Author’s Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.
Abstract

A map is a chart or diagram that uses spatial relationships to communicate information. Through the medium of the map a desired goal can be impressed on people’s minds as a first step to changing the environment. The history of mapping shows that changes in technology brought about ideologies of progress that were communicated in maps. The digital revolution has brought about an image culture that is changing the way we connect with space. Instead of physical rules limiting the way we interact with space, we are now able to redefine it entirely. As architect Richard Wurman writes in the preface of *The Exposed City*, digital maps allow people “to see the things they’ve always seen but never seen,” and choose to respond to that new knowledge in space. Architects such as Richard Wurman, Buckminster Fuller, James Corner, Ole Bouman, Raoul Bunschoten and MVRDV, to name a few, have acknowledged the need to be involved in the design of digital mapping programs to maintain our position as advocates for quality built space.

Digital mapping techniques are considered by many to be a tool of agency for marginalized people in the developing context. The last twenty years have seen a wave of “public participatory GIS (geographic information system)” programs being initiated in communities around the world. Digital maps offer the ability to store and represent an infinite amount of information, make it available to the masses, and apply techniques to make it dynamic and interactive. Beni Atlas explores mapping theory, analyses current employment of digital maps and then employs what is learned to the design for a mapping framework for the community of Beni in the eastern Democratic Republic of Congo in partnership with a local university.

The design uses a framework methodology because the image of a map is never alone but is surrounded by a set of community programs and digital sequences that drive how a map is created, used, shared, stored, connected, etc. This framework is the atlas’ (prime) that is taken to a new level of possibility with the use of digital technology. The goal of the framework is to unite data from bottom-up and top down sources, provide clarity and understanding for users, and become a tool that allows for communication and partnership between different actors in the community.
Acknowledgements

I am thankful to God for the opportunity to study to be an architect, and giving me the interest and nagging questions that started me on this journey.

To my supervisor, Maya Przybylski
Thank you for being the steady voice of reason and offering clear direction for how to improve the work.

To committee members, Val Rynnemer and Lola Sheppard
Thank you for offering your additional perspectives and critique.

To my external reader, Peter Johnson
Thank you for the preliminary guidance that you offered early on in the thesis and for lending your experience to the final discussion.

To professor and mentor, Philip Beesley
Thank you for your ongoing encouragement and interest in my work. Working with you on your research over the last few years has given me an open mind and a drive to pursue cross-disciplinary work that is a little outside of the norm.
To CI-UCBC and the Integrated Research Institute,
Thank you for partnering with me in this research and opening up your community to me.

To Jonathan Shaw
You have been an excellent role model in the way you pursue research with the goal to impart positive change in a community. Thank you for being the force on that side to make this collaboration happen.

To PDVs Othy Vitswamba, Archip Lobo, and Bora Mukovi
Your hope and energy never cease to amaze me. Working with you has been inspiring and I hope our collaborations continue.

To my Family
Thank you for always supporting me in my goal to become an architect, even when it took me far away from home on crazy adventures. Thank you for your support in the challenging moments, and for the constant love, prayer, and encouragement.

To my close friends
You know who you are. Thank you for listening to my complaints, giving critique and encouragement, and on occasion, forcing me to take a break when I needed it.
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1.1 Introduction

Study of Mapping

Maps have existed throughout history as a means to understand spatial position within a surrounding context. The Oxford Dictionary defines the map as “a diagrammatic representation of an area of land or sea, showing physical features, cities, roads, etc.” This is the typical definition of road maps that many people are familiar with. A second definition is that a map is “a diagram or collection of data showing spatial arrangement or distribution of something over an area.” The range of imagery that can be called a “map” is therefore very broad, but what all maps have in common is that they always represent spatial relationships, be they of streets, stars, atoms, or system flows. The maps that this thesis addresses have two qualities: they represent the physical world at the visible scale ranging from a plot of land to the globe, and they communicate past, present, and future realities of the site. An atlas is a collection of maps that are published as a book or multimedia application.

The medium of the map has changed over the centuries, as has the type of agency it provides for people to bring about change in their environments. For example, the digital map is a new medium developed over the past three decades that changes the possible content and reach of maps. The digital map is available to the global community and can be shared and manipulated by people despite their physical distance. The digital map can also represent complex data that cannot be easily mapped by hand and can serve to better understand and design complex systems. These capabilities have brought digital mapping to the forefront in recent years as a democratic tool. Public Participatory Geographic Information System (PPGIS) is a term representing a wave of initiatives occurring around the world in the past two decades that structure the involvement of the community in contributing data to improve equity and influence policy. Many initiatives have been deployed in underdeveloped countries with the hope of shedding light

2 Ibid.
3 Ibid., /atlas.
The Bayeux Tapestry that depicts the narrative of the 1066 Norman Conquest of England

First portolan map by Giovanni Domenico Cassini based on latitude and longitude points, 1696
on complex issues related to land ownership, resource use, and other conflicts.

History of mapping reveals that mapping is a complex and fragile practice because it is dualistic and inherently political. Writer and landscape artist J.B. Jackson highlights the duality of the map in his book *Describing the Vernacular Landscape* in his example of how “forum follows function”. He writes how a simple plan for a city piazza serves two purposes. For the inhabitant it is a place where people come together, whereas politically it is a space designed to bring together members who are aware of their communal responsibility.¹ Scholars of mapping such as Jerry Brotton and Armand Mattelart describe this same duality in maps from the renaissance, early modern, and modern periods.² ³ A common pattern emerges that the practice of mapping can benefit one party while simultaneously exploiting others, and that technology as an amplifier has the ability to achieve greater benefit or greater detriment. The vast application of digital mapping around the world and across disciplines suggests a need for mapping and design discourse to address what is effective design in the domain of digital mapping and how the full capabilities of digital mapping can be defined and explored. The research proposes that it is important as designers to establish what makes a well-designed framework for a map. The term “framework” is used because the image of a map is never alone but is surrounded by a set of programs and digital sequences that drive how a map is created, used, shared, stored, connected, etc. This framework is the atlas’ (prime) that is taken to a new level of possibility with the use of digital technology.

**Historical Shifts of the Map’s Form and Function**

By studying mapping through history, it can be determined that as the medium of the map changed with developments in technology, the function of the map also changed. In the *Atlas of Science: Visualizing What We Know*, author Katy Börner summarizes how maps changed over time.⁴ In ancient times maps were primarily used for story telling. Although nothing was spatially accurate, key icons determined location and a sequence of events. Portolan charts in the 13th and 14th centuries grew more accurate and portrayed the expansion of empires and establishment of trade routes.⁵ The maps were based on Ptolemy’s Geographia, but were framed to benefit the political aspirations of the

5. Ibid., 10.
Beni Atlas’ cartographer’s patron who was often a ruling monarch. The printing press allowed for the wider distribution of the same map, and the ability to restrict distribution to a single map that depicted desired political interests. The technology of the printing press also allowed maps to be compiled into atlases for the first time. Mapping became more prevalent at the smaller scale with the end of the feudal serfdom and the shift toward land ownership. The first cadastral information was collected in what was known as a gazetteer in the seventeenth century.

The next developments in technology that changed the function of mapping were the combustion motor and the first electronic devices of the modern period. The role of maps shifted from having a purpose of accumulation to being used to also represent the complexities of cities and infrastructure networks in order to make them productive. Maps were used not just to convince people of land ownership, but also to involve them as active participants in the productive life of the city. The productive assembly line that drove the automobile and other manufacturing industries became mirrored in society. Maps were used to design cities in which the individual became a productive participant in the way that they lived, circulated, and worked. Maps projected the benefits of this lifestyle. The first air and space travel re-enforced the idea of a communal perspective of change. For the first time an image could be produced that looked down on a place in all exactitude.

The final and current shift in mapping occurred with the advent of computation and the world wide web. Frederic Jameson in his book Post-Modernism, or, the Culture of Late Capitalism, describes the digital age as entering a whole new dimension. It has brought about an image culture that operates primarily in the digital realm and therefore has a disconnect from what occurs in physical space. Digital maps attempt to bridge the divide by representing the flows of information of our increasingly complex environments using digital tools, a framework of hardware and software that prescribe the design and rules of functionality of the map. Technologies that support digital maps include GPS devices, applications on cell phones, GIS software, databases, code, and web applications. Although writing computer code is a skill possessed by few people, digital maps can be packaged into an interface that, like most machines, can be employed without the user understanding how the inner parts function.

3 Buckminster Fuller, Nine Chains to the Moon: An Adventure Story of Thought (Philadelphia: Lippincott, 1938).
4 Frederic Jameson, Postmodernism, Or the Cultural Logic of Late Capitalism (Durham, NC: Duke University Press, 1991), 44.
How Architects Today Use Maps

There are many architects that have recognized mapping as an integral part of architectural practice. They recognize that buildings themselves are no longer objects alone in a landscape but are a part of the systems and networks that serve them. As architect Manuel Gausa describes in *Metapolis*, architecture will expand into the processes, networks, and territories that support and contain it and therefore mapping is a first step to develop strategies for shifting space. Landscape architect and theorist James Corner argues that the role of the architect is shifting and that architects today have a responsibility to decipher increasingly complex environments by the practice of mapping. It is the only way by which architects can design buildings and cities that continue to respond dynamically to complex site conditions. Corner’s writing is reflected in his work that often uses hybrid map-drawing and collage as tools to better visualize the often invisible forces acting upon a site. Dutch architects Winy Maas, Jacob van Rijs and Nathalie de Vries of MVRDV have done many experiments in creating “data- scape”, imagining how data can visualize itself in a spatial way and begin to project design solutions. Spatializing data has the ability to make information tangible by applying it to the physical reality that people inhabit.

Other architects have gone beyond just the design of maps to designing mapping as a participatory process. Raoul Bunschoten of Chora uses a design methodology called the “urban gallery”, that involves the actors and agents of a community in experimental design discourse by building prototypes and testing scenarios. In the 1960’s Architect and theorist Buckminster Fuller proposed a theoretical World Game that would map and simulate events in real time. The World Game would drive political decision-making and incite people into action. He believed that being able to see and interact with a big picture of the world would encourage a global response for corporate well-being. Design plays a role in creating the structure by which a system’s rules and actions can be employed and communicated and

Participation needs to differentiate between the demands of the clients and the desires of the users. Architects, needing clients with power and money, are usually on the side of those in power and willing to embrace and express in built terms the ideology and economics of these clients, to the exclusion of the desires of the potential users. There is thus a removal of the general public from the processes of architectural production, which in turn leads to a sense of alienation of the users from their environment.

– Architecture & Participation (Jones et al. 2005)

3 Ibid.
Conflicts are stepping stones in the unfolding of scenarios – tools triggering interaction between actors and agents that otherwise would not meet. Stepping stones are instruments for managing urban change.

– Raoul Bunchoten, Urban Flotsam (Bunchoten 2001)

digital mapping is a design strategy that can bridge the gap between the digital and physical realms and perform as an autonomous structure of gathering and connection.
Public Participatory GIS

There are areas, particularly in lesser-developed countries, that are subject to not only the complexities of rapid informal urban growth and very little data or documentation, but also additional layers of local conflict that stem from multiple, interrelated sources. It is situations like this that have sparked the Public Participatory GIS movement that is attempting to use mapping as a democratic tool to address problems from the bottom up. Renee Seiber in her article Public Participation Geographic Information Systems: A Literature Review and Framework, gives the definition and history of PPGIS and outlines critical questions within the domain. The term PPGIS originated in 1996 at meetings of the National Center for Geographic Information and Analysis where members were trying to define what the next phase of GIS would look like.¹ The term was meant to express how GIS would become a tool used by the public in order to better inform policy. PPGIS is essentially the involvement of non-expert actors and agents in the use of GIS technology to create maps. It is broad in its application because it has been used across a range of fields and across public, private, and non-profit sectors.² Although it has the words “public” and “participation”, the level of participation varies and sometimes is limited to minimal input or analysis of outputs by the public. The field has received significant critique in recent years because there are examples of initiatives that have caused more harm than good. There are numerous factors that influence the outcome of a project such as the scale and culture of the place, the level of inclusion, the distribution of technology, levels of cartographic literacy, data appropriateness, data access and ownership, strategies of representation, and data quality and completeness.³ The more recent free and open source software (FOSS) movement gives agency to small and limited capacity groups because they no longer have large start-up and overhead expenses to begin a project. For this reason open source has become appealing for community mapping projects in developing countries. Limited capacity groups still face additional challenges because they may be required to bend their goals to that of an outside funding agent, or work with technologies without adequate training or that may be incompatible.⁴

³ Ibid., 493-498.
⁴ Ibid.,
Most academics, policy makers, and practitioners interested in questions of war and peace share a remarkably similar approach to their topic; they look for causes of violence at the regional and national levels, and not in the realm of the local.

— The Trouble with the Congo: Local Violence and the Failure of International Peacebuilding (Autesserre 2010, 42)

Context of Beni, DRC

Beni is a small city in the eastern great lakes region of the Democratic Republic of Congo (DRC). Like many cities in Africa it is growing quickly but with little intentionality because of the lack of resources and knowledge to develop urban strategy. Resulting challenges are that there is very little development of infrastructure or municipal services to support the population, and there is land conflict because of layered and confusing land administration strategies. Séverine Autesserre in her book Trouble with the Congo: Local Violence and the Failure of International Peacebuilding, argues that peacekeeping efforts have failed due to a centralized strategy of conflict resolution instead of, in addition to those actions, applying local resolution initiatives and making an in-depth attempt at understanding what is happening in the cities and the surrounding region.¹

The Christian Bilingual University of Congo (UCBC) is a university that was established in Beni in 2007 and has an active role in the community. In 2014 the university established the Integrated Research Institute (IRI) to promote collaborative research across faculties and with other community actors. One of the first initiatives of the IRI was the launching of their GIS program in response to the clear need to know more about the city and region. The IRI recently received grant funding to move forward with mapping research but realized that a comprehensive strategy would be necessary to achieve their short term and long term goals. I had seen this same need when I first visited Beni back in 2012, and when I began my thesis research in 2013 on the topic of digital mapping, sent them a proposal to partner with them to design a mapping framework for the city.

¹ Autesserre, Séverine. The Trouble with the Congo: Local Violence and the Failure of International Peacebuilding (New York: Cambridge University Press, 2010), 42.
I had early discussions with leaders at UCBC and IRI to discuss the context of Beni and their goals for the project. I learned that the city does not have a city-wide power grid and that the municipality has no digital base map of the city. There is a growing 3G mobile internet network and an estimated 5-10% of adults have smart phones, though the number is growing exponentially each year. The university has no server or computer network at the present time because of intermittent power. This will also change as the university is setting up a solar panel system that will supply power around the clock. The IRI has particular interest in creating maps that address land conflict, agricultural methods, and basic demographic information. They also expressed interest in forming the maps into a platform that could be a resource for the community, and apply the newest developments in digital mapping, such as the ability to simulate and interact with data, or to collect reports from the public.

Framework

All of these ideas are laudable but there exists real challenges in implementing them, especially in a developing country. All of the challenges that Renee Seiber addresses in her article on PPGIS need to be considered in the establishment of a mapping program in Beni. The thesis proposes a framework methodology for organizing the community and digital processes so that the design of the program can be easily understood, critiqued, and manipulated by the project initiators. Buckminster Fuller’s proposal is an example of a mapping framework. Even though it couldn’t be realistically implemented, he
saw the need for an intellectual structure that establishes how the data is gathered, stored, shared, and interacted with. He realized that there is a structure of inputs and outputs. There is a community framework that is the structure of physical programs that feed data inputs into the machine; a digital framework is the digital processes that calculate, transform, and visualize the data; and finally another set of community processes implement changes in the physical environment as a response to what is learned from the map. PPGIS initiatives establish similar frameworks to that of Fuller’s but they are actual implementations and are applied on a smaller and more focused scale than what Fuller imagined. The initiatives also differ considerably depending on the goals and purpose of each initiative. As drawn from my analysis of mapping theory, I will address a selection of precedent initiatives and my own initiative under the themes of agency of accumulation, participation, and re-territorialization. In the following chapters I will locate these dialectics within mapping theory, then analyse a selection of precedents through the lens of several questions I develop, and finally I will seek to respond to each of the questions in the design of the framework for Beni Atlas.

