'presenting its congealed, outer surfaces to our inspection', the thing is 'a place where several goings on become entwined' (Ingold, 2010: 4). These 'goings on' are the affairs of individuals and groups, interacting with each other. With each individual having their own way of life, and way of 'threading a line through the world', Ingold describes the thing as "a 'parliament of lines'" (4).

A thing is not a black box that resists interpretation, and neither are the remote sensing maps constructed to map 'slums'. These maps are a gathering of interactions (technical, social and political), a 'parliament of lines' which when investigated, reveals the traces of choices made by geoinformation scientists and map users. For instance, the expert meeting discussed in Sliuzas (2008) and review of remote sensing literature by Kuffer et al (2016), shows such a tracing of the decisions that are made by map makers regarding the technical, social and institutional demands for the project of slum mapping. And the aspect of a 'gathering' of interacting individuals and groups is mentioned, whereby a 'major priority is to get slum mapping on the agenda of various key events, bodies, organizations, e.g. international research networks' (Sliuzas, 2008: 11). The map as an object assumes an absoluteness, while the map as a thing reveals that it is a gathering in the sense spoken of by Ingold. As a gathering, the map then is a site where affairs are determined and contested. They are determined in the sense that decisions are made about what to use to make the map as well as what the map makes visible (given what it can and cannot measure/show), and it can be used to allow for planning about what to do with the living environment that is mapped. And the map can be contested when it is either used or constructed in a manner that underrepresents those within the living environment, is too costly for the actors who need to make use of it, or infringes on the privacy and security of slum dwellers. This dynamic way of conceiving of map making as a parliament of lines is pointed out in the following way:

> 'Spatial data are surveyed, processed and cleaned; geometric shapes are drafted, revised, updated, copied, digitized and scanned; information is selected for inclusion, generalized and symbolized. A map is then worked upon by the world and does work in the world.' (Kitchin et al, 2009: 16).

Maps and map-making are therefore caught up in a 'parliament of lines' which orients how decisions are made concerning the construction and uses that maps engender. As such, *thinking of maps and map-making involves thinking about engagement*, and what maps do. In order to better elaborate this, I shall refer to maps and mapmaking as aspects of what Deleuze and Guattari (1987) refer to as assemblages. Deleuze and Guattari define assemblages as comprising of two segments, one of content and the other of expression. They state that on the one hand an assemblage is "a *machinic assemblage* of bodies, of actions and passions, an intermingling of bodies reacting to one another" which is its form of content, while on the other side it has "a *collective assemblage* of enunciation, of acts and statements, of incorporeal transformations attributed to bodies", its form of expression (Deleuze & Guattari, 1987: 88). The 'incorporeal transformations' that expressions can have over bodies include speech acts (e.g. 'I now pronounce you husband and wife' that gives a couple the status of married) or judicial statements such as when someone goes from being free to being imprisoned, changing what status and relations with other bodies the person has (Patton, 2010: 13). In the context of making maps of 'slums', such 'incorporeal transformations' include classifying living environments as slums (affecting how the area is viewed and treated) as well as the act of deterritorialization that captures slums and reterritorializes[4] them on a graphic field where relationships not visible become made visible.

This visibility can then lead to new initiatives (e.g. for slum dwellers to fight against unlawful evictions or contrarily the visibility leading to evictions and land privatisation). In this way, maps "cease to be understood primarily as inert records of morphological landscapes or passive reflections of the world of objects, but are regarded as refracted images contributing to dialogue in a socially constructed world" (Harley, 2009: 129). By refracting rather than being clear windows giving access to the territory, the active capacity of maps becomes revealed and in the actions they make possible, varying forms of content and forms of expression become realised. Geographic information scientists, slum dwellers, government officials, governmental and institutional bodies along with technological devices and infrastructure, comprise the form of content; while specific acts, policies, laws, agreements and agendas comprise the form of expression, of what I shall call the geo-policy assemblage. This assemblage orients what techniques are used, what indicators are employed, what ontology to implement, as well as what kind of maps to construct and how to package them.

[4] Corner also refers to plotting as reterritorialization (Corner, 1999: 230).

I refer to this assemblage as a geo-policy assemblage because it is concerned with how to make claims over territories that entail actions over those territories, as well as further investigation into more effective actions through geovisualization techniques and humanitarian agendas. The concept of assemblage is useful as it allows thinking of maps and map making practices in an active sense, as acting on bodies and territories through specific forms of content and forms of expression. Maps and mapmaking can have real effects on those that they map, and for those making use of these maps, because they are tied to a geo-policy assemblage that can legitimise their representational power over a territory. The notion of legitimising is especially important in situations where different bodies may reject or find issues with the construction of a map and the actions it engenders, as a result of disagreeing on indicators of slum morphology. For instance, Leonita et al (2018) highlight how Ministry staff, municipal staff and academics criticised the indicators used for survey based slum mapping (SBSM) in a case study in Indonesia as being an ineffective way to properly document and map 'slums' in the city (Leonita et al, 2018: 20). But "as the SBSM data is complete, the government is currently not considering alternative approaches such as MLBSM" perhaps because "the Ministry is not certain about the long-term utilization and capacity of [MLBSM], being unfamiliar with machine learning and remote sensing" (21). Thus whether or not a map is accurate, complete or final, depends largely on the forms of expression (that sanction and define what levels of accuracy and indicators to look for in the final mapping product) and forms of content (i.e. what institutions, departments and stakeholders are involved) of the geo-policy assemblage[5].

So far, I have only discussed the agendas, techniques and decisions made from the side of remote sensing approaches and geoinformation scientists studying these approaches. The discussion up to this point reveals that map makers have the responsibility of ensuring the selection of tools and techniques that can render the territory being mapped accurately, though accuracy is a variable that depends on what mapping methods are used. But it is also clear that the choice of tools and techniques can have the effect of either inviting map users (in this case, governance bodies, NGOs, and even slum dwellers) to become part of the map production or inhibits their involvement. There is thus an ethical aspect (to be delved into in more detail in the third chapter) to the project of mapping slums using remote sensing approaches. This ethical aspect concerns to what extent geoinformation scientists can balance the technical demands of mapping slums with the socio-political demands of promoting the welfare of slum

[5] Throughout their text *A Thousand Plateaus*, the term assemblage is referred to in multiple ways, depending on the specific domain/plateau that the authors are discussing.

dwellers (e.g. as a means for empowerment, not infringing on their privacy, not becoming a security risk).

Chapter 2 - Managing slums from the ground: community based approaches to slum mapping

In this second chapter, I will look at the process of map making from the side of those on the ground being mapped. I shall refer to the work of Slum Dwellers International (SDI) in order to ask: while the technological demands of making maps of 'slums' may be the focus of remote sensing strategies outlined in chapter 1, what about the social demands of those being mapped? To answer this, I will analyse SDI's framework for gathering and making available information of 'slums' through the data collection, representation and sharing methods used by slum dwellers themselves (Beukes, 2015). More so, it will also become clear to what extent government authorities are responsible for the state of 'slums', and how slum dwellers can take up responsibility for their slums by utilising community based mapping as a form of advocacy for their rights. I will begin this chapter by looking at how indicators that determine what is or isn't a 'slum', frame how these territories are governed. In this way, I will be assessing how the activities brought about by the work of SDI and communities of slum dwellers, aim to challenge traditional top-down forms of governance, through processes of bottom-up community-based participation in how 'slums' can be governed.

2.1. **The role of indicators as legitimising signs**

In the last section of the preceding chapter, I drew attention to the point that maps are sites of gatherings. They reflect the form of content (i.e. various actors, institutions and technologies) and form of expression (i.e. specific acts, policies, indicators and agendas) of the geo-policy assemblage that orient what techniques are used in selecting and packaging maps and how slums are managed and treated. In this section I will elaborate on how the form of expression of the geo-policy assemblage is used to determine what can be done in the governing of slums. At the international level, indicators such as the five measurements used by UN-Habitat in defining what 'slums' are at the household level (i.e. security of tenure, adequate water, access to sanitation, structural quality of housing location and structure, and overcrowding) can be looked at as tools of incorporeal transformation (Deleuze & Guattari, 80). They can be looked at as tools of incorporeal transformation because these indicators change how the living environment and its inhabitants are classified and acted on once it becomes designated as a 'slum'. These five indicators are used in the reporting and tracking of the SDGs and

correspond to a specific understanding of what a 'slum' is. The rationale behind the use of these indicators, I will aim to show, is to enact methods of governing from a distance. As Miller and Rose (1990) point out, to 'know' an object in a way that allows governing it "requires the invention of procedures of notation, ways of collecting and presenting statistics, the transportation of these to centres where calculations and judgements can be made" (Miller and Rose, 1990: 5). This is not to say this need and use for procedures of notation is only found in the governing of 'slums'. But it is to stress that the territory and category 'slum' becomes an object that can be governed once it has been quantified. Indicators therefore serve an active role because they affect the determination of what is and isn't a slum, and what is or isn't within the domain of governance. A concern that I will turn to in the second section of this chapter, is whether the means used to document and represent what is going on in the living environment represents the interests of those living in these environments, or instead makes no consultation with them and simply speaks over them. But how do these indicators gain their legitimacy?