The research, titled Beni Atlas’, studies theory of mapping, analyses a current use of digital maps, and proposes how current mapping tools can be applied in a designed framework to work for the more productive empowerment of a community in the developing context. It argues that digital maps are instrumental in shaping physical space, and challenges architects today to see design as a participatory process that goes beyond just the static forms of buildings. I am implementing and testing my methodologies by partnering with UCBC in Beni. The research proposes the design of a phased mapping framework that responds to the needs of the context, could be initiated by the university, and could become a tool that is owned by the community. The framework is comprised of a selection of open source digital tools and a proposal for how they might be combined into a wrapped interface. It also addresses the community framework that would be required for the digital framework to be grounded in the community, both for creating the inputs and receiving the outputs. The phases apply digital mapping tools in three levels of map creation: base maps, thematic maps, and an interactive map interface. The goal of the framework is to unite data from bottom-up and top down sources, provide clarity and understanding for users, and become a tool that allows for communication and partnership between different actors in the community.
1.2 Study of Mapping

Form and function of the map

The framework was introduced in section 1.1 as the system of community and digital processes that are used to create a map and implement changes in a community based on what is learned from the map. Because the principal goal of the framework is to provide agency to a community, a useful reading of mapping theory is to explore how maps have provided agency in the past. Agency can be defined as an “action or intervention producing a particular effect.” In mapping, the effect is being acted upon the site by a person or group that are the “actor” or “intervenor”. Maps are therefore an intensely political tool because they are an expression of authority and are used to direct and control an environment to achieve a desired (particular) end. This is the maps root function.

Maps are created across multiple mediums, particularly today. People apply methods of mapping that have existing for hundreds of years such as hand-drawing, and employ other mediums invented at different points in history such as applying triangulation to drawings, creating prints, using GPS devices, or taking a photograph of the earth from space. As the map took on different forms throughout history because of changes in technology, its spatial function also changed. In studying different mapping applications in history, I have pulled out three particular functions of mapping that evolved at different times. The first function of the map was to primitively accumulate land and to state ownership over it; the next function with change in technology was to make the land productive, mostly made manifest in the design of cities that were being established by that time. The last function comes with the advent of digital technology that is using maps to redefine our physical environments altogether.

A study of these three general functions of mapping reveals that they have two characteristics in common. The first is that there is an ideology associated with each jump in technology of mapping. Ideology can be defined as “a visionary speculation, especially of an unrealistic

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or idealistic nature.” The newest mapping techniques of each time period were often used to imagine and impose the ideas of a perfect society. The second shared characteristic is that each function is dialectical in the way it operates. To call something dialectical is to pose that it is “concerned with or acting through opposing forces.” The following section explores these characteristics in order to give the map-maker a better understanding of the intricacies of mapping. By understanding the pursuit for perfection and the dialectics that exist in mapping, it is possible to become more sensitive designers. Drawing from the theoretical exploration I will pose a series of questions that can be asked of any mapping framework, and also see how maps have changed the fabric of Africa, particularly the Democratic Republic of Congo where I am proposing the design of a mapping framework.

Agency by primitive accumulation

The first and most basic form of agency of mapping is the process of imprinting one’s intention onto the physical world by representing it on a map. As Rousseau describes in his book *On the Origin of the Inequality of Mankind*, “the first man, who, having enclosed a piece of ground, to whom it occurred to say this is mine, and found people sufficiently simple to believe him, was the true founder of civil society.” *Primitive accumulation* is a term coined by Marx to describe how the capitalist movement was driven to expand and accumulate wealth. Although Marx does not speak of maps in his writing, he describes the technological expansion and territorial exploration that was achieved with the use of maps. Although the map’s role of primitive accumulation could trace itself to the beginning of history, it is with the technological inventions of navigation, the steam engine, and the printing press that mapping became an agent of widespread change. In the early modern world maps took the form of hand-crafted depictions ranging from the scale of land plots to the expansive discovery of new territories. The function of maps can be seen from two different perspectives. Perhaps the most visible purpose was for the progress and growth of the state. The other perspective is that maps served as a method to claim false ownership over land, and to represent biased imagery to distract and pacify the public. Primitive accumulation is dialectical because once an object is represented on a map, it at once gets simplified down to a point in a cluster of many nodes. The simplification makes the map easier to imprint on people’s minds, but also disconnects it from the richness and complexity of the real place.

A primary example of maps with the function of primitive accumulation are some of the maps that were created in the early modern period (1500 – 1800). In his book *Trading Territories: Mapping the Early Modern World*, Jerry Brotton describes how the maps created in that time were primarily tools to visualize and establish imperial authority by depicting territorial conquests and commercial trade routes.¹ Brotton describes the example of the “Spheres” tapestry, a map of the globe commissioned by Joao III of Portugal that depicts the trade routes along the coast-line of Africa and Asia. The map itself embodies the places on the map by being made of the very materials of wealth that were being brought back from the distant lands. The king and queen are portrayed on the map as divine stewards over the territory. Maps such as these, however inaccurate compared to maps today, impressed themselves onto the culture of the day and allowed the crowns to succeed at their political and commercial exploits.

After navigation, the printing press was the next technological advancement that changed the form of mapping. For the first time maps could be distributed to the masses. Geographers at that time were hired by sovereigns to visualize their spatial interests and even establish monopolies on which maps were widely distributed. Brotton describes Mercator and Ortelius as two such geographers who found their niche in the field and learned the balance of being politically sensitive while still following the trends of the market.²

2 Ibid., 153.
Mapping as primitive accumulation impacted Central Africa during colonization when King Leopold II of Belgium claimed the Congo basin as his personal land to transform Belgium into an empire. Beginning in 1870 he sponsored the explorer Sir Henry Morton Stanley to lead the expedition to plot out what would become the Congo Free State and would initiate the European colonial race on Africa.\(^1\) Mortenson’s charts of the Congo River basin removed the last unknown territory from European maps and delineated areas of British, French, Portuguese, and Belgian control. At the Conference of Berlin in 1885, Leopold used his knowledge to convince the US and European powers to formally acknowledge his ownership of the territory.

The preceding examples demonstrate how the main function of maps at the time was to accumulate new territory by imprinting an image of it onto society. Either the process of mapping can be viewed as progress or the very opposite. Mezzadra and Neilson explain in their article *Fabrica Mundi: Producing the World By Drawing Borders* that representing objects on a map transforms space into a commodity that can be bought and sold and causes it to lose its true character and take on a “phantom-like objectivity.” It allows decisions to be made on the “object” without having to think of the complexity of the real place. It can also express an ideology of progress in the way that the intentions are communicated.

**Agency by optimization**

Maps would change form and function again with the invention of the telegraph, combustion engine, and electrical devices. Mapping began to become increasingly scientific and take on the form of complex networks and flows that served the purpose of making land, and particularly cities, more productive. In 1950 Norbert Wiener described; “The city is primarily a communication center, serving the same purpose as a nerve center in the body. It is a place where railroads, telephone and telegraph centers come together, where ideas, information and goods can be exchanged.”\(^3\) A part of making the city and territory productive was to involve the public as active participants in the process. Once again a dialectic exists as productivity can be viewed as either growth and progress or as the transformation of the city into an objectified machine. Participation can similarly be viewed as the public being encouraged to be active participants towards a communal goal, or the

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Beni Atlas’ participation as docile and distracted citizens that leaves space for exploitation. Maps are used to design the networks and cities but also to represent the ideologies to the public.

In Armand Mattelart’s essay Mapping Modernity, he traces the origin of the “network” back to France where charts were created to coordinate movement through military barracks. The word also came from biological connections such as the nerves in the body. By the mid 17th century, France boasted of an optical telegraph network over 5000 kilometers in length. As the telegraph reformed communication, development of the railway network reformed transportation. Many writers, geographers, theorists, and engineers speculated on how the new freedom in communication and movement would create ideal, democratic societies that mirrored the concept of the Greek agora.

Organized networks were also used to make cities more efficient. One example is the Haussmann renovation that cut networks of boulevards through the old city of Paris. Though the project greatly improved sanitation and movement through the city, critics denounced the project as a way to be able to keep military control of the city, and to impress the population with the monuments that were the focal points of the grand avenues. Walter Benjamin in his book The Arcades Project describes the great public monuments and exhibitions as “phantasmagoria”, a distraction to keep the minds of people proud of the accomplishments of the state and too busy to question authority. Along with the great monuments there were also large exhibitions during the period that displayed maps and artefacts of progress. Mattelart points out how the universal exhibition was represented by a miniature globe that symbolized human community and communication.

New inventions in the 1900s of the electric telegraph, radio communications, and aviation, all supported a vision that shifted beyond the state to the international community. The participative role of the citizen was bolstered with the communal viewpoint introduced by travel into space. Even before a photograph of earth was taken from space that showed the earth in perfect accuracy and entirety, theorists and scientists predicted the communal perspective that the image would solicit. In Buckminster Fuller’s 1938 book Nine Chains to the Moon, he describes how the optimization of the world’s resources called for “vertical thinking and holistic views of the universe”. An efficient civilization seemed a thing to grasp when humanity could look back

2 Ibid., 176.
3 Ibid., 178.
on itself introspectively to develop strategies for human progress.¹

In the same way that maps were being used to design efficient European and American cities and encourage a participative ideology, mapping was also used to project an ideology to affirm the reasons for having a colonial presence in Africa and also to make the cities efficient for collecting and shipping the goods back to the colonizing state. In the book *Kinshasa: Tales of the Invisible City*, author Filip De Boeck writes about a simplified “African village” that was displayed at the 1930 World Exhibition that promoted an Africa that was inferior and in need of European influence. It is but one example of how the way Congo is pictured renders “invisible” the actual place. He writes;

\[\text{The great discrepancy which is generated in the mirroring process between this topos, the Congo of the imagination, and the topicality of the physical Congo, seems to go unnoticed by most. The strength of the imagined place renders invisible the reality of the African site. What the African Village of the 1930 World Exhibition revealed is precisely this rupture, this fault line between representation and reality which is so characteristic of the problematic place of “place” in the colonial and postcolonial contexts.}^2\]

1–13 Photograph called Earthrise taken on first manned mission to the moon in 1968

In addition to representation of the Congo back home and changing their own capital to be like Paris, the Belgians also developed the capital city of Leopoldville into a productive city. De Boeck describes how the Belgian state worked to establish an indigenous working class similar to the proletariat in their own nation state, and put them in their (participative) place in society by the use of “state technologies of power and control.” The Belgians were fearful of the illness and degeneracy associated with the Congo and therefore their prime strategies were to sanitize the spatial layout of the villages by creating a new settlement typology and restricting the movement of colonized citizens. The plan of Leopoldville located the western “Ville” at the center and the “Indigenous Cite” to the periphery with a buffer zone in between.  

These types of city plans were not limited to Kinshasa. Much of the planning in colonial cities in Africa adopted similar spatial strategies. In his book Planning Power, Ambe J. Njoh compares the planning of cities across states that were colonized by the British and French. Although their style of governance was very different, Njoh argues that many of their spatial strategies were much the same. One significant change was how colonizers implemented their own land ownership legislation in territories originally based on communal ownership. It began by colonizers trying to purchase land from local chiefs and went so far as to create legislation that defined “unoccupied and ownerless land” as property of the colonial state. The colonies needed qualified administrators and so designed suburban neighbourhoods with large plots and European style homes to attract Westerners. Administrative centers were often placed on the highest elevation and immediately to the outside was the commercial zone tied to a seaport or railway station. Housing for the indigenous people was denser and located separate from the white neighbourhoods further in the periphery. Even though he doesn’t describe Kinshasa in his book, the image Njoh paints is very similar.

The map’s ability to oversimplify reinforces the dialectic of the relationship between representation and production. Although an object is not yet built, it still represents an imagined result in society and therefore imprints itself there whether or not it portrays the real truth. Mezzadra and Neilson describe it well in Fabrica Mundi when they touch on the very title of their article; “The use of the expression fabrica mundi signals, in the form of a slippage, the cartographer’s awareness of the fact that representing the world on a map also means producing

1 Ibid., 24.
2 Ibid., 28.
4 Ibid., 30.
Maps functioned to design the societal machines that would bring the west into a modern world. Critics would argue that participants in the efficient network thought that they were actively participating to produce positive change, but it was only a mirage to hide the realization that they were themselves transformed into a commodity to be exchanged.

Agency by re-territorialization

 Territory is the politics of a space since it is defined as an area that is under the jurisdiction of a ruler or state. The term “re-territorialization” was coined by Gilles Deleuze and Félix Guattari in their writing *A Thousand Plateaus* as the political restructuring of space by the design of new power. Since then the term has been used to describe the affect of mass media on global culture. Re-territorialization is used in this discussion to describe the potential of the digital map to redefine the politics of the space it represents. The digital map re-territorializes by offering a new, community contributed knowledge that can drive political decision making. Agency by re-territorialization not only expands on the previous two forms of mapping agency, it also creates new opportunities. Expansion is possible because unlike the traditional forms of agency that are only designed by a select few who direct the development of society, digital technology offers the ability to distribute agency to the masses. Two key capabilities that digital tools have are the ability to store data beyond human capability and the ability to represent a dynamic image. Because the computer’s memory is as long as the space available to store the data, the digital map could represent an indeterminate amount of information and can change what the user sees over time. Unlike the physical world, it defies physical laws and is capable of instantaneous inter-connectedness that does not exist in physical space and opens up a realm of opportunities. Re-territorialization is also dialectical in nature. It takes the dualities of the other two forms of agency and exponentially increases their scope and consequences. Similar to the other two forms of agency, re-territorialization could be considered the ultimate democratic tool for solving political and social problems around the world. The other side reveals that the system is still designed and therefore has someone in the role of designer or monitor of the system who establishes the rules and can perhaps even change them. A third dimension of digital map-

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ping is the opportunity to get so lost in the ideology of the represented space that it can no longer function in real space. The digital map offers the greatest opportunity for change but the greatest danger to cause harm in a massive way.

Just as the first two functions of mapping have their associated ideologies that came with the advent of new technologies, the case is no different in the digital era. Armand Mattelart in *Mapping Modernity* describes how the ideology of the growing communication network mirroring Greek democracy transformed with the invention of computers into an ideology of the “information agora”.\(^1\) If information could be made available to everyone, the concept was that the world could become a democratic “global village”. In 1994 Al Gore proposed his idea for an “Information Superhighway”. He presented it as a network that “will circle the globe with information highways on which all people can travel...The GI will not only be a metaphor for a functioning democracy; it will in fact promote the functioning of democracy by greatly enhancing the participation of citizens in decision-making. And it will greatly promote the ability of nations to cooperate with each other.” Critics, however, considered these utopian ideals folly. In one of the first texts to locate problems of the communication network, authors Simon Nora and Alan Minc saw the network as the guarantee of a “new global mode of social regulation” and proposed national independence in the installation and maintenance of it’s own databanks.\(^2\)

Frederic Jameson in his book *Postmodernism, or, the Cultural Logic of Late Capitalism*, tries to resolve what it is that brings the digital period to a new dimension. He describes the digital age as the instigator of an image culture where a large amount of human experience is lost in the image realm and creates a “disjunction point between the body and its built environment”. He defines the change as “Mutation in space - postmodern hyperspace - that has finally succeeded in transcending the capabilities of the individual human body to locate itself, to organize its immediate surroundings perceptually, and cognitively to map its position in a mappable external world.”\(^3\) He describes the hyperspace as a space we haven’t learned how to represent and challenges the need for “an aesthetics of cognitive mapping” to help us to re-situate ourselves.

Brian Holmes in his essay *Counter Cartographies* and Ole Bouman *Re: Orientation*, highlight the same problem as Jameson and offer their current perspectives. Holmes brings his readers through a selection of mapping and graphing projects using the newest research in

2. Ibid., 186.
mapping computation and proposes that they are resolutions to the spatial chaos that Jameson describes two decades earlier.¹ I agree with him that the tools have now reached the capability (or are very close) of creating such an aesthetic, but disagree that the maps he discusses (see figures 1-18 and 1-19) offer the type of digital-physical orientation that Jameson refers to. The maps bring agendas to the forefront but do not provide an avenue for acting on that knowledge. Bouman also proposes current tools to offer the solution, but he goes one step further to realize that connecting the map with the community is no easy task. He outlines three barriers that must be overcome in uniting digital maps with the physical environments they represent: For an idea to turn into a change there needs to be “political-administrative underpinning”, there needs to be cohesion between gaps across scales, and architects must stop thinking that the execution of ideas is outside of their scope. Images can hold an ideology that can’t function in reality until we establish the programs and frameworks necessary for the maps to have physical agency. Tafuri writes in his essay Toward a Critique of Architectural Ideology; “Architecture as the ideology of the Plan is swept away by the reality of the Plan the moment the plan came down from the utopian level and became an operant mechanism.”³ These realities are important because if we can’t connect maps to real space then we risk being lost forever in the world of images and our minds becoming entirely disconnected from our physical bodies. As advocates for quality, physical, built space, architects need to firmly oppose this direction of digital media.

Response

By studying theory that outlines the different forms and functions of mapping, it is clear that there is a consistent rift between what is intended and what is produced. James Corner in his essay Agency of Mapping argues that a map is never neutral and that it always has underlying intentions. Ideology can be an effective driver because it motivates innovation and positive change but there is a need to learn from the experience where a too simplified version of the world can actually mean doing the opposite of what was intended. From studying what I have determined as three functions of mapping I have drawn out several questions that can be asked of maps: Accumulation asks of the map whether it allows the individual to represent their own Participation needs to differentiate between the demands of the clients and the desires of the users. Architects, needing clients with power and money, are usually on the side of those in power and willing to embrace and express in built terms the ideology and economics of these clients, to the exclusion of the desires of the potential users. There is thus a removal of the general public from the processes of architectural production, which in turn leads to a sense of alienation of the users from their environment.

information and how it might personally benefit them. It also asks whether their interaction with the map is at all personal or if they become objectified into raw information. **Optimization** asks of the map whether users are cooperating to accomplish a greater goal and what that goal might be. It also asks who is in control and whether users are full participants, partial participants, or only have the semblance of participation. **Re-territorialisation** asks what the scale of the initiative is and if it can be extended, if the map redefines space by changing the way a person perceives or interacts with it, if the map is personalized for users, and if the framework is administratively grounded by having programs in place that affect change.

Although James Corner in *Agency of Mapping* does not address the problem of the image disconnect, he opens up a perspective of what mapping is capable of. Without even focusing on digital tools he outlines that maps can personalize themselves to the user, not necessary presenting itself in the orthogonal view that we are most familiar with (Corner defines this as “drift”), maps can work in a rhizomatic way that establishes networks, and that maps can run through interactive simulations. All of these capabilities hold great promise for how they can offer ways of learning about our physical communities and propose ideas that can then move through the sometimes challenging process of implementation. As a response to my exploration of the theory around the functions of mapping, I have learned that a map framework needs to find ways to root into the community and needs to clearly address the realities of how people establish themselves on the map and participate with the map to change their circumstances in real space. In the following section I will address the context of Beni where I am designing a mapping framework, and then will review a series of interfaces, frameworks, and concepts and establish how they align with my critical explorations.

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1.3 Context

Summary

Beni is a small city in the province of North Kivu that has an estimated population of 300-400,000 inhabitants and covers an area of approximately 184 square kilometers. The city appears to be growing quickly as rural villagers are migrating to the city for employment and security. There is very little intentionality in directing the growth of the city or knowledge of the city’s general makeup. Beni was established in 1929 by Belgian colonialists as an administrative outpost because of its strategic location close to the border of Uganda. Beni had very little colonial influence in the years before independence in 1960 because the population of the town remained very low during that time.

Form

The city has four “communes” that are divided by the Routes Nationales no. 2, no. 4, and no. 44 that cross at the city’s central “rond-point” (round-about). The only street that is paved is the main road running north-south. The communes are each divided into six to twelve “quartiers” (thirty in total) that each have their own administrative office. There are several streams and small ravines that traverse the city and are used to define many of the neighbourhood boundaries. There are hundreds of bridges throughout the city, many of them informally constructed out of logs and timber. The northeast and particularly the southeast communes have a hilly terrain that climbs up steadily toward Virunga National Park that borders the east of the city.

There are households within the city that are considered a “slum household” as defined by UN-Habitat because they lack one or more of the following:

Durable housing of a permanent nature that protects against extreme climate conditions, sufficient living space which means not more than three people sharing the same room, easy access to safe water in sufficient amounts at an affordable price, access to adequate sanitation in the form of a

1 Rapport Annuel de l’Adminstration de la Ville de Beni pour l’Annee 2014
Map depicting partial water grid

Map from the mayor’s office depicting administrative divisions
Chapitre I — Contexte
Based on my observations of the city I estimate most of the households in Beni as having one or two “shelter deprivations” and would not be classified as living in extremely poor conditions meaning that households lack more than three basic shelter needs. Houses are typically built out of wood and earth or brick with corrugated metal or thatch roofing and are located on individual plots of land. Land is administered by the neighbourhood cadastral offices that are managed by Heads of District (“Chefs du Quartier”). The city has no city-wide power, water, or sewer grid. There is a partial water grid near the centre of the city. The rest of the city gets their water from either personal or shared fountains, wells, or springs, and for sanitation either use personal septic systems or communal latrines. There are several businesses that have established partial power grids that run off of diesel generators.

**Culture**

The culture of the city is very much that of a large village. Most people get around the city on foot and so the streets are always populated. There is farming on small plots within the city. There is a significant informal retail sector of market stalls, fuel stations, money exchangers and street vendors that occupy centres that are spread through the city. The second form of transportation is by “moto” (motorcycle taxi) and main intersections or landmarks generally have a “stage” (stop) with motorcycles available to hire. Many of the streets could be considered footpaths because they are not traversable by car. Although the larger streets have names, they are known informally and people find their way around using landmarks. An important type of landmark in the city is the “rond-point”. Roundabouts are often established by neighbourhoods throughout the city as community landmarks and places to gather. Because there is no electricity, food is purchased daily from open-air fresh-food markets and cooking is done on charcoal stoves.

**Players and Resources**

UCBC is a university that was established in Beni in 2007 and offers degree programs taught in English and French across applied sciences, social sciences, and humanities. The university applies three principles of “academic inquiry, community engagement, and institutional service” that are meant to encourage participative learning that asks how problems can be solved to meet the needs of the population.

2 Ibid.
4 Ibid.
2013 the university established the Integrated Research Institute (IRI) to promote collaborative research across faculties and with other community actors. One of the first initiatives of the IRI was the launching of their GIS program in response to the clear need to know more about the city and region. The IRI recently received grant funding to move forward with mapping research but realized that a comprehensive mapping framework would be necessary to achieve their short-term and long-term goals.

With its first funds the IRI arranged two weeks of training in the use of ArcGIS, a survey application called ODK Collect (OpenDataKit) and a GPS tracking application called GPS Essentials. The IRI purchased eight smart phones that could be used for field data collection. The IRI performed a search for existing maps of the city and discovered that only a few hand-drawn maps exist with very little information. Knowledge is restricted to what the local chiefs know of their neighbourhoods and a few localized hand-drawn maps from several neighbourhood cadastral offices. The IRI approached the municipality to measure their interest in the project and received a very positive response.

Project Needs and Objectives

The thesis uses Beni as a context to formulate a mapping framework. I identified the following project needs and objectives that the framework should address:

Big plans but start small: Maps have not been used in the city and therefore it is important for the framework to introduce maps into the community sequentially before publishing maps of more sensitive themes. For example, mapping could eventually be used to map the problem of land conflict in the city and region by using knowledge and transparency as a first step to resolution. The framework can be brought out in several phases as a response to the need to start small but eventually map the bigger issues. The creation of a base map is a good starting point because it can serve as a valuable reference layer that all other data can be built on, and can work to establish key information that is necessary for future data analysis such as road names, neighbourhood boundaries, and points of interest. It also gives the GIS team time to hone their skills with the GIS tools.

Demographics: A second step for the community to know more about itself would be to perform a demographic survey. The last formal census was thirty years ago and the population is unknown. Other useful information could be obtained such as household infrastructure information for power, water, and sanitation, and migration data describing where people came from when arriving to the city. Although this type of information may not be immediately valuable to the population, the data could be analysed in research to inform next steps of the city’s development and build up a historic understanding of how Beni was formed.
Beni Atlas’
Framework that grows with the development of infrastructure: There is a lack of dependable electricity in Beni that greatly influences where work can be performed and where the digital processes can take place. At the beginning of the project any volunteers or researchers would need to work off of personal or university laptops. For this reason and also because the internet is slow and expensive, it would not be possible for participants to download or purchase proprietary software. It is necessary for the framework to propose open source and easily transferable data collection and framework solutions that can then grow over time with the formal infrastructure of the city and the university.

Map as community resource: The region has 3G internet and the use of smart-phones is on the rise, but my estimate is that it is still only limited to 5-10% of the (adult) population though the increase will be exponential over the next few years. For the map to be made available as a community resource it is important that a program is in place that disseminates the maps in both physical and digital mediums. A second program needs to be established to consult the community and involve them in the creation of the maps. The framework must address these physical community programs as clearly as the structure of digital tools. Dissemination strategies can include making the digital map available on a computer in the university library, publishing them in community journals, and painting the maps as murals around the city.

Innovative and extensible: Digital mapping tools have capabilities that allow for activities that include aggregating data from different sources, collecting and reporting, networking, and running simulations on a map. The methods allow community members to have the ability to actively contribute to a dynamic map of the city. The framework can imagine how these methods could be used to respond to specific problems in the city of Beni and can be designed to be extensible so that it is able to include additional thematic layers and functions that can be added in the future.
1.4 Study of Mapping Frameworks

The following chapter outlines a selection of mapping framework precedents. Precedents include work of Chora, Stamen Design, Extreme Citizen Science, MIT Media Lab, and Engagement Game Lab among others. The selected precedents have different ambitions and methods to demonstrate how broadly digital mapping tools can be employed. The first four precedents are web and mobile interfaces that have been developed and used in North America and are on the front-line of digital mapping capability; the other four are frameworks that have been established as part of development initiatives mostly in Africa. The goal of the framework analysis is to understand the tools and methods used by each initiative and how they respond to the context, and to look at them through a lense of questions drawn from the theoretical discussion. The questions are the following:

From the function of accumulation:
Does the user add anything personally to the map?
Does the user gain agency?

From the function of optimization:
Are the users active participants?
Is there shared agency?

From the function of re-territorialization:
Is the framework scalable in space and time?
Does the framework redefine space by changing the way a person perceives or interacts with it?
Is the framework personalized for users?
Is the framework administratively grounded by having programs in place that affect change?

Sequence diagrams describe the process of inputs and outputs in each framework and the relationships between agents, the technology, and users. Grey boxes represent the community processes and black the digital processes. The analysis uses three terms of “framework”, “platform”, and “tool”. For the purpose of describing the precedents, a framework is the full structure of the mapping program, a platform is a wrapped portion of a digital framework, and a tool is a digital element that is being used within the digital framework or platform. The circular diagram like the blank one in figure 1-20 visualizes the
Chesapeake Bay Grasses by Stamen Design

The Chesapeake Bay Grasses map is a simple and elegant website that was designed by Stamen Design. The interface was designed to visualize information about the wetland grasses in the region. The map allows users to interact with the content and comprehensively displays a large amount of data. A user starts by looking at the map as a whole, but by moving the mouse across the screen, can choose to select a region to zoom in and view in more detail. For example, by selecting a region one can discover the specific trends of water temperature, salinity and turbidity, and see what plant species grow there. The user can also see data through time by selecting a different point on the time-line or pressing play to watch time pass in a stop-motion sequence. Graphs beside the map dynamically summarize the data from whatever region or time that is selected.1

By analyzing each framework in this way, the intention is to learn from the community and digital techniques that were used, uncover the dialectics present in the frameworks, and determine the level of success the designers had in meeting their ambitions.

2 “Chesapeake Bay Program,” http://www.chesapeakebay.net/.
maps, though the content likely draws researchers along with similar individuals or groups that contribute to the Bay Program. The map aggregates and represents years of data collected by the Bay Program. The website was created using Javascript, the Javascript mapping API Leaflet, and the data management API D3 (Data Driven Documentation). The Leaflet library was used to build the interactive map, and D3 adds additional dynamism to the data displayed on the map and the corresponding graphs.

The map of the grasses contributes an idea to society by being an accurate and comprehensive source that displays data that the program deems important. It might be more difficult for other groups to do development that would have negative impact on the wetlands if the visualization would predict a negative impact. In this way the website gives shared agency to the Chesapeake Bay Program to be an authority on issues related to the wetlands. Other groups such as individuals living in this region do not have any input into what is displayed on the website, but do gain knowledge by being general viewers of the content. The project redefines space by representing data about the region that a user could not process visually and therefore offers a new perspective that may influence decisions in the site. The map is indirectly administratively grounded because it can be assumed that the Chesapeake Bay Program organizes their community initiatives based on what they have learned from the visualization of the data.

Does the user add to the map?
Does the user gain agency?
Are the users active participants?
Is there shared agency?
Is the framework scalable?
Is the framework redefining space?
Is the framework personalized for users?
Is the framework administratively grounded?

1–31 Wheel diagram rating the functions of the framework

1–32 Framework diagram: Processes

1–33 Framework diagram: Relationships
Sourcemap

Sourcemap is a software tool that locates and connects the people and places that are involved in the process of making a product and putting it on the market. The project started as research at the MIT Media Lab and then became an enterprise software start-up. The tool allows companies to create a supply chain map of their business so that they can understand the big picture and more easily manage vendors, shipments, and inventories, and analyse risk, cost, and environmental impact. Companies can also share the map with their customers to promote transparency about their products. Users have the choice of having a private, semi-public, or public platform and can choose to use the tool to connect and communicate with suppliers and manufacturers along the chain. To date the enterprise software has been used by global brands in pharmaceutical, apparel and furniture sectors. A free Sourcemap option is available for anyone who wishes to create and publish a supply chain map.¹

The scale of the framework is global and Sourcemap is the agent of the framework who makes sure that the servers are secure and operating. There are two levels of users of the framework: The first level is the companies that are using the framework and the network along the supply chain; the second level is the consumer who can see the network if it is made public. The map connects nodes of information and connections.

Chapter One — Study of Mapping Frameworks

Does the user add to the map?
Does the user gain agency?
Are the users active participants?
Is there shared agency?
Is the framework scalable?
Is the framework redefining space?
Is the framework personalized for users?
Is the framework administratively grounded?

SourceMap presents the networks visually to the user. SourceMap does not share what specific set of tools they use, but they have created a desktop application that connects to a cloud of servers.