In order to draw out the role of indicators and their determining power in the mapping of 'slums', I will turn briefly to the role and act of governance. Foucault (1991) offers an insightful way of thinking of governance[6] by framing its operation in terms of the rationality of governance, or what he terms governmentality. For Foucault the act of governmentality entails looking at the relations that people and things have within a given territory. He states that the focus for governments is:

> "[people] in their relations, their links, their imbrications with those other things which are wealth, resources, means of subsistence, the territory with its specific qualities, climate, irrigation, fertility' as well as 'customs, habits, [and] ways of acting and thinking" (Foucault, 1991: 93).

Governmentality is therefore about how individuals in a populace and the relations they have to each other (psychologically, economically, culturally and environmentally) are intervened upon by the policies and laws that governments draw up and make use of. And an important point that Foucault states is that the focus for the government is not just the exercising of laws but the welfare of the

[6] Foucault's analysis traces the shifting role of governance from the Middle Ages, but the notion of governmentality emerges from 18th century writings that are concerned with how the state governs populations, by tracking "the correct manner of managing individuals....[and] how to introduce this meticulous attention of the father towards his family into the management of the state" (Foucault, 92). Governmentality therefore expresses itself in a paternalistic manner, a paternalism that focuses on how to deal with the interests and activities of populations.

population. As the government either acts directly on the population through large-scale campaigns, "or indirectly through techniques that will make possible, [with or] without the full awareness of the people, the stimulation of birth rates, the directing of the flow of population into certain regions or activities" (100). And a similar framing of the role and act of governance by Marlor (2010) is that two important principles of modern democracy are: "the state represents the needs and interests of its citizenry" and "state officials are accountable to citizens for their actions" (Marlor, 2010: 513).

But in the context of mapping 'slums', *to what extent are the interests of slum dwellers taken into consideration in the choice of mapping tools and policies or schemes devised in the governing of 'slums'*? This question is of particular relevance for two reasons. Firstly, as mentioned in the first chapter, making maps of 'slums' is part of the wider goal of achieving SDG 11 to improve the lives of slum dwellers (Kuffer et al, 2018: 1) through provision of sustainable housing. More so, 'slums' represent a failure of governance and a problem for the management of cities, as they impact areas such as education, health and child mortality, and social and political exclusion (Mahabir et al, 2016: 400). Slums therefore present a challenge for map making (as discussed in the first chapter) and governance, as the kinds of policies and schemes implemented as well as mapping technologies and methods used, I shall show, affects the welfare of slum dwellers and their communities.

And secondly, it also matters whether or not slum dwellers are made part of the process of governing what is done to the areas they reside in, and their level of comprehension of the mapping tools used by those far away from them. An important question is whether remote sensing methods that are responsible for making 'slums' and informal settlements visible and thereby objects that can governed from a distance, work in the interest of slum dwellers or for governments. If these methods are based on indicators derived from international bodies that determine what is or isn't a slum, then they operate without consulting with those they are mapping. They may therefore further top-down structures of governance that leave out the very people this governance is meant to be concerned with. To think about the use of indicators, SDGs, the project and purpose of mapping of slums, the tools and techniques used for mapping, the actors and institutions involved - in short, this geo-policy assemblage - *means to think about the effectiveness or weakness of governmentality specifically in terms of how marginalized groups are or are not represented*. As Foucault states, "the population is the subject of needs, of aspirations, but it is also the object in the hands of the government, aware, *vis-a-vis* the government, of what it wants, but ignorant of what is being done to it" (100). Thinking in terms of 'population' points back to the issue of visibility and invisibility on maps and census data, especially

when it is brought to mind that if slum dwellers and 'slums' are not visible, not counted, not recognised - they essentially do not exist as part of the population or city. If 'slums' and slum dwellers are to be objects of governance, the tools used to make them known and governed are as important as the policies that either respect or diminish the aspirations of slum dwellers and 'slums' as subjects (i.e. as part of the population), by including or excluding them from the act of governance.

The act of governance over a territory can thus be considered as having two dimensions, social and spatial (Alemie et al, 2015). The social dimension refers to how bodies interact with the territory they are in, this interacting occurring through the creation and implementation "of formal land policies, laws and administrative systems regarding land tenure, land use, land value and land development" (Alemie et al, 2015: 289). And the spatial dimension refers to the space where these social processes are enacted, and the relationship between the spatial and social dimensions are key drivers in developing economic, cultural and environmental conditions in the territory where governance is enacted (289-90). While the SDGs are stipulated at the 'top' by the UN, it is the responsibility of states and municipalities to implement the necessary forms of governance that can deal with the social and spatial dimensions of 'slums' and informal settlements, for each respective state and municipality. The governance of 'slums' informal settlements is made possible through this interaction, in terms of the form of content and form and expression of the geo-policy assemblage, which orient the kinds of policies that are drawn up, what bodies are part of devising and deciding how best these policies are to be implemented, and the effects of these policies. But to properly assess the act of governance requires measuring its effectiveness, by looking at the inputs, processes and outputs which indicate how governance performs. Inputs are the policies, laws and regulations used by government, while processes refer to the range of tasks and activities that diverse actors engage in the formulation and implementation of policies and laws, and outputs are the manifestation in the spatial dimension of the inputs and processes of governance (290).

'Slums' can be considered as outputs of ineffective and inadequate governances, as some of the causes of their growth include: exclusion of minority and low-income people from accessing urban lands, lack of pro-poor housing policies, poor urban planning and land management practice, political uncertainties and transitions, and inappropriate tenure systems (293). Their growth persists despite the promises made in clauses 27, 77, 97, 107, 109 and 110 of the UN's New Urban Agenda (UN, 2017) all of which aim at deploying support to slum dwellers through development of policies, tools and mechanisms to ensure that sustainable housing options are made available. These efforts and clauses of the New Urban Agenda can be considered as expansions, especially when deployed in African societies,

of the Governance Agenda of the 1980s, which aim at "strengthening public sector management, promoting rules and institutions to provide predictable and transparent framework for public and private business, and promoting accountability for economic and financial performance" (Kelsall, 2008: 627). The New Urban Agenda and its predecessor the Governance Agenda each rely on giving stipulations, but it is not clear whether or not municipalities must follow these stipulations or if municipalities that do not follow them will face any kind of reprimanding. Even though if these municipalities do not recognise slum dwellers and their communities, the growth of 'slums' points back to the inadequacy of these municipalities. I shall return to describing this chain of responsibility, and the gaps therein, in more detail in the third chapter.

The weaknesses in the inputs and processes of governance may, therefore, be characteristic of not just inadequate policies, but also inadequate means of representing 'slums' and their inhabitants. Miller and Rose contend that a prerequisite of governance is to make the object to be governed intelligible, which entails considering the kinds of tools, methods and acts used for the representation of what is to be governed. As such, the use of written reports, charts, statistics and importantly maps, are means of enabling 'pertinent features of [social processes] - types of goods, investments, ages of persons, health, criminality, etc. - to be literally re-represented in the place where decisions are to be made about them' (Miller and Rose, 7). But these are processes that may not be shown in a state sanctioned census (especially if the censuses are inaccurate or leave out slum dwellers purposefully), and especially are not features that may be displayed in remote sensing based maps. This lack of proper representation is, therefore, a reflection of the choice of mapping strategy. As pointed out by Hessen et al (2014), social phenomena cannot be mapped in the same manner as physical objects, because social phenomena "belong to a distinct ontology, and they evade geographical fixation as they are not tied to objective representation" (Hessen et al, 2014: 77).