SourceMap offers agency to companies to make more calculated decisions based on being able to see the big picture and understand and therefore better address the weakest points of the supply chain. On another level it provides a certain amount of shared agency to buyers to select products based on where they come from and pushes for common transparency in the commercial sector. The framework is scalable because any number of companies can choose to use the tool. The map shows a simplified strategic image when zoomed out and shows more details when zooming in. The framework redefines space for the reason that it gives a spatial footprint to a product and decisions affecting that footprint can then be manipulated in response to the information. The framework allows the software to be personalized to suit the needs of the company.

1–35 Wheel diagram rating the functions of the framework

1–36 Framework diagram: Processes

1–37 Framework diagram: Relationships
Community PlanIt by Engagement (Game) Lab

Community PlanIt is a framework that can be employed by a municipality or organization to involve the community in assessing community needs through participation in an interactive digital environment. By giving reports and voting on different elements, a community member can participate in an ongoing discussion of community needs and what physical measures might be implemented to meet them. The framework uses a base map of the city so that reports and discussions can be visually localized and analyzed by location.\(^1\) An example of a Community PlanIt initiative is a city-wide visioning project called Detroit 24-7 in partnership with Detroit Works Project Long Term Planning. The game occurred over 21 days with 1033 registered players and over 8400 comments.\(^2\)

The framework is at the scale of the neighbourhood or the city. Community PlanIt is the agent in partnership with a local municipality, organization, or institution. While Community PlanIt is in charge of making sure the digital game runs smoothly, the two groups together plan the vision and objectives for the game and the partner group is responsible for coordinating the supporting programs in the commu-

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The users are any community members who wish to be involved and have internet access. The framework employs game mechanics to motivate users and crowd-sourced reporting to collect and analyse the data from users.

Community PlanIt is intended more for shared agency than individual agency. The user contributes democratically to the game along with other users, but their contribution is evaluated as one node out of many and the parameters of the game are preset by the game creators. For this reason the personal contribution, agency, and participation are only partial. The project is highly scalable as different versions of the game can be created to suit community objectives in different cities. The framework only partially redefines space as it offers a user the opportunity to express how they think the city should change but does not visualize it. Users have a profile that allows them to navigate the game and vote and comment. It is the role of the municipality or other community partners to design a program to implement community actions that respond to the information collected from the framework.
LocalData

Local data is a tool that allows organizations, governments, and researchers to be able to better collect and work with spatial data. Instead of using paper maps and surveys, LocalData combines those tools into a digital framework that automatically updates on the map as the data is collected. The base map and custom surveys are prepared in advance and then connected on the cloud with the LocalData smart-phone application. A group of participants can then go around town to collect data using their phones.¹ LocalData has been deployed in over twenty cities, mapping spatial data such as vacancies, site selection for transportation hubs, and supply chain logistics. They plan to expand their capability to include non-spatial data like education and health data, environmental data, and transit data. An example of one of their projects is the mapping of vacant properties in the city of Muncie Indiana in partnership with the consulting group Place Economies and the municipal government. Fourteen students from the University of Pennsylvania participated in the data collection and documented 4286 lots in four days.²

The framework is at the scale of the neighbourhood or city. The agents are LocalData in partnership with the municipal government, an organization, or an institution. Users are the partnering agents, however

the participants of the data collection can also be considered users. They would primarily be students, organization volunteers, or community members. The framework is designed for the purpose of data collection. Although the data is represented during the collection of the data, what happens to the resulting data is at the discretion of the partnering agents. The method that the framework employs is collecting and reporting with a select group of participants. The framework is built with HTML5 and Javascript using the Leaflet and Node.js libraries. They employ an open-source document database called MongoDB but are working to transition to an open-source SQL database called PostGIS.

Only partial individual agency is gained because the user is participating as a collector of information that is prescribed by the organizers of the initiative (the agents). Agency for this framework is more for the agent than the user. The person might be involved because they agree with what the data collected will be used for. There is only partial participation in the initiative because the participants do not necessarily have a say in what information they are collecting. There is shared agency because there is generally a community goal for each initiative. For example, the collection of vacant lots and buildings in Muncie will allow planners to make decisions based on the data, that in the long run will benefit the city. The project is scalable because it can be implemented anywhere with other partners and initiatives.
Chora Taiwan Strait Atlas

Taiwan Strait Atlas is a research initiative lead by Chora Architects to map the area of the Taiwan Strait. The goal of the project is to promote collaborative projects across the strait by creating a comprehensive set of maps that document the shared history, ecology, movement, trade, and potential developmental opportunities of the region. Chora is partnering with two local universities in both China and Taiwan who are then reaching out to various stakeholders and community groups. The project team performed thorough research to create a detailed base map of the region. They are then layering more informal information collected from community charrettes that involve stakeholders and community participants in a series of design scenarios. The maps and research will be published as a hard-copy atlas.

The framework has a regional scale and the agent is Chora. They intentionally remain the sole agent to present the atlas with as little bias as possible; however, they attempt to involve as many user groups as possible. There are two levels of users of the map. Participants in the project’s community programs represent all user groups and contribute by providing their ideas and feedback in the scenarios. Other users will be the people who read the published map. The framework uses two mapping techniques of aggregation and simulation to collect and represent data. Aggregation is the main technique because the creation

1 “Chora Research: 2006 to CURRENT Taiwan Strait Smart Region,” http://www.chora.org/?p=139.
of the atlas is primarily a collection and curation of data from different sources. Simulation is a secondary strategy to involve participants in a series of scenarios for community action prototypes that Chora develops in response to the data. Chora uses a GIS map editor and then relies on printed maps to present the prototypes and scenarios.

Participants have a partial imprint on society and individual agency because they are able to participate in the community charrettes that are contributing to the research of the region. Participation is limited because it involves only a small group of individuals. The common goal of the initiative is the creation of an atlas that will foster interest in development and problem solving in the region to shift focus to future economic opportunities between China and Taiwan instead of past tensions. The initiative is at a very large scale covering an entire region and yet also addresses the finer grain of local communities. The project could not be reproduced elsewhere because it is very customized to the context, but the methodologies could be reapplied. Although “Action Plans” are included as the final methodology for the project, it is uncertain how they would be implemented in the communities and region.
1–50 Diagram showing relationships across the strait

1–51 Chora methodologies for Taiwan Strait Atlas project

1–52 Team of students working on mapping scenario from Xiamen Climate Change workshop
Map Kibera

Map Kibera is a community information and advocacy framework that was put in place for the Kibera slum in Nairobi. The goal was for young locals to participate in creating a map of the slum and for the program to gain momentum as a mapping, media, and advocacy tool by and for the community of Kibera. The initiative used phases of initial mobilization, applying the tools, developing action plans, advocating on behalf of the community, and then entering negotiations with the local government and community leaders. Initial mobilization involves connecting with community groups, organizations, and municipal officials to develop partnerships and begin the discussion of what the framework could provide for the community. The second step is to learn about the community by creating an initial base map, discovering people’s stories, and analysing the information to determine community response. The third phase involves sharing the findings with the community and leadership, establishing future goals, and agreeing on leadership for the framework. The fourth step involves reaching out to the community through a wide range of mediums to bring issues to the forefront, and the final step is the negotiations with decision-makers to bring about change in the community.

The initiative is at the scale of the neighbourhood. The agent was a small team of Americans who launched the initiative but quickly put it into the ownership of a team of Kibera locals. The users of the framework are community members of Kibera that wish to reach out and use the tools that are available. In the initial phases Map Kibera used collecting and reporting with a group of participants to form the

initial map, and then later expanded it into a crowd-sourcing platform. They use several open-source tools for the data collection that include OpenStreetMap (OSM) and other tools that extend OSM including Java OpenStreetMap (JOSM) Editor, Field Papers, and OSMAnd. Field Papers is a tool that allows field notes with a scan-code to later be photographed or scanned and then digitally geo-located. OSMAnd is a smart-phone application for field data collection.

The initiative has a high ranking in the areas of individual and communal agency. People can have personal contribution and agency by adding their information to the map and getting involved in the community programs. There are many avenues and levels of participation in the framework that include contributing to the mapping or forms of media and advocacy. The shared goal of the initiative is to “make the invisible visible” by putting Kibera on the map and creating an outlet for communication between the community and also from the community to the city, nation, and the world. The methodologies and tools as applied in Kibera can be expanded to other slums as has already been done in the slums of Mathare and Mukuru in Nairobi. By mapping the unmapped and giving citizens a voice on the map, space is redefined by being associated with voices and potentials for the space. There is a community framework in place that establishes community action plans based on the information, advocates for changes, and then negotiates with decision makers on behalf of the community.

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Data collection platform: Ushahidi

Map Kibera uses a platform called Ushahidi (Swahili for Testimony) for their data collection/reporting, a crowd-sourcing data management system developed to map reports of violence in Kenya. Since then it has been employed as an openly available platform that can be used by other initiatives around the world. 60,000+ maps have been deployed using Ushahidi in 159 different countries. The Ushahidi software is built with Kohana (a PHP framework) and has features that include the ability to map data interactively, to organize and filter data by time, and to manage multiple data streams such as text messages, e-mail, twitter, and web-forms. Ushahidi can only be analysed under the banner of the initiatives that employ it because in being provided as a tool it was disconnected from the community framework that localizes it. Initiatives that employ Ushahidi have had various degrees of success because they choose how they implement the tool.

Citizen Science: Forest Management in Congo Brazzaville

The Extreme Citizen Science (ExCiteS) group at University College London (UCL) is in the process of developing and testing a framework they have developed for working with indigenous communities who live in some of the most remote regions in the world. In Congo there are many indigenous villages that overlap logging concession areas that threaten their way of life. The goal of the initiative is to give indigenous people a voice so that they can protect the forests that they depend on for their subsistence. The framework is a combination of a community engagement protocol called “Free, Prior, and Informed Consent” (FPIC) and a digital framework called Sapelli.

The community framework involves steps of gathering representatives of the community and proposing the project. If they receive consent to proceed, they involve the community in participative design to determine what information in the forests is important and should be collected. The next step is training community members in using the tool and finally sending participants to document different elements of the forest. In 2013 a team from ExCiteS went to Congo Brazzaville for six weeks and tested the framework in eight villages. The villages included indigenous groups that do either farming or hunting/gather-

1 “Extreme Citizen Science: ExCiteS,” https://www.ucl.ac.uk/excites.
The initiative is at the scale of the region and the agents are UCL ExCiteS in partnership with an intermediary NGO called Forests Monitor. The users are Forests Monitor and any other regulatory organizations, the logging companies, the government, and the indigenous villagers. The framework uses the digital mapping technique of collecting and reporting with a team of participants, and uses a smartphone application that ExCiteS developed called Sapelli.

The framework gives the user partial agency to contribute to a project that they think is important, but mostly the project is for communal agency to give the whole community a voice in forest management. There is partial participation because users are following a structured procedure, even though they participate in the design of it. The project is highly scalable because the same community methodologies can be applied in different places and the digital framework is meant to accept custom designed surveys. Space is partially redefined because...
the parts of the forest that are considered valuable by the villagers can now be communicated as valuable to other stakeholders. A forest that might commonly be perceived as an abstract idea of trees, can now be understood by the complex array of species that inhabit it. The framework is not yet administratively grounded because there is no strategy in place for how the data will be used to benefit the indigenous groups; the data is only useful if it can influence policy.

**Data collection platform: Sapelli**

Sapelli (named after an endangered tree in the Congo rainforest) is a digital framework in development by the ExCiteS group. The platform was designed to simplify the creation of the surveys and streamline it with collection and aggregation tools.1 The interface is a visual decision tree that users navigate to report on different elements in the forest. Although the interface is designed to be completely visual, there are also options to display images with text or just text depending on the targeted user. To work in remote areas the application is designed to send data only if it senses a strong internet connection, and there is also an option to send the data in multiple SMS strings. In the earlier developments of Sapelli, ExCiteS tried to build off of existing open-source survey tools from Open Data Kit (Open Data Kit); however, they found them too complicated and limiting for their purposes and so developed their own platform from scratch.

**Data collection platform: Cybertracker**

The Sapelli platform resembles a first-generation platform called Cybertracker. It is worth mentioning because it was developed in 1995 for the original purpose of tracking wildlife, but since then has been employed around the world in the varied domains of scientific research, indigenous knowledge, environmental education, forestry,

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farming, education, health, crime prevention, and disaster relief. The framework was first developed for use on rugged handheld computers but later expanded for use with smartphones. The framework includes Cybertracker software that allows the user to customize the application and later aggregate, analyse and export the resulting data. The application is available for most mobile devices and has the ability to register a user’s track and specific waypoints on the way to a destination. An example of a framework that employed the Cybertracker platform is a community forest management project that took place in Tinto Cameroon in 2005. The project had very similar objectives to the more recent ExCiTes project.

Game Theory: Evaluating Water Allocation in the Kat Basin, South Africa

One last example of a different approach to digital mapping is the use of companion modeling – a combination of role playing games and cooperative game theory – to aid in the management of shared resources. Both of these methods were applied in the management of water resources in the Kat Basin region of South Africa. Role playing games are the involvement of all stakeholders in a game that represents as realistically as possible the factors involved in the resource management. The game has two goals of getting the stakeholders to understand all of the problems and to negotiate, and also allow the game administrators to study how the stakeholders respond when they play the game. By consulting the stakeholders on all factors and seeing how they act within the game, the administrators can develop a theoretical simulation that can calculate optimal results for all stakeholders and make future predictions. The software that was developed for the theoretical simulation is called KatAware. Both the role playing game and the cooperative game theory have the objectives to cooperatively maintain the ecology of the region while individually gaining a profit (or in the case of village leaders, having a satisfied village). The games will always be a simplification because they cannot predict all environmental and political factors that may influence the region. They also assume that all stakeholders report to a single body that governs water release from the dam and that nobody can cheat.

1 Ariel Dinar et al., Game Theory and Policymaking in Natural Resources and the Environment, (New York: Routledge, 2008), 85.
The framework is at the scale of the region and the agents are researchers in partnership with the Water Users Association (WUA). The users are the organizations and political bodies that address and govern water allocation, the farm businesses that use water for irrigation, and villagers that use water for domestic use. The digital technique that is employed is using games and simulations to collect, gather, and represent flows of data. The tools that the framework employs are a physical board game map and the simulation software called KatAware.

The framework creates partial agency by allowing stakeholders to make their individual problems known. The business owners, leading officials, and village chiefs participate in the framework on behalf of their respective employees, citizens, and villagers. The shared agency is that the negotiations and simulated findings can influence the creation of water management policies that can benefit everyone in the region. Although the companion modeling method can be applied in other places that have common pool resource disputes, the software KatAware is customized very specifically to the context inputs and would need to be redeveloped to respond to a whole new set of variables. Space is redefined because the map reveals problems and proposes resolutions to a complex collection of problems that until this point were only seen and understood in fragments. The games are personalized very specifically to the variables provided by the stakeholders and the context. The framework is partially administratively grounded because the findings from the games will be discussed and will inform a water management plan that the UWA will submit to the Department of Water Affairs and Forestry.
1–73 Chart showing combined analysis of eight precedents

|--------------------------|------|-------|------|-------|-------|-----|----------------------|----------|------------|--------------|------------------|-------------|---------------------|-------------|------------------|---------|---------------------|------------------------|------------------------|------------------------|---------------------|------------------|-----------------|-----------------|-----------------|------------------------|----------------------|------------------------|
Conclusions

The precedents demonstrate how widely digital maps are being applied around the world, and how they traverse disciplines and combine subjective discussions of sociology and the precision of computation. Each precedent offers helpful insights into the community methods and digital techniques and tools that were applied in each context. The precedent frameworks always employed at least one of the following digital mapping techniques: Aggregation, Collecting/Reporting, Networking, or Game/Simulation. Collecting/Reporting is the most commonly used technique, though some frameworks apply it publicly while others limit it to a group of participants. All of the frameworks use different types of databases and servers online to host their digital components, the exception being Taiwan Strait Atlas and Game Theory precedents that use in-person negotiation and use offline databases to document the interactions. Only the precedents from the developing or underdeveloped contexts produced physical artefacts as a part of the process.

The precedents are also useful by comparing how they responded to the questions drawn from the mapping theory. Although diagramming the theoretical questions does not give objective results, it allows the shapes to be compared and to see very quickly where each project has its focus. The diagrams also demonstrate that no project is the same, and no project is strong in every area. It is possible to see and understand familiarities in the shapes. For example the Chesapeake Bay Grasses framework and the Taiwan Strait Atlas have similar forms except that Taiwan Strait Atlas has higher ranking in the area of personal accumulation. It is logical that they are alike since they are both designed to display complex data in the form of an atlas to the public. Taiwan Strait Atlas went a step further by arranging community programs to envision what the city could look like next. Another set of similar shapes is LocalData and the Citizen Science project. Both projects focus on data collection with a team of participants. The ExCiteS project does more to redefine space for the average person because it is mapping a theme that has never been mapped before. Most of the frameworks have agents that are local intermediary organizations, and express the intention of being administratively grounded; however, none show concrete examples of how the data collected informs change in the physical environment.

Each precedent has certain strategies that could be applied in Beni. Chesapeake Bay Grasses demonstrates a strong interactive web interface that displays complex data; Sourcemap and Community PlanIt demonstrate how a person can interact with a map from a personal profile that allows for customization and personal input; Local Data and Citizen Science use different methods of data collection and methodologies for personal involvement; Map Kibera and Citizen Science have thoroughly developed community frameworks and apply wrapped platforms for their data collection and management; Taiwan Strait Atlas and Game Theory use strategies of personal interaction and game playing to receive community feedback.
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Application

By looking back on the objectives for the project and the frameworks presented in this section, it is possible to determine what kind of tools and methodologies could be applied to the framework in Beni. The scale of the initiative will begin in the city and neighbourhood but can later extend to aggregate data from regional, national, and global data sets. The agent is the IRI at UCBC and the users will be the community, but like Map Kibera the framework can be handed over so that the community can become the agent. To begin with the framework will produce physical publications to best disseminate the maps in a community that is not very familiar with the practice of mapping. The next addition would be a simple website likely using a javascript mapping API library like the Chesapeake Bay Grasses project. Because there is no existing digital map of Beni, Collecting/Reporting will be the first technique employed to build the elements of the map with a team of participants similar to the LocalData and Citizen Science projects. The framework can later be extended to use other techniques to solicit more engagement, expand the reach to other devices, and make the data personal and interactive such as what Sourcemap, Community PlanIt, Map Kibera, and Game Theory seek to do in different ways. These initial thoughts will be developed further in the next chapter that proposes a detailed design for the Beni framework.

Beyond the technical and community elements, it is also possible to predict what dialectical questions the Beni framework will have to address. The same lens of questions applied to the precedents can be applied to the framework proposed for Beni. Just like the other precedents the framework will have strengths and weaknesses, but analysing it in this way helps to see the gaps and to see where the map might not be doing what it intends to. Below are some speculations on ways that the Beni framework might respond to the same theoretical questions:

Accumulation: The map gives community members the option to place their businesses, organizations, and institutions on the map and other themes they consider relevant such as infrastructure and security. The map will allow the university to expand its research and become an authority in the domain of GIS and development in Beni. The maps will also become utilized by the municipality in city planning decisions. When the IRI progresses to map land conflict like they intend to, the map will bring disputes out in the open. Revealing land tensions could cause additional conflict but in the long term would reduce conflict.

Participation: Allowing the public to access and contribute to the map is a way of placing the map as a tool for the community. Because only a small percentage of people have smart phones or internet access, it is very important that the GIS group finds multiple avenues to connect with the community. This can include making both the physical and digital maps accessible in the library, publishing physical maps to be
distributed to the community, and holding participatory workshops
to gather community input. If there is enough associated action in the
physical environment that is having a reflection on the map, then the
participation can be defined as active and not just the semblance of
participation. IRI is the entity in control of launching the framework,
and they need to be wary about using that position for the purpose of
exploitation. A way to reduce this risk would be for the university to
give the tool over to the community. The framework could be man-
aged by a committee made up of community stake-holders.

Re-territorialization: The overarching ideology of the project is that
mapping can be a way for the community to learn about itself and
therefore allow leaders to be able to make more educated decisions
about the city’s growth. It also allows citizens to democratically
express their thoughts and ideas about the city and contribute to an
expression of the city’s identity. Though the ideology is an impor-
tant driver to bring the project forward, it is important to maintain a
realistic perspective. The reality is that there is nothing to stop people
from using the knowledge from the maps to make decisions that have
a negative impact. That does not mean that the project should not be
pursued since the positive impacts still outweigh the negative. It is
important for BeniAtlas to develop future programs that can initiate
strategies to respond to what is learned from the map. For example, a
study of current waste disposal methods has no impact on the physical
environment until there is a solution proposed that can improve the
current system.
2.1 Framework Design and Implementation

Design Methodology

The following section outlines the design of a digital mapping strategy for Beni that responds to the context and objectives listed in the last chapter. The objectives are to plan big but start small, to get demographic information of the city, to develop a framework that grows with the development of infrastructure, to establish the map as a community resource, and to design it to be innovative and extensible. The project employs a framework methodology because it gives structure to the various inputs, components and processes that are being used to create a desired output. The framework requires the designer to be specific about what the goals are for the project and provides flexibility in how it is implemented. The inputs of the digital framework are a range of bottom-up data that is collected from community activities, and top-down external data obtained from outside sources. The digital framework outlines a series of tools and processes that use the inputs to prepare working maps, collect and formulate the data, and prepare it for interaction by users, either by hard-copy publication or digital visualization.

The complete framework can be divided into two components: the digital framework that outlines the digital tools and processes, and the community framework that organizes the community programs necessary to collect the data, distribute the maps, and initiate community response.

2–01 Diagram showing example of community and digital processes. The solid boxes are elements that will be broken down further in later diagrams and clear boxes are elements that are in their final form. The black boxes are the digital processes and red are the community processes. Where red and black boxes overlap, the community process is handing over an input or taking an output from the digital process.
As the project objectives make evident, the context of Beni does not allow for the framework to be implemented all at once. Time is needed in the implementation of the framework to allow for community readiness and the development of infrastructure and resources to support the project. To respond to these contextual realities the design of the framework is broken down in stages to collect simple data inputs and have simple representation of the data, before moving to collecting more complex data inputs and having a more complex representation of the data. The scope of the framework is to establish the steps to developing a community mapping interface that can be easily employed and manipulated by a local team.

The design has been divided into four possible extensions of the program’s mapping capacity: Base Collection, Detailed Collection, Digital Visualization, and Digital Extensions. Base Collection is the creation of a base map in order to introduce maps into the community sequentially before publishing maps of more sensitive themes, and to provide a valuable reference layer that all other data can be built on. Detailed Collection extends the data inputs to include detailed surveys of neighbourhoods for migration data, demographic data, and household infrastructure data. Digital Visualization makes the outputs available online and offers a route for future bottom-up inputs to be added. Digital Extensions proposes how top-down sources can be added as a resource to the framework, how crowd-sourced reporting can be a dynamic bottom-up input, and how interactive techniques can enhance the user experience. At this point in the research only the first stage of the framework has been implemented. The following paragraphs will describe the initial base collection in depth and, based on reflections from this first stage, will propose how the project might move forward into the subsequent stages.

Design Implementation

The base collection was spearheaded by IRI in consultation with the municipal government and myself. The inputs were roads, bridges, points of interest, and quartier boundaries; the desired output was to produce a base map to be published in the community. The data collection was performed by a team of community and school participants that were recruited by advertising the project within the university and the community. The base collection had a significant community component because it was important to firmly establish the initiative in the community of Beni. There was a long process of establishing partners, formulating a team, training the team, researching existing maps, and preparing a working map by tracing a satellite image. Before this project there was no existing map of the city for volunteers to be able to use to locate themselves and so it would have been impossible to assign a group of volunteers to map a specific area without knowing where its limits were to begin with. The digital side of the framework used a selection of open-source tools for the steps of map preparation on the computer to prepare the working map and survey, data collection in the field using mobile devices, and then map post-processing back on the computer to analyse and edit the map.
Diagram showing community and digital components of framework for Base Collection

- digital processes
- community processes

Diagram showing breakdown of Map Preparation, Data Collection, and Map Post-processing from figure 2–02 into the specific digital tools used by each
The working map was traced in an offline editor for OpenStreetMap (OSM) called Java OpenStreetMap (JOSM) Editor. Basic roads were uploaded to OSM because other open source tools that I selected used the OSM map. By adding the roads to OSM they are automatically made available for the Track Collector and Survey Collector tools.
Creating assignments for the field collection

Originally the intention was to use existing neighbourhood boundaries as the extents to assign to groups who would collect data in the field. Since no boundaries exist, the city was divided up into areas that were of a manageable size for the groups to take responsibility for. The lines were drawn in QGIS over the satellite image and then saved as a gpx file to be added as a layer to the Track Collector tool.

OSMAnd was selected as the Track-Collector tool because it can download the updated roads from OSM, take the gpx assignments file as a layer, and download the maps so that they can be made available offline. The tool has the ability to mark a user’s current location, log the track where a user has walked, and log waypoints. The Survey Collector tool was used instead of OSMAnd for the purpose of logging waypoints because this part of the OSMAnd application was found to be confusing for users.

Garmin GPS devices were used as a back up to the phones. They perform all of the same tasks as OSMAnd but are more durable and have a much longer battery life.
While the OSMAnd tool was used for locating a user on the map and tracking a user’s movement, the Survey Collector was used for the main task of collecting the new data points. A tool called ODK Collect acted as the Survey Collector. It allows forms to be completely customized, offers options for styling the form, and does not need consistent web access. It also has the important capability of making the form available in multiple languages. The Survey Collector is a valuable tool because it decreases the margin of error in data by providing multiple choice answers. An enumerator can still choose the option “other”, but only if it doesn’t fit any of the already specified options. Unlike OSMAnd where waypoints are marked with an ID that is associated with the information that is written on the field notes, ODK offers GPS coordinates and photos as a survey question so that it remains associated with the data. IRI created three different forms: one collecting information for roads, one for bridges, and one for points of interest. The forms were created in Excel, uploaded as xls files to FormHub, and then uploaded to each of the phones.

To ensure that no data would be lost because of battery life or technical difficulties with the phones, a second Survey Collector tool called Field Papers was employed. It is a tool that offers a digital component for the ease of physical note-taking. Similar to OSMAnd, the tool connects to the OSM map and then exports a selected area of choice.
as tiled PDF pages. The front page is a legend showing how the following pages are tiled using letters and numbers (A1, A2, B1, B2) to identify each page. Each page is also marked with a scan code so that when the page is later photographed or scanned it can be brought into the JOSM editor to be traced digitally. The scan code functions to geolocate each page of the field papers.

Finally after the preparation of the tools and phones, recruitment, and training, thirty volunteers divided into ten groups and went around the city to collect the data for the base map. The collection of quartier boundaries was a separate task with select participants because it involved connecting with each neighbourhood cadastral office and asking the district chiefs to show the boundaries. Afterwards the data was taken off of the phones. For OSMAnd and Garmin it was pulled directly off of the phones by usb connection and for ODK Collect was uploaded back to the FormHub server and then downloaded from the server back to the computer. The data from ODK had to be edited extensively in Excel before bringing the data as a csv file into QGIS. The field papers were used as a reference where data was sometimes incomplete.
2–15 Map showing neighbourhood boundaries (note: they are still in the process of being resolved)

2–16 Map showing roundabouts and roads with their names (if they have a name)

2–17 Locations of hospitals, health centers, and “dispensaires” (small clinics)
Reflection

Data collection in Beni was a slow process that was more about connecting with people than it was about registering the data points. For the points of interest the enumerators often sat down and explained the project to the organizations they were asking to be placed on the map. People were always doubtful at first because the finished map would often have no immediate benefit to them. A schoolmaster wondered why they should bother contributing to the map if it would not get them the funding and materials they desperately needed. A nurse at a small “dispensaire” (health clinic) was worried that being located on a map would make it easy for the government to come and close down the clinic for not having the proper credentials. At the same time they understood the benefit that the map would offer and liked that it was a university and community led initiative. Community members would be able to more easily find out where schools, health centers, and different commercial areas are located. Being located on a map would be a way for businesses or schools to become better known in the community to increase their clientele or student enrolment. In the event of a disease outbreak it would be easier to determine where people live so as to contain or find the source of the disease. One of the biggest accomplishments is resolving the neighbourhood boundaries. Although it took months working in partnership with the Mayor’s office and cadastral offices and going out in the field to trace the boundaries using GPS tracking, the boundaries have now solidified the areas that each cadastral office is responsible for. Above all the map would be a step forward to understanding the city for future city planning and could be used in future to resolve land disputes.

The Base Collection stage begins to meet the objectives set out for the project by creating a map that is ready to be published in the community and by laying out the groundwork of a map that can be easily updated and built on with future layers. The main challenges were the incompatibility of some of the tools, dependence on tools that had servers that were sometimes down, and the learning curve of knowing how to use so many different tools, many of which could instead be combined into a simpler, more comprehensive system. The tools were appropriate to start with however, because there were no costs outside of the phones and laptops except providing water and transportation allowance to volunteers. The use of these open-source tools demonstrates how non-experts can map their own community. The following section offers a discussion of avenues of how the base map can expand to further meet the objectives of the project.
IRI training session with volunteers

Data collection in the field
Chapter Two — Framework Design and Implementation

Data collection in the field

Editing the map
Base map at 1:10 000 showing points of interest in Quartier Residentiel
Further Development: Detailed Collection

The next way to grow the framework would be to begin collecting more detailed information at the scale of the neighbourhood. *Detailed Collection* could be done with all of the same tools and processes that were used for the base collection. A new set of community processes would need to be planned including the preparation and running of workshops that can get community feedback about the mapping program and also make the neighbourhood aware of the upcoming surveys. This is necessary in a community that is not familiar with the practice of door-to-door surveying. The information collected from the survey can fit into three categories of migration data, demographic data, and infrastructure data. The digital steps in the framework involve the building of the survey, the collection of the data, and the editing of the map. In the post-processing the demographic data can be layered onto the original base map.

2–24  Tracing building footprints in JOSM Editor

2–25  Using QGIS to count the data from each building footprint and represent the quantity in each quadrant by colour
Instead of tracing roads like for the preparation for the base map, for the neighbourhood surveys it is necessary to trace the buildings. Because of the informal nature of the buildings, households could easily be missed or surveyed twice if not marked down on a map. Another reason is because once a neighbourhood has been surveyed, that data can be used along with size and number of structures in the rest of the city to estimate the population of Beni. The demographic analysis can be applied to neighbourhood boundaries or to a set grid in order to create a gradient of comparison across the city while de-identifying the data from the individual households. Three very different neighbourhoods in the city could be surveyed to begin with to collect a range of data that can be representative of the city.
Further Development: Digital Visualization

A second avenue of development is to represent the map in a digital interface. The design of an interface responds to the project objectives because it allows the content to be easily updated, can layer data from top-down and bottom-up sources, and creates a new avenue of participation from the community. The goal of this stage of the framework is to propose a very simple set of tools that are free and widely available so that the application can be developed and manipulated by non-experts. The tools and mapping techniques were selected by experimenting with the building of a raw beta version of the application. Similar to the previous two stages, the interface can be implemented as a simple and more static digital map before considering additional ways of extending the map’s capability. The first stage can be the development of a simple digital map that allows users to turn on and off a few layers (i.e. points of interest, streams, roads, and bridges) and click and zoom to a particular neighbourhood to see more detailed information.