The importance of what mapping techniques are used, and their effects on either taking account or being unable to take account of social phenomena accurately, can be better shown by looking on the one hand at what is lacking in remote sensing technologies. Kuffer et al. (2018) list the following necessities in their review of remote sensing technologies: i) there is a need for clear conceptualisation of informal settlements[7] and indicators used to determine their delineation; ii) a need to improve the

[7] The terms 'informal settlement', 'deprived areas' and 'slum' are treated interchangeably in the remote sensing literature, and is why I have been referring to them together so far in this chapter. For this reason, along with SDI also using the terms informal settlement and slum interchangeably, I shall refer to them without quotation marks from hereon.

training data and algorithms used; iii) a need for re-conceptualisation of how to think of spatial growth from formal to informal settlement areas; iv) algorithms need to be able to capture the temporal dynamics of deprivation in informal settlements; v) identifying suitable image data in terms of accuracy and costs; vi) evaluation of results needs a holistic understanding of uncertainties of using remote sensing techniques; vii) better modelling techniques need to be developed for extracting robust population estimates; viii) ownership of the data that is collected and used should be in the hands of the communities being mapped, as well as a need for ethical standards on how data collected is to be made publicly available (Kuffer et al, 2018: 23-24). The first seven of these concerns each focus on the technical demands of remote sensing mapping in terms of accurately representing informal settlements spatially, and only the eighth concern refers involving slum dwellers (i.e. by owning the information about their settlements) in the mapping project. As such, to better know what life is like in informal settlements and slums, alternative strategies may be required in order to ensure that better representation is made not just of spatial characteristics of slums but also the social processes within them. And such an alternative approach is taken up by those engaged by Slum Dwellers International (SDI).

2.2. **SDI, taking community involvement as priority in governing slum redevelopment**

SDI is an NGO which aims to ensure that the mapping of slums is an activity that is informed by involvement with the communities that live in them. SDI was officially launched in 1996 as a transnational social movement of the urban poor after exchanges between Indian and South African slum dweller movements, led to similar exchanges across Africa and Asia at large. SDI affiliates "are mobilised around dynamic saving schemes networked at the settlement, city, and national levels to drive a collective, bottom-up change agenda for inclusive and resilient cities and to influence global development agendas" (SDI, 2018: 2). SDI is a global network of community-based organisations, and the network of affiliated slum dweller communities are referred to as federations, which address issues of 'urban land, shelter and service needs, and shift urban policy towards a more pro-poor stance' (Watson, 2014: 76). Their community-based approach focuses on placing the communities living in slums actively in the act of their governance. Their goal is to keep the data collected about these settlements, and tools built around the data collection, within these communities rather than relying solely on actors outside of the informal settlements to promote inclusive urban development (Dobson et al, 2014: 4).

There are three components to SDI's community based mapping: creation of community conducted settlement profiles, community ownership of knowledge (produced from data collected about the slum) and community driven negotiation and partnership (Beukes, 11). These processes are important especially when, as pointed out in the first section, informal settlements and their inhabitants may not be counted or recognised as part of the population or city, and therefore may not get the necessary resources to alleviate the issues they face living in 'slums'. Settlement profiles are the 'collective snapshot of a settlement's baseline information' which includes 'the history of the settlement, its security of tenure status, an estimate of its population and access to basic infrastructure such as water and sanitation' (10). This snapshot is not captured by a satellite image, it is instead captured by those living within the informal settlement through household surveys, containing information about the social, political and environmental conditions along with the scale and nature of informality and assets within the settlement (10). An example can be seen below (fig. 5), of the Jamaica slum settlement in Nairobi (Kenya). As can be seen, the last time the profile was updated was 2016 (an issue I shall return to).

Settlement: **JAMAICA**

Established: **1970** | Last Updated: **01.06.2016**

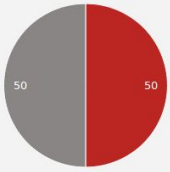
History: THE SETTLEMENT WAS STARTED WITH A WOMAN WHO WAS KNOWN AS NYANG'IRO SHE SETTLED THERE IN 1970'S AND PEOPLE STARTED JOINING FROM OTHER SETTLEMENT ROUNDING.

Basic Information

Prioritised development needs:

1. **Water drainage**
2. **Electricity**
3. **Land tenure**
4. **Housing**
5. **Other**

Ownership of land (%):



Current eviction threat level:
None

Status:
Declared, legal, protected

Estimated population:
9,456

Estimated number of structures:
870

Population density:
550 peoples / acre

Area size:
17.2 acres

Fig. 5. A snapshot of the Jamaica settlement profile, in Nairobi. The full profile also includes information the sanitation, water, infrastructure, organisation of the community as well as access to commercial establishments and facilities. (Source: http://knowyourcity.info/settlement/1847/2965129)

Along with slum dwellers, there are also other stakeholders that are part of the profiling, which include settlement and community leaders, community based organisations and interest groups, as well as government officials that meet to discuss the results of the data collected in the profiling process (10). The activity of data collection and the participation in deliberation over the results collected, build a collective ownership over the data as well as provide an important sense of belonging for those who participate in the process. It is through this "understanding of the location and extent of land and access to basic services, [that] the community as a collective may engage in informed planning for their settlement" (11).

This collective engagement focuses on ensuring four pivotal concerns are met. These concerns are that: i) the communities organised around the settlement profiling can help direct resource flows to their settlement; ii) data gathered helps build a positive identity for slum dwellers and organisational structure around this identity; iii) the data gathered can become the basis of advocacy and opening dialogue, as an asset for negotiation for slum upgrading at local and global levels; iv) the process of data collection gives an opportunity for collaboration for communities in the implementation of their own prioritised development (12). The act of creating these settlement profiles are a form of self-enumeration (Appadurai, 2012: 639), which takes the traditional tools of the state, namely surveys, census and mapping, and turn them into "tools that enable poor urban communities to mobilize knowledge about themselves in a manner that can resist eviction, exploitation and surveillance in favour of advancing their own rights, resources and claims" (639). As I mentioned, using the analysis of Miller and Rose, for a domain to be governed it must be known, made intelligible. The social processes that slum dwellers engage in with SDI allows slum dwellers to gain knowledge about their own settlements. And in so doing, these processes shape their mobilization as it allows group formation of slum dwellers for the sake of slum dwellers, instead of relying on the research of external and remote agencies (640). The processes of creating settlement profiles therefore aim to provide context on what life is like within these settlements, and give slum dwellers and their communities a means to engage in the governing of their settlements.

But similar to the challenges encountered in the setting up and use of a slum ontology for remote sensing approaches, settlement profiling also needed to overcome a number of challenges that made it

difficult to standardise the process of data collection across the entire SDI network of slum dwellers and their respective informal settlements (Beukes, 16). Firstly, there were categorisation difficulties as across countries different names are given to informal settlements as well as the fact that government definitions (as well as recognition) may be at odds with how the communities experience the settlements they live in. If settlements were not named appropriately or in line with an agreed terminology, they were not counted (16). Secondly, each settlement's SDI affiliates collected and presented data in their profiles that showed their respective priorities, which made it difficult for there to be a common profile format. Thirdly, some of the profiles were either not properly dated, or had duplicated data, or included inconsistencies in identities, government delineations and historical boundaries (16). These challenges were identified in June 2013 once 7, 000 profiles had been collected (15), and uploaded to a newly set up SDI informal settlement data platform in March 2014, the Ona platform.

The platform allows data to be captured even when there is no internet or poor internet connectivity, with the data uploaded once internet connectivity is available again, where the data can be viewed, managed, analysed and visualised. The platform displays basic information about the slum (such as its history, demographic and structure of the settlement), water access and facilities, sanitation access, health services, infrastructure (access to electricity, roads and transport), commercial establishments as well as organisational capacity (to show the capabilities of self-organising groups such as savings and women's groups, especially as most of SDI federation processes are led by women) (18). Two further components of the settlement profile are two geographic profiles. The first geographic profile captures the boundary and land area that the informal settlements occupy, this mapping performed by community members trained in using GPS technology to plot the GIS coordinates of the settlement boundary, to be verified by the community once the GPS data is uploaded to the Ona platform (19). An instance of this is pictured in Fig. 6 below. And the second geographic profile maps the coordinates of service sites in the settlement, that records whether a service such as water taps are in working order as well as if the water is safe for drinking. This information is collected through the use of smartphones, tablets as well as in tabular form on paper (19), and verified by the communities in the settlement after focus group discussions. Alongside the Ona platform is the knowyourcity.info website (where Fig. 5 is from) which enables SDI affiliates to have their own public visualisation platform that displays information from the two geographic profiles of each settlement (18). But an issue with regards the information collection and storing is the fact that the data is not gathered simultaneously, and even a cursory look at knowyourcity.info reveals that some slums have not had their information updated in a

number of years (some had their last update in 2014), while some have been updated more recently. *It is therefore important to consider how often and with what temporal consistency this data is collected, distributed and updated*.