Publishing on the web is becoming increasingly accessible to non-experts because of the abundance of open-source mapping tools and libraries. There are many existing proprietary and open-source tools to choose from so that the digital map does not need to be created from scratch. In developing the beta site as a non-expert, one of the first decisions was to use an application programming interface (API) to make the map. APIs are libraries of components that are used for making software applications. The beta application uses an open-source Javascript API called OpenLayers 3. Javascript was the coding language of choice because it is the language of the web and is most commonly used for web mapping applications. OpenLayers 3 was selected out of the many APIs available because it has broad capabilities, is flexible in customizing components, has thorough descriptions of all of the library’s components, and has a very large and active support network. The digital catalogue in the appendices outlines several more APIs that were researched before selecting OpenLayers 3.

Another question was what kind of server to use. There are a multitude of proprietary and open source servers that are designed specifically to manage map data. They are called Web Map Services (WMS) as prescribed by the Open Geospatial Consortium (OGC). The advantage that WMS offers is that a request is made to the service, the image is processed by the server and then sent back to the client as an image or set of image tiles. The disadvantage is that it adds another layer of complexity and could be subject to change and compatibility problems. The beta website uses a generic server that could either use cloud hosting or dedicated hosting. This means that instead of the map server preparing the image and sending it to the client, the client’s browser draws the map elements if they are vector based.

1 “Open Geospatial Consortium,” http://www.opengeospatial.org/
Diagram showing community and digital components of framework for *Digital Visualization*

- **Digital Processes:**
  - Workshop Analysis
  - New Thematic Data
  - Base Map
  - Migration Map
  - Demographic Map
  - Infrastructure Map

- **Community Processes:**
  - Map Post-processing
  - Digital Map
  - Thematic Layers
  - Map Publishing
  - Map Distribution
  - Framework Testing

Diagram showing breakdown of Map Post-processing, Server, and Client Device from figure 2–27 into the specific digital tools used by each.
How the data is stored is another choice with many options. The beta application uses a file based system to store the data. This is the simplest choice because the application can refer to javascript and xml files that store the respective geometries and point data. Each layer on the map is a file in the data folder on the server. This method is a good way to start but has limitations once the map wants to take on more interactive functionality such as crowd-sourcing. At that point the application would need to shift to use a database system. There are two well known open-source databases called PostgreSQL and SQLite that offer database extensions for spatial objects: PostGIS and SpatiaLite. SQLite is a lighter and transferable system that is good for stand-alone applications or early web development, and PostGreSQL is more bulky but has many more features. It is probably the database of choice when considering multi-user database access. PHP and SQL would need to be used as the back-end languages to access the data.

The only extra infrastructure required to set up the basic website is a web host. Once the framework is established, thematic data from new research can be inputted into the system as well as any data obtained from the workshops. The data can be styled dynamically in the code instead of being a fixed image. For example, the road widths can change as a user zooms in and out of the map. The beta application successfully demonstrates the zoom-in, layer selection, and neighbourhood zoom options, but is crude and needs to be further developed to be a fluid interface for users. Additional elements that need to be considered are the creation of a tutorial to introduce users to the interface, formulating it into an offline application option, making it compatible with mobile phones, and making the application as accessible as possible. If computers or phones can’t work with the interactivity, the user should be brought to a collection of static maps that show the same content. There would still need to be a program in place to publish hard-copy maps in the community since not everyone will be able to access them electronically.

Further Development: Digital Extensions

A final proposal for extending the framework is to use the most recent techniques in digital mapping to increase the scope of inputs and also make the represented map dynamic, allowing for a new level of community engagement. Digital technology allows the map to become dynamic and intelligent by being able to collect data from other sources and from the public, compare and analyse it, and simulate possible outcomes. To demonstrate how non-experts can contribute to even a more complex interface, I developed the basic website further to include examples of aggregation, crowd-sourced reporting, and simulation techniques. Although much development would be needed to make it a smooth and completely comprehensive interface, the idea is that by using the most open-source and globally available tools, control can be put completely into the hands of the community without needing significant outside influence.
(a) Global aggregator

Global aggregator is an extension to the framework that imagines how top-down data that is already publicly available can be aggregated into one place to make it available for educational use and comparison with other data sets. Because the spatial data can be represented in code, it is easy to curate and represent in an online map. Although the first aggregations would require finding the data, transplanting it, and creating static diagrams that describe it, the data could eventually be fed live into the site and for the diagrams could adjust accordingly.

The beta website demonstrates the aggregation extension with data collected from the Vision for Humanity Peace Index and the Armed Conflict Location and Event Data (ACLED) Project. The reason for using two different data sets is to experiment with how they can be curated on the site and explore data that belongs to various scales. Vision of Humanity Peace Index is a global index that ranks countries based on 22 qualitative and quantitative indicators of peace that include measuring levels of internal and external conflict, safety of cit-
izens, and levels of militarization.\(^1\) ACLED is a collection of political violence data in Africa that includes event locations, dates, and other details.\(^2\) It can be presented in different levels of detail at the scale of the continent, country, province, or region. The data is a series of xml files that are referred to and styled using Javascript and OpenLayers3. Javascript with another API called Data-Driven-Documents (D3) can be used to create graphs that respond to the data and automatically update as it changes.

(b) Reporting/collecting

The widespread use of smart phones with GIS capability has offered a way for the general public to contribute to the gathering of data. Instead of going door to door with surveys, it is possible for someone to find the survey online or on an associated application where they can report a specific piece of information that is geo-located. This capability would require establishing a form that can collect the data and a system for verifying the data before it gets published. The Beni framework could either set up its own system, or use an existing one such as Ushahidi that was introduced in section 1.4.\(^3\)

The beta application demonstrates the Collecting/Reporting method by allowing a user to report on the state of infrastructure in the city of Beni. Javascript with Openlayers 3 allows the user to draw a point on the map and submit a description of the condition of the infrastructure. It is also possible to vote on a report to confirm its importance and make it appear larger on the map. The beta version registers the input on the map immediately, whereas in the real version there would have to be a verification process to determine whether the report is true. Similar to the aggregation extension, graphs can summarize combined statistics from the reports.

(c) Game/Simulation

Digital tools offer the ability to imagine different futures on top of a map. Simulation is a way to propose designs and see outcomes that would not be easy to understand otherwise. The IRI is establishing partnerships with organizations working within the forestry and agricultural sectors where using simulation with maps could serve as an educational tool to demonstrate how changes in the sector could bring about long term benefit.

For example, research indicates that the continued use of charcoal for cooking, particularly in densely populated urban areas, is causing unnecessary deforestation. Efficient stoves have been developed as well as biomass briquettes as an alternative to charcoal, but people do not realize the negative impact that using charcoal has on the environment.

and are hesitant to change old habits. Game/Simulation could be used to simulate the effects that the continued use of charcoal will have on the forests and how the impact can be lessened by making decisions to use alternate methods.

2.2 Storytelling

The following sequence of images tries to give the reader a better understanding of what the implementation of the framework would look like in Beni. It imagines scenarios where the map is useful for the community and where it might present challenges.

Participants walked around the city and took notes of the names, type, surface, and condition of roads. On more major streets some of the road names could be found on make-shift signage that was fixed to the outsides of compound walls. In other instances, the participants asked locals and determined that the road was known by a certain name. The participants confirmed the road name by asking multiple people. It was common for smaller roads not to have names.
In a similar way to the roads, participants also collected the name (if applicable), type, size, construction, and condition of bridges. Beni has hundreds of bridges of all shapes and sizes because of the network of small ravines that traverse the city. Large bridges often have a sign beside the bridge while smaller bridges are known more informally and are usually called by the same names as the creeks.
Points of interest were collected under the categories of commerce, hospitality, educational institution, place of worship, organization, financial institution, governmental institution, health facility, public place, recreation, industry, infrastructure, and other (if it did not fit in any of the categories). Based on the category selected in the survey, the enumerator could then choose a subcategory. In this image the category was “public place” and the subcategory was “market”.

Many people that the groups encountered recognized the value of the map to help with way-finding in the city. A map allows someone to be able to share what street they live on or where their business is located.

Performing the base collection in the field was an effective way to increase community awareness about the project. The survey included an input for phone-numbers if people were interested in receiving more information about the project and news about upcoming workshops and events.

2–41 Enumerators collecting information on points of interest
Can we put your health centre on the map? What if it makes it easier for the government to find a reason to shut us down?

One valid concern for people was the validity of their operation and ability of the state to possibly acquire the map to use for corrupt purposes. Some organizations, schools, and health centres exist to meet community need and might not have the official paperwork they need to be formally recognized on a map.

Another concern is that the maps would affect people’s livelihoods because the public might change what they decide to buy. At the same time maps have the potential of initiating new commercial ventures.

The IRI used a procedure of informed consent to obtain data for points of interest. The participants explained the project to the heads of organizations, schools, health centres, etc. and only took the information and coordinates if consent was given. Many people were suspicious of the project at first and disappointed that it would provide no immediate benefit, though once they understood what it was about they often changed their minds. On occasion a person would refuse to have their site added to the map.

Can we put your school on the map? What good will it do? It’s not as if it will help us to get the funding we desperately need. But go ahead.

I don’t like that the forestry map is discouraging people from buying charcoal. It may be bad for the environment, but this industry is my livelihood.

2–42 Enumerators collecting information on points of interest
Chapter Two — Storytelling

More examples of points of interest
Several months later...

Do you know of a good seamstress?
I would recommend my friend’s sister. She’s located on Av. Mwenze. Here, I’ll show you on the map.

I’m learning skills in GIS and I also think that this project will be good for the city.

Why are you wasting your time with this mapping project? You aren’t even making any money.

Several months later...

Participants in the project were unpaid and so they likely received critique from family or friends asking why this work was worth their time.

Now the woman from figure 2-41 can advertise where her business is located and even her friends and family can direct potential customers her way.

Now the woman from figure 2-41 can advertise where her business is located and even her friends and family can direct potential customers her way.

Imagining how map might be used for way-finding
Do you know what you are going to do for that mapping project?

I think I’m going to map parks like this one and propose how Beni might be able to plan a strategy for parks.

This is a complete map of Beni and this is the population information that was drawn from the BeniAtlas demographic survey.

Can we put your school on the map? This is a complete map of Beni and this is the population information that was drawn from the BeniAtlas demographic survey...

Beyond learning from a map of Beni, students can also potentially contribute their own research and reading of the city to the framework.

2–45 Imagining how map might be used for education and research
This water is muddy. This fountain needs to be cleaned out. What can I do about it though? I guess I could try to report it on the map everyone has been talking about...

Two weeks later...

The map can be used to monitor the condition of infrastructure in the city. By allowing the public to contribute and discuss issues, solutions can be more efficiently developed by the municipality and the community.

2-46 Imagining how map might be used for crowd-sourced reporting
I wanted to buy the land behind this wall, but when I checked the map I found out there was existing conflict. Did you hear about how two cadastral workers got fired and then the boss who fired them got fired? That’s what revealing the corruption will do. It will get worse before it gets better.

The map can eventually be developed to map reports of land conflict; however, because there are powerful people who benefit from the currently corrupt system, trying to uncover it will present new difficulties that are hard to predict.

To be continued...

2–47 Imagining the discussion and affect of mapping land conflict
2.4 Discussion

The process of designing the framework and testing it reveals the detail involved in the planning and then implementation of a mapping framework. As the precedent studies suggest, each framework has strengths and weaknesses depending on what the goals are for each. If we spoke to the creators of the precedent frameworks they would probably describe them as infinite works in progress. For example the Cybertracker software has transformed considerably in its two decades of existence. It is important to be self-critical and recognize that there are always ways that the design can be improved. This section reviews the strengths and weaknesses of the framework as it is currently proposed and reflects on if it meets the objectives established in the previous chapter, how it might be improved, and how the framework methodology could be applied to other projects.

A strength of the framework is that it meets most of the objectives that were established in response to the context. The framework meets the objective of starting small by offering a collection of simple open-source tools and proposing that the framework grow in stages that allow participants become proficient with the tools and the community accustomed to the wider use of mapping. The framework still establishes the structure for bigger plans in the future. For example, the beta interface could be further developed to incorporate mapping of land conflict. The framework meets the objective of collecting demographic information by outlining the tools and process that could be used to accomplish that task. The framework also meets the objective of growing with the development of infrastructure. The framework proposes tools that do not require internet access and are open source so that they can be installed freely on personal laptops. The framework proposes publishing the maps in the community because a large percentage of the population still do not access computers. The beta version of the web application uses the most openly available coding languages that can be read from any browser. Lastly the framework partially meets the objective of being innovative and extensible by exploring opportunities of future development and growth. The project acknowledges that any mapping framework is very customized to each context and must recognize the community processes that are connected to it. By specifying existing tools that can fit into one another or designing custom tools so they can be interchanged, a different community could apply a different arrangement of the tools based on their needs.
A weakness of the framework is that in its current state it is very much in the ownership of the university. Similar to most of the mapping precedents, it was necessary to establish a partnership with a local intermediary that was very familiar with the context and had the resources and interest to pursue the project. The risks of partnering with an intermediary is that too much power and control can be put into one place, and despite best intentions, the data that is collected can become biased to suit the needs of the university with less concern for the community. The university is an asset in establishing the framework and getting it off the ground, but to better ensure that the framework is adopted as a tool by the community it is necessary for the university to let go of it institutionally and put it in the ownership of a group formed by interested community members and representatives from a range of community actors. Even though the university is highly invested in the community and the community framework includes workshops for community input, the university can still be seen as an outside entity.

The scenarios in the previous section suggest that the framework (and even the digital components) get accepted and employed by the community, but in reality it is a slow and challenging process.

2–48 Diagram showing relationship of agents and users for Visual Extensions and how framework can be managed by a group that is made up of community representatives.

- **Digital connections**
- **Community connections**
By analysing the Beni framework in the same way as the precedents, it is clear that the Beni framework does not receive a high rating in response to all of the questions. The darkest shaded area is the rating of the framework after the first three phases that are thoroughly developed and therefore could be implemented at any time. At the completion of the three phases there is shared agency and participation in the initiative but most of the other categories are still low because there is only partial personal contribution through community workshops. By fully implementing the extensions on multiple themes that are initiated by the community the rating could expand to the light grey area. To obtain a full rating in all areas would require further development by introducing personal profiles and establishing a system for how data that is collected can directly inform policy.

The future of mapping will likely see more complex frameworks like this one and even to the scale that Buckminster Fuller imagined but with a network of frameworks. It will be a necessary response in the time of the anthropocene where the human population is so large that we have the ability to affect the geological makeup of the world. Not only will monitoring of both natural and man-made systems become more common, the gap between the digital image and real space will continue to get more blurry as the interface between them thins. Human beings will try to do what they can to influence change in their environments and with their creativity will develop tools to address the growing complexity. As James Corner writes, “the function of mapping is less to mirror reality than to engender the reshaping of the worlds in which we live.”

On a clear day in Beni one can get a glimpse of the Rwenzori mountains in all their magnificence. Many people call them the “Mountains of the Moon”. Because I was curious where the name came from, I looked it up and discovered that the mountains were first depicted on Ptolemy’s map of Africa in his Geographia. He cited the source from the tales of the Greek merchant Diogenese who claimed to have journeyed inland from the East African coast and came upon a mountain range that fed two lakes that were the source of the Nile. He supposedly took the name “Mountains of the Moon” (“Lunae Montes”) from the natives he met there. From that point on the Mountains of the Moon would be found on maps of the next several centuries until further exploration would determine that there was no clear mountain that was the source of the Nile (there are several mountain ranges that in fact feed the Nile). Nevertheless, it has been widely accepted that the Rwenzori were the mountains that Ptolemy referred to and they have since adopted the name of Mountains of the Moon. It is yet another example of the power of the map to fix an idea onto the physical world.

View down the main road toward the Rwenzori Mountains
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Appendix A: Congo by Mapping

A–01 Street in Beni
Infrastructure

The Democratic Republic of the Congo faces possibly the most daunting infrastructure challenge on the African continent. Because of continued conflict, the DRC’s road and rail infrastructure is seriously damaged, and the vast geography, extensive forests, and large river network only complicate the development of new networks. The DRC’s economic activity is concentrated in three distinct centers that form a triangle – Kinshasa in the southwest, Lubumbashi in the southeast, and Kisangani in the northeast (African Development Bank Group 2011). There is no well-developed infrastructure linking these three cities, particularly for road and rail. Power and ICT is somewhat developed along the Kinshasa-Lubumbashi axis, though there is no fiber optic network to speak of and the main power transmission line is in need of major rehabilitation. The rest of the country is almost entirely void of power and ICT coverage, although GSM coverage (mobile) has been recently expanded in the east. With respect to transport infrastructure, many regions of the DRC (notably the southeast and northeast) are better connected with neighboring countries’ infrastructure corridors than they are with domestic ones. Beni is primarily serviced through the Mpondwe border with Uganda, through which all imported and exported products come and go (African Development Bank Group 2011). The small stretch of road from Beni to Mpondwe is a short 80km but the journey takes twice as long as it should because of the rugged dirt roads and ill-maintained bridges.
Appendices — Congo by Mapping

A–03 World Bank 2011 Infrastructure Index

- 1.27 – 2.12
- 2.12 – 2.54
- 2.54 – 2.96
- 2.96 – 3.43
- 3.43 – 4.26

A–04 National ground transportation networks

- Paved roads
- Unpaved roads
- Rail
- Rail (not operational)
- Waterways
Beni Atlas’

A–05 National medium and high voltage electricity transmission network

- Electrical transmission lines
- Power plant

A–06 National road network showing road surface types on the lower layer and road conditions on the upper. For roads not shown the conditions are unknown

- Asphalt
- Gravel surfaced
- Earth road
- Good
- Average
- Bad
- Very bad
Road conditions map overlaying Open Street Map and Google Earth image

- Roads
- Asphalt roads
- Good condition
- Average condition
- Bad condition
Forestry

The Eastern Great Lakes Region of the Democratic Republic of the Congo has an uneasy interdependence among people and between people and nature. Since civil war finally ended in 2003, the challenge remains of preventing conflict and fostering cooperation for sustainable development (SAIIA). The DRC has 155.5 million ha of forestland including half of Africa’s rainforest and is the country with the second largest extent of forest in the world. Another important element is that a significant proportion of DRC’s largely rural population is dependant on forests for part of their subsistence (CIFOR). Although deforestation in the DRC is very low at only 0.2% per year, the distribution is uneven with the greatest impact occurring in the Kivu provinces. Reasons are the proximity to centers of high population and also the need for agricultural land (CIFOR). There are three timber sub-sectors in the DRC: the Formal Timber Sector, Informal Timber Sector, and Fuel and Charcoal Sector.

(a) Formal Timber Sector

Out of the 155.5 million ha of forest, approximately 20 million ha are granted as timber concession to about 60 companies, although only 12 are in operation using half that concession. Most timber from the formal sector is transported by river, primarily as logs, to Kinshasha. The timber is destined almost exclusively to the European market - principally France, Belgium, Portugal, and Italy (Forests Monitor).
(b) Informal Timber Sector

Timber is one of the key industries moving through Beni, however informal. The bulk of timber from East African markets is from the DRC. About 80% of it leaves and crosses the border into Uganda, the most popular timber trading route being from Beni, through the Kasindi-Mpondwe border post, along the Northern transit corridor to Kampala, Uganda, and then on to Nairobi, Kenya (SAIIA). There are estimated 8000 small-scale logging companies ranging from a few individuals who join together to harvest timber two or three months a year, to permanent enterprises with a dozen or more regular employees (Forests Monitor). The flow is unregulated with very little revenue for the country of origin, and although there are many sustainable standards for internationally exported timber, this timber is exported almost entirely to the region of East Africa. One estimate states that the informal trade is double the size of formal trade reported by the DRC (SAIIA).

(c) Fuel Wood and Charcoal Sector

Wood is a primary necessity for all Congolese people, especially those living in a rural environment. Wood energy accounts for 80% of all domestic energy consumed in the DRC (Forests Monitor). Only 10% of homes across the country have electricity creating a lack of alternative energy sources and therefore wood is very commonly used for fuel because of it’s readily available and low initial investment (SAIIA). National wood energy consumption is about 72 million m3 per year. This is a very disproportionate number compared to the formal (0.3 million m3) and informal (2 million m3) sectors. This means that the overwhelming majority of wood harvested in DRC is used locally for heating and cooking (Forests Monitor). Possible solutions to reduce pressure on natural resources are to increase the area of plantation forests, use better designed hearths to reduce charcoal consumption by 50-60%, and raise awareness of hearth efficiency (SAIIA).
Percentage forest degradation by province

- 0%
- < 1%
- 1 – 2%
- 2 – 4%
- 4 – 6%

Percentage of forested land in DRC

Intact forests and probable areas of deforestation

- Degraded primary forests 2010
- Intact primary forests 2010
- High probability of agriculture areas expansion (model-based prediction)
- High probability of selective logging expansion (intact forests within actively managed concessions)
Mining

The DRC is very rich in mineral wealth, having seventy percent of the world’s coltan (an essential material in most mobile devices), fifty percent of the world’s cobalt reserves, and thirty percent of the world’s diamond reserves. It also has important potential for gold, uranium and manganese. Under Belgian colonisation the mining industry flourished and continued under the Mobutu regime. The looting of minerals was a major contributor to the Congo Wars in the 1990s, dissension only increased by the lack of infrastructure and a center of power at the far west of the country. The DRC is subject to what some call the “resource curse”. No other country in Africa presents such an extreme combination of potentials and problems. Reform measures are being strongly encouraged to create a new legal framework and a set of standards aimed at improving practices as a means to obtain development objectives. However, in the name of “good governance”, strategies are often denying the political dimensions of the socio-economic considerations associated with the management of this sector. Encouraged, conceived, and often implemented from abroad and/or with the participation of international experts, the very origins of these reforms create problems of the legitimacy of their application and approbation by the national and local authorities (Campbell).
Artisinal Gold Mining

Artisinal gold production is a substantial contributor to the local economy in and around Beni. There are twelve main regions with artisinal and small-scale gold mining in North Kivu: Walikale, Masisi, Lutunguru, Manzia-Luholy-Lubereri, Mohanga, Lundjulu-Loiki-Ubiro, Lubero, Makwasu, Lutela (includes Manguredjipa), Biabune-Loya and Bilolo-Mobissio-Abakuasimbo (Congo Gold). Up until now, very limited exploration has been conducted at these locations apart from the prospecting and simi-industrial exploitation that was conducted by a Belgian colonial company at Manguredjipa. North Kivu’s artisinal gold mining communities have been under heavy pressure during the past fifteen years of violence with additional problems steming from relative isolation, poor state of roads, and complete dependance on regional traders.

Manguradjipa

Manguradjipa is an example of a large mining village located in the jungle 100km west of Beni and is the center of sprawling gold-mining communities. Several thousand people live in Manguredjipa, while anywhere from 30,000-45,000 in the 10,000 square kilometers of surrounding forests and mountains. Until very recently, miners operated without protection from state security, and Mayi-Mayi groups would periodically come and “disturb them”. Recently however the threat of militia attacks decreased with presence of a recently deployed FARDC regiment (Congo Gold). Violence in the area is still considerable however. There are many bandit groups who are often organized by FARDC soldiers that extort payments from miners; gangs of young villagers pretend they are militias, and there is a large amount of robbery on the roads to and from the mines. Another challenge the miners face is an accumulation of exuberent fees and taxes imposed by corrupt agents of the Provincial Mining Division and national government authorities. The inability to pay for papers within the legal space...
provokes people to conduct illegal artisanal mining activities instead. Portions of road are so deteriorated that only 4x4 vehicles can get through. The only practical modes of transport are light motorcycles, bicycles and lengthy treks on foot. On average, a truck takes one to two weeks to cover the last forty kilometers to Manguradjipa. Lastly, the region witnesses serious violations of human rights, especially against women and children (Congo Gold).
Appendices — Congo by Mapping

A–18 Mine locations North Kivu

Coltan
Niobium
Tin
Tungsten
Gold
Diamond
Monazite
Beryllium
Tourmaline
Garnet
Bauxite
Zircon
Phosphate
Platinum
Agriculture

A large portion of the population in the DRC is very much dependant on agriculture for their livelihoods. The most common crops in the North Kivu region are: potatoes, sweet potatoes, casava, taro, yams, wheat, beans, cow peas, bambara beans, soybeans, groundnuts, rice, bananas, plantains, and maize (FAO). Agriculture was severely reduced during the recent years of civil unrest, and many traditional crops are no longer grown (IRIN).

The region has a great potential to not only improve growing methods to produce more food per area of crops, but also to move into crops that were lost over the past thirty years but that grew well in the area. For example, coffee, a traditional export crop, shrunk from 110,000 metric tons in the late 1980s to about 50,000 metric tons in 2009, according to the DRC’s national coffee office (IRIN). Coffee has become a major export for neighboring Uganda and Rwanda, there is an increasing demand for coffee in middle-income countries, and the temperate climate in the region is thought to be protection against diseases affecting the plant. In seeing these benefits, NGOs have in recent, more peaceful years launched coffee projects in the Kivu provinces. NGOs are of the perspective that teaching efficient farming methods could be an effective way to provide good employment to excombatants, therefore reducing the desire for employment by military groups.
Appendices — Congo by Mapping

A–20 World Bank 2011 Agriculture Index

A–21 Land use map of Africa (see following page for legend)
Land use in the DRC (top) and North Kivu (bottom)

- Open water inland fisheries
- Open water - protected
- Wetlands - protected
- Wetland - unmanaged
- Urban land
- Agriculture - protected
- Crops and high livestock intensity
- Crops and mod. intensive livestock density
- Rainfed crops (Subsistence/Commercial)
- Shrub moderate livestock density
- Shrub low livestock density
- Shrub protected
- Shrub unmanaged
- Grassland - moderate livestock density
- Grassland - low livestock density
- Grassland protected
- Grassland unmanaged
- Forest with moderate or higher livestock density
- Forest with agricultural activity
- Forest protected
- Forest virgin

A–24 Graph showing percentage land use in North Kivu
Aid

As described in many of the previous themes, aid has a major role to play in all parts of life in the Eastern Great Lakes region. The United Nations Organization Mission in the Democratic Republic of the Congo (MONUC) was established in 1999 following the Congo Wars. They helped organize the country’s first free and fair elections in 46 years, held in 2006. In 2010 MONUC was renamed to the United Nations Organization Stabilization Mission (MUNISCO) to reflect the new phase reached in the country. MONUSCO has a very significant presence in the region, with almost 20,000 military personnel. They extended their time in the country because of current unrest in the Kivu provinces. Beyond the United Nations, there are a substantial number of NGOs, both international and community-based. The International Council of Voluntary Agencies is an example of how organizations are seeing the need to work in cooperation.
Appendices — Congo by Mapping

A–26  World Bank 2011 Assistance and Official Aid Received (Current US$)

-660,900,000 – 424,210,000
424,210,001 – 1,122,810,000
1,122,810,001 – 2,070,790,000
2,070,790,001 – 3,595,160,000
3,595,160,001 – 6,710,870,000
An attempt to find national data for aid in the country. I only found one organization – USAid – that publishes the locations of their nation-wide initiatives.
Data for the Community-Based Organizations Database was gathered from a Landscape Analysis conducted in 2010 by USAID and the Eastern Congo Initiative (ECI) to identify Congolese-lead organizations that are improving outcomes in their communities.
Conflict

The country has experienced a large amount of conflict, even since the last Congo War ended in 1999. In the past fifteen years an estimated total of four million people have died either from violence or the hunger and disease that ensue. Most of the deaths were civilian. Conflict stems from multiple sources, most of which are touched on in the six other themes of this chapter. The main bulk of conflict was initiated after the 1994 Rwandan genocide when Rwandan Hutu militant forces fled to eastern DRC and used refugee camps as a base for incursion against Rwanda. A coalition of Rwandan and Ugandan armies invaded the DRC to overthrow the government of Mobutu, and ultimately control the mineral resources of Zaire. This was the beginning of the First Congo War. This is only a small part of a whole history of the Congo that has been fraught with corruption and exploitation, reaching all the way back to colonization by King Leopold II in the late 1800s. Rape of women and the enslavement of children as child soldiers are of common occurrence.
A–30 Vision of Humanity 2013 Global Peace Index


A–32 (right) Armed Conflict Location and Event Database (ACLED 2013).
A–33  Armed Conflict Location and Event Database for DRC (top) and North Kivu (bottom) (ACLED 2013).

A–34  % conflict type North Kivu
Conflict actor locations overlaid onto Open Street Map and Google Earth image (IPIS Research 2013).

FARDC - Armed Forces of the Democratic Republic of the Congo
FDLR - Democratic Forces for the Liberation of Rwanda
PARECO (Mayi-Mayi) - Coalition of Congolese Patriotic Resistance
ADF/NALU - Allied Democratic Forces

North Kivu % of all conflicts in DRC
Culture

Often overlooked, ethnicity has a significant role to play in the instability of the region. The relationship of ethnicity with national dynamics, specifically its position compared with national citizenship, has allowed it to become an object of manipulation for political elites. It is often overlooked as a root cause of conflict because attention is focused on the symptoms of conflict rather than the source. A research initiative carried out by the International Refugee Rights Initiative and the Social Science Research Council, *Who Belongs Where? Conflict, Displacement, Land and Identity in North Kivu, Democratic Republic of Congo*, suggests that ongoing violence remains rooted in a lack of clarity over the critical question of citizenship in the region, and specifically over the relationship between national identity and ethnic allegiance. The war is seen as both an external conflict that is being played out on Congolese soil, and one that draws upon pre-existing localised divisions. Both of these aspects relate to disagreements over the definition of who legitimately belongs as a citizen in the DRC, and are mostly expressed in ethnic terms. The fact that this dispute over citizenship has persisted throughout the recent fighting emphasises the fact that the cyclical forces that drive the conflict have not been broken.

So how can ethnicity be accommodated within this highly charged environment? For many of those interviewed, the solution to ethnic-based fractures within communities, and therefore to violence, was to
construct a Congolese national identity that could over-ride ethnicity. If properly realised, national identity would represent itself as political systems working in ethnically neutral ways. One displaced man in Rutshuru said, “This thing could be settled by making us feel that we are one people and are Congolese.” However, there is something of a paradox because while there was a strongly anti-ethnic and pro-nationalistic emphasis, at the same time it was clear that the basis for national belonging was strongly tied to ethnicity. An example of this can be seen in the charged relationship between Congolese and Congolese with ties to cross-border ethnicities. Particularly the Hutu and Tutsi ethnicities have been blamed for exporting the conflict from the Rwandan Genocide in the 1990s (African Arguments 2010).
A–39 Numbers of Ethnicities by Country

A–40 Areas of ethnicity in Africa (Ethnicity 2001 Felix).

A–41 Areas of ethnicity in the DRC (Ethnicity 2001 Felix).
Appendix B: Digital Mapping Tools Catalogue

The following are a selection of tools that I researched in my endeav-our to become a master in GIS and to find the tools that were most appropriate for application in Beni. I have included a rating based on my own experience testing and using the tools and a short description of what the tools do. Tools with yellow stars are the ones that I chose to use in Beni and in the next section I include more detailed descriptions and procedures for a selection of those tools. If there is no rating then I discovered the tool but did not test it.