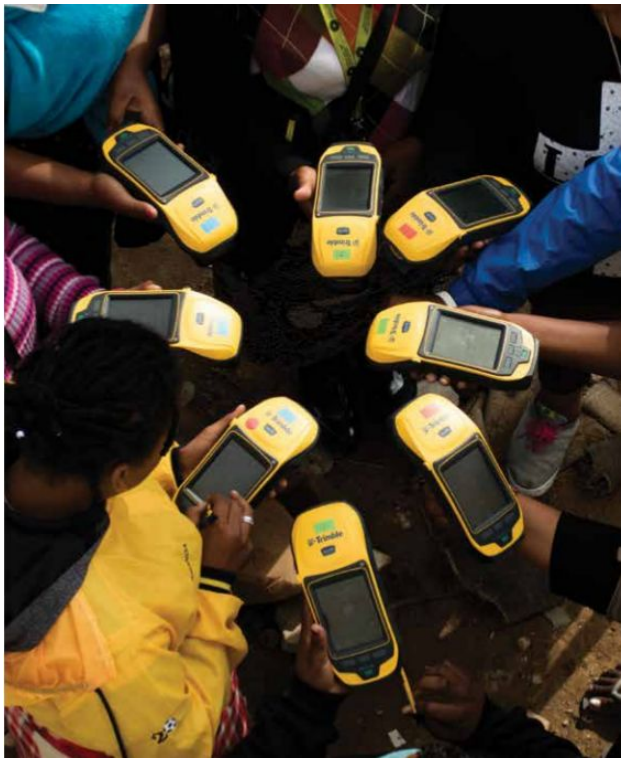


Fig. 6. Youth mapping their settlement with GPS devices in Cape Town, South Africa. (Source: SDI, 2017 :13)

This community-based approach is meant to operate from settlement-level, to network level (i.e. as a collection of settlements), and then at the city-level to forge urban redevelopment schemes from grassroots discussion meetings and data collection (Dobson et al, 10). These schemes gain their force from the collaboration that takes place between federations of slum dwellers. Another example of this approach besides the efforts by SDI, is the work done by the Asian Coalition for Community Action (ACCA) programme of the Asian Coalition for Housing Rights (ACHR). ACCA processes utilize the scattered savings from different settlements into city level community development funds (CDFs) that enables the use of these funds for infrastructure and housing. This allows savings groups to come together and have a stake in the governing of how resources are distributed, thus giving them a positive political influence (Archer, 2012: 424). More so, funds being used in the settlement "can serve as the incentive to keep community savings and collective activities going, as the community can see a visible

impact arising from their savings" (426) and thus such schemes that come from the communities within informal settlements gives these communities more financial savings as well as more confidence in the impact of their collaboration.

Additionally, *the choice of which technological tools to use, also needs to be taken note of because mapping tools can also be instruments of inclusion/exclusion* (or as also pointed out in the first chapter, instruments of invitation or inhibition). If the mapping process is done exclusively using GIS and remote sensing techniques, as was done in Cuttack (India), community participation may be reduced as slum dwellers may not be able to understand the data and representation tools, and thereby not be able to challenge the results (Watson, 2014: 69). But the option to use less technical devices allows slum dwellers to participate with the mapping of their settlements on site, through training to better utilize and understand the data that they themselves collect (69). In summary, the advantages of the community based approach in contrast to relying on external actors (i.e. data collected by governments, consultants and geoinformation scientists) can be presented in a generalised way in the table below (Table 4).

Table 4: Key differences between perceptions of community-based mapping and remote sensing based mapping. (Source: Dobson et al, 2014: 17)

Data collected by communities:	**Data collected by others**:
The data remains 'alive' in the community (and is less reliant on expert knowledge given the use of more affordable and easy to use technologies)	The data is analysed in complex ways (e.g. using techniques such as machine learning means that these methods will not just be expensive but only experts can properly assess the data) and is rarely returned to the community
The data contributes to a realignment of power between the community and the authorities	The data reinforces the power of those outside of the community and the gap between their knowledge and that of the community
The process of data gathering organises communities in a way that facilitates productive engagement with other urban development stakeholders (especially government and other SDI networks)	Has no positive impact on community organisation, excluding them from the process and may lead to the eviction of slum dwellers
Generates a dialogue on planning at the community level	Generates a dialogue in professional/academic circles
Is often more comprehensive owing to improved	Often relies on samples and is prone to

access to those in informal settlements and is a product of dialogue which reduces misinformation	misinformation from communities (whether because of community strategy or suspicion)

2.3. **Participatory mapping as a process of co-production**

These community-based social processes therefore make it possible for slum dwellers to direct the flow of resources and activities alongside community organisations, governmental and non-governmental organisations. The community based strategies so far considered, specifically the community driven negotiation and partnership, *make it possible for slum dwellers to be the ones making claims about their settlements instead of being spoken over*. These strategies are also useful for building relationships between the networked slum dweller communities, and fostering exchanges concerning "materials, practices, designs, knowledge, personal stories and local histories" (Watson, 68-9). These strategies therefore show that the activity of mapping, especially when it concerns the mapping of marginalised groups, can be a means of galvanising advocacy when they take the mapping into their own hands. SDI's network of federations appropriate the tools commonly used by the State, i.e. surveys, maps and plans, as mechanisms to further slum dwellers' claims about the urban space they dwell in (67). This is one of the aspects of where remote sensing techniques may fall short on, as social phenomena is not easily mapped from VHR images.

And by leaving out the social phenomena, it may not be seen when looking at the maps produced by remote sensing methods, that territories are not neutral and instead express claims being made either by those residing in them or by those from without. Urban planners Hillier and Abrahams (2013) use the work of Deleuze and Guattari to point out that territories "express or claim something (my share of the pitch, my palace, my story) as well as occupying space" and deterritorialization can be seen as "a form of action on, or capture of, individual or social forces which seeks to limit or constrain their possibilities of action" (Hillier & Abrahams, 2013: 17). The work done by SDI and their federations can be considered as *attempts to give greater possibilities for slum dwellers and their communities*. The community-based approach to map making is therefore useful in affecting change by opening the possibility for slum dwellers to be part of the democratic process of city management, as community-based mapping helps foster "the political self-consciousness of these communities" (Appadurai, 641). This political self-consciousness is fostered as it makes slum dwellers and their social

issues visible not only for themselves (from the city-level to the transnational level through data visualisation on the Ona platform and knowyourcity.info website) but also visible to governments that may otherwise not include them in state-based documentation or urban planning processes. However, as already mentioned, in certain instances slum dwellers are not counted in census data and thus may not be considered as part of the democratic process or even population to begin with. Thus to be made part of this process would necessitate state and municipal bodies to shift from exclusionary to a inclusive or pro-poor stance. But by making themselves visible in their own terms, and also by collaboration that enables redevelopment schemes using CDFs from collective savings, communities in 'slums' can effectively draw government authorities into the process of participatory collaboration. And show the state and municipal authorities that '[slum dweller] community members are capable of implementing projects and that they (the authorities) may also want to play a part in this' (Archer, 427).

The engagement with governments that community based social processes make possible, can be considered as instances of co-production (Ostrom, 1997) for a number of reasons. Co-production refers to the process "through which inputs used to produce a good or service are contributed by individuals who are not 'in' the same organization" (Ostrom, 1997: 86). Slum dwellers, community leaders, government urban planners and officials, as well as NGOs such as SDI, are actors that can each contribute in the governing of how resources and services can be invested in, distributed and used within informal settlements. Especially when this collaboration develops through participation from community-based social processes. Participation is a vital component because it ensures that slum dwellers and their communities are not treated as 'clients' of resource and service distribution and investment who are acted upon, but they instead "play an active role in producing public goods and services of consequence to them" (86). As such, the activities of SDI and other pro-poor collaborations such as ACHR can be conceptualised as activities that lead to co-production, as elaborated in the table below (Table 5). Recognising the potential of co-production for slum dwellers and making governance more effective, means there is a need for map-making techniques that can both represent the spatial as well as social dimensions of slum developments.

Table 5: Community based mapping leading tof co-production (Watson, 2014: 69-70)

How community based mapping leads to co-production
Community based mapping improves the quality of life of either poor or marginalized groups, through outcomes that improve socio-spatial justice through state intervention in urban development.

The community based activities do not take radical approach to social change, instead operating through patience and slow gains by utilizing learning exchanges and resources from within informal settlements but also recognising the need for collaboration with government officials.
These activities enable the communities living in 'slums' to become visible and able to act upon improving their material and political conditions.

This effectiveness relies on recognising that for cities to become "engines of inclusion, growth, and development" for all its inhabitants, especially those who are marginalised such as slum dwellers and their communities, "policies and institutions must be constructed with the explicit intent of facilitating and safeguarding social, political, and economic inclusion for all residents" (SDI, 2015: 8). This points towards the fact that *the governance and mapping of slums (and actors involved) are responsible for affecting change in the living conditions within slums*. But then the important question is what mapping techniques should be used, and how should governance be structured, to ensure that all actors involved can collaborate responsibly together? As mentioned in the last section of the preceding chapter, the case study of Lenonita et al (2018) shows in its concluding remarks that government officials (much like slum dwellers) may not immediately agree to using remote sensing technologies due to unfamiliarity with how they work (Leonita et al, 2018: 21). This makes clear the connection between technologies selected, bodies involved in their use (and those unable to make use of them), and the potential (or constraints) for changing the social and spatial characteristics of slums and informal settlements. These connecting aspects of the form of content of the geo-policy assemblage, are reciprocally related to the policies (at the local, national and global level), indicators used, ontology of defining what is or isn't a slum and acts of governmentality - in short, the form of expression - that make slums objects for governance. In addition, the work of SDI and ACCA show that slum dwellers can take up the responsibility of not only engaging in the mapping of slums, but also in the governance of slums (especially through processes of co-production).

Chapter 3 - Bridging the gap between remote sensing and community participation

In the two preceding chapters of this thesis, I aimed to demonstrate that the act of mapping slums can be considered as having two sides. On the one side, are the efforts made by remote sensing approaches which utilise satellite imagery and machine learning for producing maps. On the other side, are efforts by those 'on the ground', as initiated by NGOs such as SDI and ACCA who aim to help mobilize slum dwellers and their communities into mapping their slums for themselves. These efforts assist slum dweller communities in creating settlement profiles, tools and platforms for these communities to own and share the knowledge they produce, that allows them to initiate dialogue with governments. The focus of this third chapter is to bridge the gap between these two sides, by attempting to cover what technical and social issues can and need to be crossed, in order to develop a system of real-time collaboration of geospatial data using GIS. More so, the discussion in this chapter will be framed by the need to conceptualise how responsibility is meant to be delegated as well as enacted in the mapping of slums.

3.1. Responsibility, governance and mapping

This section will serve as a return to the research question of the thesis, namely, what does responsible mapping of slums look like? The definition of responsibility that will be in use here is:

> '*Someone*: the subject or bearer of responsibility (a person or a corporation) is responsible for something (actions, consequences, situations, task) *in view of an addressee* ('object' of responsibility) *under the supervision or judgement of*: a judging or sanctioning agent in relation to a (prescriptive, normative) criterion of attribution of accountability within: a *specific realm of responsibility and action*' (Lenk and Maring, 2002: 259-260).

In the context of slum mapping, this formal description of responsibility can be schematised as follows:

Table 6: A matrix of responsibility for the mapping of slums

Subject or Bearer of responsibility	Addressee or Object of responsibility	Agent(s) in charge of oversight	Realm of responsibility and action
UN	States and	?	Ensuring that the SDGs

	municipalities		are achievable within the necessary timeframe by every country, and that no one is left behind
States	Municipalities and slum dwellers	UN	Ensuring that municipalities have the necessary tools and resources to implement policies that can help improve the living conditions of slum dwellers
Municipalities	Slum dwellers	States	Urban planning and non-infringement of the rights of slum dwellers
NGOs	Slum dwellers	?	Empowering slum dweller communities through participatory mapping
Remote sensing mappers	Research community of remote sensing mappers	Municipalities	Producing maps that can be used to show where 'slums' are, highlighting which techniques are capable of capturing more accuracy and what problems there still remain
Slum dwellers	'Slums'	State and municipalities	Raising of CDFs and collaboration with government authorities to make sure the necessary resources reach to the 'slums'

The formal definition and matrix of responsibility illustrating the bearer of responsibility, addressee of responsibility, agent(s) in charge of oversight over the bearer, and realms of responsibility and action, shows that responsibility is a relational concept. An attempt to make responsibility the focus of mapping

slums therefore needs to address the relations at work between the different actors involved in order to properly trace who has responsibility for what. As Lenk and Maring claim, the 'concept of responsibility gives a *structure* to social reality (of norms and actions) and to social relations' (260). And this is the function of the matrix of responsibility I have outlined above, a way of tracing the social reality and social relations involved in the mapping of slums. States, municipalities and NGOs have a collective responsibility (263) towards slum dwellers with regards urban planning and protection of their rights, and empowerment through providing tools for community based mapping. But states, municipalities and NGOs may not have the same interests. As mentioned already, states and municipalities that do not recognise slums and slum dwellers do not take up the necessary responsibility to allocate the necessary urban planning resources, and so it becomes necessary for NGOs such as SDI to take up this responsibility. Thus municipalities need oversight from the state, and states may have oversight from the UN, but the extent of control the UN has (and range of actions to be taken) over what states do with regards the population of slum dwellers (especially when states refuse to acknowledge them) is not clear.

While remote sensing mappers have a collective responsibility to communicate their insights of what technologies and techniques to make use of in producing these maps. The bulk of the literature I looked through revealed that on the one hand this research is written and prescriptive for mostly only the remote sensing research community, given the complexity of the technologies and methods discussed. As accuracy is especially a problem that is not yet solved (as no perfect mapping techniques exist), this responsibility reflects the scientific view of the map, i.e. as an instrument. But in the end whether or not a mapping technique and technology is actually used for the sake of improving the monitoring of slums, is a decision made by the municipality and state agencies, about whether or not to incorporate the mapping technologies used by the remote sensing community. Thus, there may need to be greater discussion between remote sensors with municipality and state agencies, regarding what indicators need to be used and which may be of less use for monitoring slum growth, as expressed in the study by Leonita et al (2018: 20). Defining sufficient levels of accuracy, how to apply the GSO to local slum contexts, selection of appropriate technologies - these are issues that the remote sensing community must communicate with state and municipality agencies.

Whereas the UN has a universal moral responsibility (265) towards states and municipalities. This obligation is to ensure that no one is left behind in their formation of partnerships to tackle the SDGs, specifically SDG 11 (i.e. the SDG focused on in this thesis). As stated in clause 27 of the New Urban

Agenda, "We [the UN] reaffirm our pledge that no one will be left behind and commit ourselves to promoting equally the shared opportunities and benefits that urbanization can offer and that enable all inhabitants, whether living in formal or informal settlements, to lead decent, dignified and rewarding lives and to achieve their full human potential" (UN, 2017: 11). This is further made clear in the framing of SDGs as means of guiding "governments as they work to address some of the most pressing challenges facing humanity" (ICS[8], 2017: 19). As well as with the creation of the Sustainable Development Goal Fund (SDG-F) as a mechanism for implementing joint programmes between UN agencies, national governments and other actors for tackling the SDGs (UN, 2016: 22). How well these challenges are faced depends on how collaborative the implementation of policies and measures are negotiated and put into practice by states and municipalities. But the UN acts more of a sanctioning agent over the implementation of these policies, rather than directly enforcing them. As such, this leaves the responsibility to the states and municipalities. Though it is perhaps necessary to argue that the state, municipalities, geoinformation scientists, and NGOs should each share moral responsibility for working towards improving the welfare of slum dwellers.

What this relational structure reveals is that failures in the respective realms of action and responsibility can either be pointed to the bearer of responsibility or gaps in responsibility. Whether or not a mapping technology opted for by remote sensing mappers is accepted or not depends largely on if municipalities agree that said technology can be used. Similarly, the extent to which NGOs can help with empowering of slum dweller communities, as well as whether or not slum dwellers' rights will be respected, relies heavily on their respective relations with municipality authorities. Whereas while it would seem as though the UN acts as the oversight agent for states, since the SDGs are a "normative framework for development" but "not legally binding" (ICS, 19), it is not clear to what extent the UN can push or direct how municipalities distribute their resources in efforts to work towards SDG 11. Consequently, municipalities fulfilling their role of providing adequate urban planning to slum dweller communities involves looking into what processes and especially what capacities the other actors involved have to either help or push municipalities into action. This is pointed out by Repetti and Prelax-Droux (2003) in their analysis of a collaborative urban management system (which I shall return to in the second section of this chapter) who state:

> "It is neither the town executive, who is focused on politics, nor the administrative services, with their sector-based point of view, who will have a sufficiently complete knowledge to plan the

[8] International Council for Science

development. It is all the political, economic and social actors, through the extremely complex relationships they have, who are organizing the development of the space and of the activities" (Repetti and Prelax-Droux, 2003: 656).

In the context of the mapping of 'slums', these complex relationships are framed by the form of content and form of expression (i.e. the actors and bodies along with policies and indicators involved) that orient the choice of technologies, how information is distributed, and how slums can be governed from a distance but also through community based approaches. I shall address this relational structure as the chapter proceeds.

Making maps responsibly needs to be coupled to the concern with what it means to be mapped or conversely not be shown on maps. To be mapped is to be made visible, and the visibility of slum dwellers is a means for these communities to have their settlements recognised by municipalities. As Fox et al (2005) point out, mapping re-inserts communities' "existences onto 'empty' state maps" meaning that mapping technologies can be viewed as "a tool of empowerment and mediation for local communities" (Fox et al, 2005: 5). At the same time, being made visible may not always work in favour of those being mapped. This is especially the case when the act of mapping may be projected as initiating recognition of land rights, but instead leads "to land privatisation that is in practice exclusive rather than inclusive" (6) as when the mapping of a village leads to the land being sold off to private companies rather than empowering the inhabitants in the village. Or in the case of communities which are nomadic, these communities do not claim specific bounded territories and may thus not be represented or reached out to in the mapping process (6). Consequently, decisions may be made about where they can and may no longer freely move into without their knowledge or participation in the decision process. *Maps and mapmaking can therefore act as a way of documenting the undocumented*, showing that to map is not just to plot and point out, but serves as giving a voice to those who may not have the opportunity to speak and participate. *Yet when used against those being mapped, maps can instead serve as depriving rather than empowering*. This therefore reaffirms the active role that mapping practices have, by acting on bodies and territories through specific forms of content and forms of expression. Maps and mapmaking can have real effects on those that they map, and for those making use of these maps, because they are tied to a geo-policy assemblage that can legitimise their representational power over a territory.

Consequently, to map responsibly is to secondly consider: whose map is it anyway? Answering this question entails returning to the composition of maps. Maps are a way of seeing and categorising. At a

basic level, mapping can be considered 'a fundamental way for displaying spatial human cognition' (Rambaldi, 2005: 5). As mentioned in the first chapter, maps reflect the choices that are made by those constructing them, with regards how territories are deterritorialized and reterritorialised onto the graphic field, where patterns can be shown and brought out which may not be visible before. And so maps display particular techniques, perspectives and forms of spatial categorization, which must be communicated for the map to be effective. But this communicability can take place in an exclusionary form, especially when the displays of maps are conceptualised in terms of ownership and language. If maps are considered as intellectual property, ownership of the visual language which maps are composed with "and the *content of knowledge* that it communicates, are critical factors in determining the success of the process to which mapping and maps are put" (5). This is why the person(s) who are in charge of the mapping, and the symbols, variables, and topography used on the maps, are of issue. As is the case in the MCM where the map is treated as tool in-between the map maker and map user, rather than as a site for interaction and potential collaboration between map maker and map user. If only certain users can understand the maps and others cannot, only certain users will benefit from the mapping process. As pointed out by Leonita et al, to promote the use of machine learning based slum mapping systems, "more user-friendly interfaces are required that allow local geospatial experts to run such systems and combine them with community-based information. This would allow monitoring changes after implementing upgrading programs" (Leonita et al, 21). In this sense, the "'talkative' capacity of maps rests in the selection of featured items, in the manner these are depicted, and in the capability of users to understand, interpret, and relate these to their real worlds" (Rambaldi, 6).

Thus if maps are displays of spatial human cognition, it is necessary to ask: whose cognition is responsible for the way a map is produced? The approach initiated by organisations such as SDI, the community-based mapping approach, highlights how the cognition of slum dwellers can offer more insight into the social, cultural and historical make-up of slums than the remote sensing approach which offers a way of seeing slums in a manner far removed from the daily life of slum dwellers. Concerns over ownership and communicability, are therefore tied. If the mapping tools chosen are too technical or cannot document the social phenomena within slums, then only geoinformation scientists may be able to use these tools, leaving out those on the ground (i.e. slum dwellers, municipality and even state authorities). Conversely, when mapping is performed by communities then the tools and techniques, along with platforms they create for updating and distributing, allows them to not only maintain ownership of the data they produce but also gives them a means to empower themselves by giving them a political voice. The approach to mapping taken therefore has to contend with issues of inclusion

and exclusion, ownership and communicability, invitation and inhibition. And not only of who is part of the mapping process and who isn't, but also once the mapping is finished there should be concern over what effects the map may have, as it becomes a means to empower or displace those that are mapped.

3.2. The geography of participation

A vital component in ensuring that the bearers of responsibility actualise what is in the realms of action outlined in the matrix of responsibility, is the need for greater participation between the actors involved to become a focal point of the mapping of slums. And the participation I will explore in this section, entails combining the approaches of remote sensing with community-based mapping. The approach that I argue can achieve this is Participatory Geographic Information Systems (PGIS), which combines "participatory mapping visualisations, spatial information technologies (SIT), spatial learning, communication and advocacy" (Rambaldi et al, 2006: 106). PGIS aims to address and respond to the following issues (I've briefly outlined in the first section of this chapter): identification of the problem (i.e. how to most effectively[9] map slums), making clear whose voice counts, who controls the process, whose reality is being put on display, who understands what is being mapped, who owns the output of the mapping process, what changes after the mapping and at what cost (108). Designing a PGIS would thus be an effort to overcome these issues. Remote sensing approaches may have minimal participatory access for communities being mapped due to the highly technical nature and lack of similar resources on the ground, lowering the communicability of these maps outside of researcher communities. Which is why community based approaches instead utilise mobile phones, tablets, GPS devices which are not only easier to use but also require lower internet bandwidth and so do not need massive computing infrastructure. But community based mapping may be more time consuming, and the data may not be updated as regularly as it should be. PGIS may be a way of finding a middle ground between remote sensing researchers and communities in slums, so that the maps constructed can serve both parties, though the hurdle then becomes how best to scale such a system for global monitoring and mapping of slums.

Collaboration over GIS, also known as computer-supported cooperative work (CSCW), can take place in a number of ways. These collaborative settings can be: a) same time and same place collaboration, b)

[9] Effectiveness here referring to the fact that the mapping of slums should not only be focused on the technical concerns, but also the social, cultural and governance related concerns as explored in the second chapter.

different time and same place collaboration, c) different time and different place and d) same time and different place (MacEachren, 2000: 445). These four settings are framed in the table below (Table 6). The most efficient work setting would be (a) as those involved in the mapping process would be in immediate spatial and temporal proximity, while (c) would be the most problematic setting as being in remote spatial and temporal distance means relying on technological infrastructure to ensure that there is minimal latency in communicating with collaborators as well as no data is lost in transmission (especially if one site is better resourced than another). Further technical concerns for collaboration to be successful include: i) figuring out how to represent multiple forms of information in group settings with interactive capability, ii) utilizing electronic meeting software to ensure individual and collective decision-making, iii) expert knowledge assisting non experts in properly using GIS, and iv) choice of display devices especially at local public meetings in resource poor communities (449). Collaborative GIS or PGIS (also referred to as Public PGIS or PPGIS) thus entails what can be called covering a geography of participation.

Table 7: How collaboration is distributed (Source: MacEachren, 2000: 445)

Collaborative work settings	Same-place	Different-place
Same-time	a) Synchronous and co-located	d) Synchronous and distributed
Different-time	b) Asynchronous and co-located	c) Asynchronous and distributed

This geography of participation, will likely operate in an asynchronous and distributed manner in the context of mapping slums. Remote sensing experts may not always be on the ground, and those being mapped are more than likely be in different time zones and locations from remote sensors (predominantly in the Global South), meaning that tools for collaboration need to be set up on both sides to give the right amount of access, mapping ability and decision-making capacity. The basic tools that a collaborative GIS will require, include: i) shared viewing, control and object manipulation of geospatial data, ii) features for annotating and marking map features with text, graphics, photos and audio/video clips, iii) interactive ways of exploring and solving spatial problems, and iv) awareness of the multiplicity of collaborators and goals (Sun and Li, 2016: 144). Further, for these tools to be effective relies on how certain design principles are implemented. It is necessary for the collaborative GIS to have concurrent control, so that multiple users can freely interact and detect as well as resolve any conflicts (147). This way each user can contribute to the work environment at the same time. User information

distinguishing name, role and location can be added as labels, with multiple pointers (i.e. mouse cursors) identifying who is responsible for what comment, action, request (148).

Such systems should also offer multiple viewing interfaces, for instance public and private, whereby users first work on their private version of the map and then update the public version for everyone to see and make suggestions/corrections. These interface features will allow collaboration to take place in real-time even though the system is asynchronous and distributed. But there are also features that can be implemented which may end up working contrary to concurrent control. If the system has a lock mechanism which ensures that only certain users can have access to certain objects on the map, this may itself lead to conflicts of deciding who can/cannot have access to the shared working environment (147). Floor control or 'token' method is a form of the lock mechanism, which essentially determines "who has the right to operate on and manipulate the collaborative environment" which includes "requesting, assigning and releasing the floor" (147). But the downside of having lock mechanisms is that rather than allowing multiple users operating simultaneously, they can instead slow the potential of concurrent control as access becomes limited. Such a mechanism may only be fruitful in situations where certain actors are identified as having agendas that are not beneficial to those being mapped and thus should be excluded from being able to have access to the data displayed on the maps. The review of such systems covered by Sun and Li (2016) shows that they have been used in a number of varying applications, including: civil public security, community emergency planning, collaborative sense-making in emergency management, decision support systems for environment design and for government workflows (149). Such PGIS and PPGIS real-time systems include GeoDF, ArgooMap, GroupArc, Habanero and Microsoft Groove (Chang and Li, 2013).

For such a collaborative system to work in the context of mapping slums, dialogue between remote sensing researchers, municipality authorities, NGOs like SDI and slum dweller communities needs to be established. Dialogue that allows each actor to express what their expectations and also what limitations (i.e. in terms of resources and cost) are in the way for effective collaboration. As remote sensing techniques, relying on satellite imagery and machine learning algorithms are costly and require expert knowledge, less resource heavy technologies may be more suitable for setting up PGIS. The study conducted by Gevaert et al (2018) researching the utility of using drones (a DJI Phantom 2 Vision+ quadcopter) for slum mapping in Kigali (Rwanda) and Dar es Salaam (Tanzania), found that the mapping project was made more effective by incorporating values of participation, empowerment, accountability, transparency and equity. While in Kigali the mapping was conducted principally by

foriegn institutions and consultants, in Dar es Salaam the mapping was done through PGIS involving community members and the data gathered was uploaded to OpenStreetMap (Gevaert et al, 2018: 11). And among the observations made in the study, was that: i) communities are better off being informed of what the mapping project is for, to alleviate any concerns they may have (e.g. while some residents were enthusiastic about seeing the drones some were scared); ii) communities are more empowered if they can also have access and training in understanding the geospatial data made of their settlements for potential land rights disputes; iii) the increasing ubiquity and falling costs of drones may lead to potential community-based drone mapping campaigns to further mobilise community members to keep the data within communities (11).

Yet Gevaert et al (2016) also point out that drone use has certain limitations. These limitations include: i) drones cannot be properly utilised during rainy or windy weather conditions; ii) the range of flight is limited, especially given the drone used, and needs to have take-off and return points which can slow down data acquisition; iii) rendering the data and storage of the images taken by the drone may be resource heavy, which may require open source software to mitigate more expensive hardware architectures; iv) there are also issues of administrative procedures such as flight permissions and documentation as well as training of photogrammetrists to process the data (Gevaert et al, 2016: 12-13). Although the training and administrative processes would likely not be as taxing as what is required to use more state of the art remote sensing technology and techniques. But an additional issue is that drones, being more capable of capturing images of slums with greater detail being at closer range than satellite images, can have a negative impact on the sense of privacy of slum dwellers. There are therefore a number of trade-offs that need to be borne in mind when deciding which technologies are best suited. These two papers on the utility of drones for slum mapping show the ambition of combining GIS with community participation, but do not go further to elaborate what a fully functioning collaborative system will look like. But they do allude to issues that need to be dealt with that are also identified by MacEachren in the making of PGIS. These issues are:

> ‘access to information and its complement of information confidentiality; power and control exerted through information access; the failure of traditional GISystems to encode what matters to many of the stakeholders affected by decisions, such as information about ‘place’ and values; the limiting map-based metaphor that underlies GIS systems and makes it difficult to encode non-metric information; and the lack of access to GISystems technology due to its cost and complexity‘ (MacEachren, 2000: 448).

The issues of access, confidentiality, encoding of stakeholders' perspectives, interests and values, along with cost, are some of the important limitations to setting up a PGIS. Making these issues clear is the first necessary step towards defining who is responsible for specific parts of the system, such as: data capture, choice of technology, information dissemination, community training, setting up of computing architecture, prescription of ethical standards and defining levels of access to the final map product. These responsibilities can be considered in terms of the matrix of responsibility, as shown below (Table 7).

Table 7: Matrix of responsibility for PGIS

Subject or Bearer of responsibility	Addressee or Object of responsibility	Agent(s) in charge of oversight	Realm of responsibility and action
UN	States and municipalities	?	Making sure that the types of indicators used are understandable, along with more direct monitoring of how states implement policies to foster participation[10]
States	Municipalities	UN	National and local level data on the conditions of slums such as where they are, what services are (un)available[11]
Municipalities	Slum dwellers	States	Establishing the necessary relations with NGOs and slum dweller communities to collaborate in setting up PGIS, and ensuring the data gathered does not go to private companies but ensures protection of slum dweller communities
NGOs	Slum dwellers	Municipalities	Helping slum dwellers

[10] ICS, 2017: 220

[11] 'At the national and local level, governments require timely access to geographic data on the location, extent, and dynamics of slums.' (Gevaert et al, 2019: 1).

			secure the necessary funding and training in how to use PGIS
Remote sensing mappers	Remote sensing mappers	Municipalities	Selection of mapping technologies that are cost-effective for municipalities, inclusive for slum dweller communities to participate in, through interface design and set up of PGIS. Also allocate GIS experts and adequate training in PGIS use.
Slum dwellers	'Slums'	Municipalities	Working towards processes of co-production with municipalities, along with NGOs, to make sure their needs and capabilities are well represented

In their analysis of an urban management system in the city of Thiels (Senegal), Repetti and Prelaz-Droux involving four stages of set-up between 2002-2005 could be a useful model for a PGIS for slum mapping. The first stage involves setting up an institutionalised central organ for participation known as a forum "which brings together about a hundred participants on 2 or 3 days every 3 months (elected representatives, representative of the state, of the villages and districts, civil organisations, [and] NGOs" (Repetti and Prelaz-Droux, 661). A forum for those involved in the slum mapping ensures a space for discussion of perspectives, criteria and necessary training and information exchanges. The number of participants need not be a hundred, but there need to be enough to ensure adequate representation of all involved actors. In this way, municipality authorities, NGOs, remote sensing researchers, and slum dweller communities can collectively discuss and work through the constraints and potential of a PGIS. And the matrix of responsibility above illustrate what each actor is in charge of securing for the PGIS to be successful. The second stage involves detailed discussion of the objectives of the map of the slum through "identification of the structuring elements of the city, with their potentialities and problems, so as to establish the terms of reference for the first iteration of the

project" (662). Such a detailed discussion of strong and weak points of the city, with slums especially as indicators of weaknesses in governance processes, will allow municipality agencies, NGOs, geoinformation scientists and slum dweller communities to collaborate better by each having a more well distributed information base. The third stage entails the establishment of workshops for all the necessary actors to look over the pictures captured of slums, for the identification of the elements in the territory "in relation with the identified problems and the fixed objectives" (662). This will rely on sufficient training in understanding how the images are captured, processed and rendered, which remote sensing researchers should be responsible for determining. In this way, such a "geographical reading allows the constitution of a territorial information base (structure and data) and the establishment of a participatory diagnosis" (662) of what each settlement needs. The final stage of this process is the suggestion of solutions through the realization of a strategic development program (662).

3.3. Geospatial data ethics

But the setting up of such a system requires also fulfilling ethical requirements. This is especially clear given the fact that the mapping of areas, as pointed out in the beginning of this chapter, can lead to inhabitants being evicted and the land privatised, rather than benefiting from the mapping project. As a result of the fact that data, specifically data about the size, growth and location of slums, is a valuable asset for all actors and bodies involved in the geo-policy assemblage, there is a need for geospatial data ethics to be an important part of the PGIS infrastructure. Ethical concerns include "standards of ethical practice, data accuracy and validation, information liability, copyright, quality assurance and duty of care, licensing, disclaimers, metadata, and intent of use" (Blatt, 2012: 80). Such issues can be divided into what Crampton (1995) refers to as internal and external perspectives on the use of GIS. The internal perspective is based on "the questions of scientific inquiry, the day-to-day technical questions of a discipline" (Crampton, 1995: 84). Such questions (and their answers) may be posed entirely by remote sensing researchers, without any attempt to consult municipalities, NGOs or slum dweller communities. But this would shut out these actors from being able to understand, and perhaps more importantly, inhibit them from being able to critique what technologies, techniques and platforms are used in capturing, processing and displaying the data about slums. Those involved in the internal perspective must therefore be included, either by the appropriate level of training or in the selection of technologies and techniques which make collaboration more possible. And the external perspective of GIS use "deals with a contextual, ideological framework" which make normative statements about the role of GIS such as making its use more democratic in regional planning, "will affect judgments in the internal"

perspective (85). There is therefore a need for the internal and external perspectives of GIS use to be in dialogue, to make the necessary choices and judgements in the formation of effective PGIS.

But what should these choices and judgements be based upon? Anna Esnard (1998) offers a list of five provisional codes of practice in the use of GIS that may be of use in the setting up of PGIS for the mapping of 'slums'. I illustrate these codes below (Table 8) along with the kind of reasoning that can be used to incorporate them into the design of a PGIS.

Table 8: Code of ethics and rationale for their importance (Source: Esnard, 1998: 38-42)

Code of practice	Reasoning
At all times the process should be given precedence over the final map or analytical product	The success of a PGIS will depend on all actors involved laying forward their preferences and what criteria they are most concerned for, and figuring out (through the forum mentioned in the second section of this chapter) how to weigh each actor's preference and criteria in establishing what information, technologies and resources are needed. Without this, disputes are more likely to happen rather than collaboration.
Data quality and data description should satisfy standards to ensure data uniformity and to make sharing possible at the local, state, and international levels	As mentioned in the first and second chapter, there is a concern over not only the accuracy of data about slums but also where to get this data. Since census data may not account for all slums within a city (due to slum communities not being acknowledged), not all municipal authorities will satisfy the need for accurate data. NGOs and slum dweller communities may therefore need to work with the remote sensing community to better gain accurate data on slums which can then be brought to municipal authorities. But as pointed out in the discussion on the GSO in the first chapter, and standardisation of SDI settlement profiling in the second chapter, there is a need for all those involved to work with the same indicators and standards. This would require meetings to establish agreement over what indicators and standards to use.
Community needs, local knowledge, and social and cultural contexts must be represented when applicable	If remote sensing researchers make use of highly technical GIS to produce maps, then they are likely to exclude municipal authorities, NGOs and slum dweller communities from understanding,

	critiquing or benefiting from these maps. As pointed out in the second chapter, there is value not only in the accuracy of capturing morphological characteristics of slums, but also the social, historical and cultural characteristics of slums.
An individual or group's right to confidentiality and privacy should not be violated, nor should there be intentional misuse, misrepresentation, or falsification of data to place an individual or group at an unfair advantage	Once the preferences and criteria of each actor is acknowledged, the likelihood of one individual or group benefitting at the detriment of the others is far less likely to happen. Such as what happened with the leaving out of nomadic communities or mapping that leads to privatisation and forced evictions, mentioned in the first section of this chapter.
Request for public access data by the public should be accommodated.	Municipalities, NGOs and slum dweller communities should have access to browse, query and add to the maps of 'slums' that are produced, rather than this data being only accessible to private companies. Open access means that all actors involved know what the data looks like, for the sake of correcting any inaccuracies as well as for making sure everyone involved is on the same level in the making of the map.

Using responsibility as a way of framing who is involved in the mapping of slums, distinguishing what their tasks and responsibilities are, allows a clearer way of envisioning how a fully collaborative PGIS can be designed. This framing also shows where problems are likely to arise, and the factors and codes of practice that may be useful in resolving them.

Conclusion

This thesis has been an investigation into the mapping of slums. In the first chapter, I highlighted the semantic issues involved in the use of the term 'slum', pointing out its origin and now formal definition as used by UN-Habitat, as well as in the remote sensing and SDI literature. I then elaborated on the many technical issues and demands that need to be met and have still not reached a consensus, regarding the selection of appropriate mapping techniques and technologies in the remote sensing community. While the remote sensing community may focus on the map primarily as a scientific tool, or the output of testing different techniques and technologies, what becomes clear from looking at the uses these maps are put to, is that displaying only the spatial characteristics of slums is not enough. What is also necessary is displaying the social, cultural and historical aspects of slums on maps, and this may not be entirely possible from using remote sensing approaches alone. For this reason, the second chapter of the thesis introduced the community-based mapping approach led by SDI, showing that putting slums and slum dwellers on the map may be something for slum dwellers to be in charge of themselves, rather than be something done entirely by those outside of the slum. Although it needs to be recalled that, as mentioned throughout the first chapter, remote sensing methods also take into account local knowledge in the production of these maps especially when the GSO needs to be incorporated into different local slum contexts. Showing the need for local knowledge in the production of remote sensing maps. But what community-based mapping makes possible, is for slum dwellers to not only be in charge of the mapping, but for the activity of mapping to become a means of advocacy. This is especially necessary when certain states and municipalities fail to acknowledge slums and the plight of slum dwellers. Community-based mapping thus allows slum dwellers better chances to fight for their rights, especially when mapping that is done by external agencies can lead to land privatisation and forced eviction, or when they have their households demolished. By turning to look at the slum dweller communities on the ground, and not just as they are seen on remote sensing maps, it becomes clear that the process of mapping (as revealed through the work of critical geography) is situated in social and political discourses which are more exclusionary than inclusive to slum dwellers.

Laying out the social and political discourses at work, brought to surface what I have called the geo-policy assemblage that orients the process of mapping 'slums'. And by designating the moving parts of this assemblage accordingly, pointing out the form of content and form of expression, it becomes possible to begin to map out who can be described as having responsibility over the necessary parts of

the mapping process. By using the formal definition of responsibility offered by Lenk and Maring, I framed a matrix of responsibility that can be useful in recognising what actors hold responsibility, who depends on them, what their realm of responsibility should be, and if there should be any actors acting in an oversight position to make sure they carry out their responsibilities. Such a matrix makes it possible to better organise a PGIS to bridge the gap between remote sensing approaches and community-based approaches, which demands the collaboration of the UN, states, municipalities, the remote sensing community, NGOs and slum dwellers, in order for it to be fully successful. But success may be curtailed when there are responsibility gaps. If municipalities do not support slum dwellers in upgrading the slums, must NGOs take up this realm of responsibility? If states and municipalities demolish slums in efforts to free their cities of them, should the UN be responsible for stepping in (especially given that slum dwellers may have no recognised rights and thus may not be able to protest themselves)? Such gaps become the causes for NGOs such as SDI, but even then, the data that is meant to be presented from community-based platforms (such as knowyourcity.info) on the conditions within slums is not always up to date. Which means that even though this approach gives greater sense of community and empowerment to slum dwellers, the lack of up to date data means that this realm of responsibility is also not being met appropriately. Which has a negative effect for slum monitoring at the local but also international level. And it is unclear whether the lack of up to date information is due to a lack in the necessary computational resources, or from lack of oversight to ensure each slum on the platform is up to date.

Furthermore, as discussed in the third chapter, there are many technical and logistic issues that need to be negotiated and agreed on in setting up a PGIS. How can collaboration take place seamlessly? What software is most useful? What is the required amount of training? How many remote sensing experts need to be deployed to the ‘slums’, and for how long? Who should be responsible for meeting the costs? These questions are not easily answered, given that different ‘slum’ contexts may require different needs given their geography (if they are in remote areas), culture (concerning issues of privacy or welcoming to foreigners) and size (larger and more diverse ‘slums’ may need more complex techniques). More so, while the examples of PGIS I have mentioned in the third chapter were mostly used for local instances (e.g. just for one city), ‘slum’ monitoring and mapping is a global issue and thus will require a standardised method that can be deployed globally so that information captured can be used for tracking SDG 11 more effectively. The overriding issue in the setting up of the PGIS is therefore the time taken. If it takes years to set up the system and have it running, then this will mean greater costs in equipment and also training of skills if complex technologies and techniques are required. But if

less complex techniques and more manpower is needed, this will also mean slower mapping and likelihood for more errors in the final mapping product. The fact that the PGIS literature has a lot of studies on example cases, shows that this is a field still working towards finding a viable solution to how to better deploy urban management systems in contexts that are lacking in financial resources, computational infrastructure and skill, and high quality information. And such systems may become realised in the context of slum mapping in the near future.

And it should also be recognised that given the amount of data that needs to be collected, and the involvement of external agencies in slums across the developing world, ethical concerns having to do with privacy, access by slum dweller communities to the information gathered, along with the protection of the rights of slum dwellers, must also be made central concerns in setting up the PGIS. The level of detail the map has, affects how likely the privacy of slum dwellers is to be infringed, and thus the need for accuracy should not supersede the protection of privacy. There may thus need to be ways for maps to be produced that still allow privacy to be protected, especially in situations where pointing out where slums are leads to land privatisation or forced evictions. Should the maps therefore hide where the slums are in some way, but still document the necessary number of inhabitants and households? Who should be allowed to know where the slums are? Such questions may need to be posed when the mapping process commences, in order for these consequences to not be realised. And the level of complexity and tools for participation, either limit or improve the access that slum dwellers can also have to the information that remote sensing mappers and municipalities have at their disposal. More access to the information will allow for ownership to be shared, rather than kept away from slum dwellers. But this will depend on the relationship between slum dwellers and their respective municipalities and states, and can be improved or worsened by the software tools chosen. In this way, ethical and social demands are to be treated on the same level as technological and economic demands.

Consequently, the question of how to make maps of slums responsibly, must be answered in a systematic way by first mapping out who are the actors involved and what are they responsible for, followed by assessing what are the most appropriate approaches and techniques that fulfill the necessary technological, economic, political, ethical and social demands that this investigation has outlined.

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