(a) Obtaining Map Data

OpenStreetMap
openstreetmap.org

OpenStreetMap (OSM) is an open-data map that is contributed to by a community of mappers around the world. It powers map data on hundreds of web-sites, mobile applications, and hardware devices. OSM uses ID Editor (online version) and JOSM Editor (offline version), tools that can edit data from various sources. The base map of Beni was traced in JOSM from satellite imagery and then added to OSM so that it would become available on other mapping applications that I selected that use OSM data including Garmin OpenStreetMap, OSMAnd, and Field Papers.

Weogeo
weogeo.com

Weogeo offers map data from around the world. It is possible to zoom in to different areas and search keywords to find specific types of data. Some datasets require payment and others like OpenStreetMap are free. Data from a specific area can be downloaded by drawing a box around the desired geographical region. I used the website to download citywide data of Beni in Shapefile format and it was also possible to select specific layers inside the dataset if I did not want to take everything. Weogeo takes some time to process the request and then e-mails the user a temporary download link.
(b) GPS Data Conversion

**Mkgmap**

mkgmap.org.uk

Mkgmap is a utility that converts OpenStreetMap data into vector maps that can be loaded onto a Garmin GPS device. It gives full control over which OSM data is integrated into the map and how POIs, streets and all other elements are displayed. The program runs out of the terminal or command-line.

**Garmin OpenStreetMap**

garmin.openstreetmap.nl

Garmin OpenStreetMap is a website that allows the user to select an area anywhere in the world using the OpenStreetMap (OSM) base map, and it converts it into files that can be used by Garmin software such as Basecamp, or downloaded directly to a Garmin device. Included in the package is the igmapsupp.img file needed as a basemap for the Garmin device. The request takes a few days and they send an e-mail with a link where the zipped package can be downloaded.

**GPSBabel**

www.gpsbabel.org

GPSBabel converts waypoints, tracks, and routes between popular GPS receivers and mapping programs. Hundreds of receivers and programs are supported. It can also perform actions such as filtering duplicate points or simplifying tracks. GPSBabel runs on all major platforms (PC/Mac) and is free to download or modify.

(c) GPS and Data Collection

**Garmin Etrex 20**

buy.garmin.com/en-CA/CA/on-the-trail/handheld/etrex-20/prod87771.html

GPS Etrex 20 has a world basemap, a colour sunlight-readable display, and a 25-hour battery life with 2 AA batteries. It has a microSD card slot and 1.7 GB of internal memory. It is possible to preload SD-cards with a custom map to use on the Garmin device. The device can be used to collect waypoints and tracks and see the user’s geographical position.

**Field Papers (five stars)**

fieldpapers.org

Field Papers is a tool built by Stamen Design to create a multi-page atlas of any place in the world. A user can print it onto tiled sheets and then take it into the field and record notes on it. After it is all marked up, the user can either scan it or photograph it, and upload it into Field Papers. Field Papers will automatically locate the scans on top of the digital map where the information can then be inputted/traced into OSM. The tool was used in Beni as a back up to the devices for the field collection.
**OsmAnd**  
(osmand.net)

OsmAnd (OpenStreetMap Automated Navigation Directions) is a map and navigation application with access to OSM data. The application allows maps to be downloaded to the phone for offline use. Similar to the Garmin device, users can view their position and register tracks and waypoints. The free version of the application only offers 10 downloads for offline use.

**EpiCollect**  
(epicollect.net)

EpiCollect is an open-source mobile application for creating forms, taking surveys with the forms, and hosting a management system for the data that is collected. A user can create a project website, design the forms, load the project onto the phone to collect data, and then view the resulting data on the project website after it has been uploaded. On the website the data can be viewed, charted, filtered and downloaded. EpiCollect was considered for use in Beni, but was too limited in the types of forms it could produce. EpiCollect uses a public profile and basic forms and EpiCollect+ is a beta version that provides a private page for the user and is working on introducing more complex forms.

**Folcrum**  
(fulcrumapp.com)

Folcrum offers data collection services similar to EpiCollect but is a proprietary application that sells to businesses. The small package is $99 per month (3 apps).

**XLSForm**  
(xlsform.org)

XLSForm is a form standard that allows forms to be authored in Microsoft Excel and then converted into code to be read by mapping applications. The standard has been adopted by multiple data collection platforms including Formhub and OpenDataKit. The website provides full instructions on how to create the forms in Excel to make sure that the data is correctly translated. The learning curve is large, but there is a great amount of control in the resulting forms.

**Formhub**  
(formhub.org)

Formhub is a website that provides a management system for data collection and analysis. It employs XLSForm to create the forms, and ODK Collect to collect the data. The Formhub website is currently experiencing technical difficulties due to being overcapacity.
OpenDataKit (ODK)
.opendatakit.org

OpenDataKit is an open-source suite of tools that provide a full spectrum of support for mobile data collection. The tools in the suite are ODK Build, ODK Collect, and ODK Aggregate. ODK Build is a desktop application for building surveys using a graphic user interface instead of using Excel with the XLSForm standard. ODK Collect is the application for data collection on mobile phones. ODK Aggregate is a management system and data repository that provides the forms to the ODK Collect application, accepts the final forms, and visualizes and exports the data. Unlike Formhub that gathers the data on its own servers, ODK Aggregate is installed on a personal webservice that the user is responsible for (they recommend using Google’s App Engine).

Cybertracker
cybertracker.org

Cybertracker is a first generation platform that was developed in 1995 for the original purpose of tracking wildlife using forms that display only images. Since then it has been employed around the world in the varied domains of scientific research, indigenous knowledge, environmental education, forestry, farming, education, health, crime prevention, and disaster relief. The platform includes Cybertracker desktop software that allows the user to custom design the survey for the phones and later aggregate, analyse and export the resulting data. The application is available for most mobile devices and has the ability to register tracks and waypoints.

(c) Crowd-sourcing Data Collection

FrontlineSMS/Cloud
.frontlinesms.com

Frontline offers SMS management tools that can act as a reporting avenue using mobile technology for two-way communication. It needs either a PC or Mac computer, and either a compatible mobile phone or modem. The software is free and so only the messages need to be paid for. Another option is to have an internet connection and an account with one of Frontline’s web-based aggregators (SMS gateway services). Frontline SMS has support for Clickatell and IntelliSMS messaging services. Frontline Cloud is different in that it has many ways to connect to mobile networks, and the data is managed by the cloud. FrontlineCloud is currently in Beta and is $10 per month.

Ushahidi
.ushahidi.com

Ushahidi is a platform for information collection, visualization and interactive mapping. It is free to download and use and has been used by crowd-sourced data collection initiatives around the world. It allows the user to collect information from the public via text messages, e-mail, twitter and web forms, offers mapping tools to visualize the information, and lets you filter your data by time.
(d) Computer Geographic Information System (GIS) Software

**ArcGIS**

[esri.com/software/arcgis](esri.com/software/arcgis)

Esri’s ArcGIS is a geographic information system for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analyzing mapped information, using maps and geographic information in a range of applications, and managing geographic information in a database.

**QGIS**

[qgis.org](qgis.org)

QGIS is a free and open source geographic information system. It is used to create, edit, visualize, analyze, and publish geospatial information. It is compatiable with Windows, Mac, Linux, and BSD (Android coming soon). QGIS was a key tool in Beni because UCBC students could use it for free, and

(e) Map-editing Software

**JOSM Editor**

[josm.openstreetmap.de/](josm.openstreetmap.de/)

JOSM is a free software that is used for offline editing of OpenStreetMap data. Once downloaded on your computer JOSM allows you to select an area that you want to download from OSM and then has the option to put a tiled Bing satellite image behind it. Then using editing tools it is possible to add to the map by tracing new elements such as roads, buildings, or waterbodies, or adjusting existing lines and information. After the edits are complete it is possible to upload the information onto OpenStreetMap or to save it as an OSM or geojson file. JOSM Is excellent for the preparation and clean-up of collected data before bringing it into QGIS.

**TileMill**

[mapbox.com/tilemill/](mapbox.com/tilemill/)

TileMill is software created by Mapbox to create attractive interactive maps. It is compatible with data-sources that include ESRI Shapefile, KML, GeoJSON, GeoTIFF, PostGIS, CSV, and SQLite. You can layer data sources to build complex maps and write code that is similar to CSS that allows you to adjust and preview the styles for each element.

(f) Map Web Display Software

**Mapbox (two stars)**

[www.mapbox.com](www.mapbox.com)

Mapbox is a mapping platform that allows developers to quickly build and style mobile and web apps that can be displayed on any website. The website code must refer to the Mapbox.js library and the map can be embedded by referred to a map ID that Mapbox provides. Map data can also be downloaded as geoJSON or KML.
(g) Programming Frameworks for Mapping

Leaflet (four stars)
www.leafletjs.com
Leaflet is an open-source JavaScript library for mobile-friendly interactive maps. It works across all major desktop and mobile platforms and can be extended with a large amount of plug-ins.

Modest Maps
www.modestmaps.com
Similar to Leaflet, Modest Maps is another JavaScript library. It is a simple base library that provides many hooks to build on.

OpenLayers (four stars)
www.openlayers.org
OpenLayers is a completely open source JavaScript mapping library. It is possible to contribute to the OpenLayers community by sharing code. The library is big and cumbersome but has expansive capabilities.

D3 Data-Driven Documents (four stars)
www.d3js.org
D3 is a JavaScript library for manipulating documents based on data. It uses html, SVG, and CSS to bring the data to life. D3 functions as a DOM framework, but unlike JQuery and Prototype it can specify functions of data and not just constants.

Polymaps
www.polymaps.org
Polymaps is a Javascript library that uses SVG to create and manipulate maps on the web.

ArcGIS API for JavaScript
www.developers.arcgis.com/javascript/

(h) Dynamically Drawn Map Servers

Map Server
www.mapserver.org

QGIS Server
www.hub.qgis.org

GeoServer
www.geoserver.org

(i) Caches for Web Tiling

GeoWebCache
www.geowebcache.org
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TileCache
   www.tilecache.org
TileStache
   www.tilestache.org

(i) Spatial Databases

PostGIS
   www.postgis.net
PostGIS is an open source database that works with PostGRE SQL.

SpatiaLite
   www.gaia-gis.it/fossil/libspatialite
Appendix C: Detailed Procedures for Selected Software

Garmin OpenStreetMap & Garmin Etrex 20

(a) Description

One way to collect geospatial data is to use a GPS unit. Although mobile phones now have the same, or perhaps even more capabilities as a GPS, the key qualities of a GPS device are durability and dependability. Not only are GPS waterproof and drop proof, they also take two AA batteries that you can get anywhere, and have a 24 hour battery life. They also donít require access to mobile internet. All of these qualities make it excellent for use in the developing context. Phones on the other hand are cheaper and more widely available, but are fragile, need to access internet, and have a shorter battery life. I have to think about all of these factors because Beni only has a few hours of electricity per day. The best action to take will be to bring a good amount of both technologies and bring extra things like portable battery chargers and extra batteries.

The first step in using the Garmin device was the most difficult. I had to determine how to create my own img file to serve as the background map for the Garmin device. From my research I determined that the best method would be to use JOSM to trace out a base map of the city that can be uploaded onto OSM, then retrieve it again using Garmin OpenStreetMap, a website that converts a chosen area selection of OSM and e-mails you a link to a downloadable zip file that includes the img file. It can take one or two days to receive the files and because it is a free service they ask for donations. The igmapsupp.imgi file can be downloaded onto the cards of several GPS devices that can then be enabled once the device is turned on. All of the Garmin devices will have the same base map for participants to navigate and work with. Because I canít really test this part of the process with the Beni map, I downloaded the OSM Garmin img file for Cambridge.

The next task was to learn how to use the device to collect data. I discovered that the Garmin device is quite limited in this respect. I thought I would be able to edit existing Points of Interest for example, or be able to rename existing streets. This is not the case; the only thing that the Garmin unit can do is log what are called “tracks” and
“waypoints”. Tracks literally mark your journey with a connected trail of points over time that save the coordinates. Tracking can be enabled or disabled and there is an option to have it enabled while not being visible on the map. I will enable the tracking because anyone editing the map later will need to know where the groups of mappers went in the city to make sure there are no holes in the gathered information. Waypoints are points that can be logged at any time and can be used for the marking of any Points Of Interest (POIs). It can be marked by choosing to save a waypoint where you are standing, or you can toggle the mouse to select a nearby element such as a road or a building. A title can be given to a waypoint as well as a short note, and you can change the icon that represents the waypoint on the map to better express what it is. Originally I had planned for participants to input the POI and street names as the waypoint titles, and use the note category for descriptors such as type or condition, but I realized that it would take a long time to input the names, especially on devices that have to toggle across a keyboard to select individual letters. The best option will be to send out participants in groups that have a GPS user as well as a physical note-taker with a legend that shows what information to include. After the storage on the device is full or a task is complete, the data can be uploaded to the computer either by USB connection or removing and reading the MicroSD. After the points are transferred they can be cleared from the device to leave space to go out and collect more. The waypoints and tracks from the Garmin device are igpx files that can be opened directly in JSOM or QGIS. A program called GPSBabel is handy if using a different brand device where conversion is required.

(b) User Instructions

1. Go in a team of three to your assigned neighbourhood, bringing with you the GPS unit and notebook. Use the GPS unit to identify location and information of all points of interest (POIs) and road names.
2. To change or add a road name or point of interest (POI) use the toggle to move the mouse over top of the road or building you want to rename and then click. A screen will come up that gives the name, elevation, distance, and location of the street.
3. Click the “menu” button on the left side of the device. A message will come up that says “Save as Waypoint”. Click to do this. A message will come up that says “This location was successfully saved as a waypoint. Click “OK”.
4. Click the “back” button on the right side of the device. You don’t want to go to this location. Click “back” two more times to get back to the main menu.
5. Click on “Where To?” button in the menu, and then click on “Find Another”. Click on “Waypoints”. Your most recent Waypoint additions should be exhibited in order. Click on the most recent street you created.
6. It will point it out on the map to confirm it is the right one. Then
click the “menu” on the left side of the device. Then click on “Review Point”. Then click the “menu” button again and click the option “Edit Waypoint”.

7. All of the options can be edited except for the location. If you are editing a street choose the blue flag icon. For points of interest choose the red flag icon.

8. Use the toggle on the keyboard to click on the keys to rename the Waypoint as an ID that can be used to associate it with your notes. In your notebook fill in the following information:

If a street: ID, Name, Type (highway, major road, residential road, footpath), Condition (very good, good, average, bad, very bad), Pavement (asphalt, gravel, dirt)

If a POI: ID, Name, Type (commercial, recreational, Address (if applicable)

9. When neighbourhood data collection is complete or your GPS is full, return to the hub to submit the GPS unit and notes to the map editors.

Field Papers

(a) Description

Field Papers is an excellent tool because it combines digital tools with the most raw form of data gathering: note-taking. In my discussions with experienced mappers, they all recommended to have a back-up to the digital devices because I will be in a place where mobile networks and electricity are not dependable. Field Papers was created by Stamen Design and its purpose is to make the note-taking process more efficient and accurate. The Field Papers website allows you to download a selected area of the OSM map of the world as a set of tiles that are print-ready on letter size paper. The papers can then be distributed to groups of participants to add notes to while exploring and mapping the city. When a certain neighbourhood is mapped, the sheets can then be scanned or photographed and uploaded back onto the field papers website. The barcodes that are on the tiles allow the program to geolocate the scanned image of the map so that all of the physical notes can be easily traced and made digital. Field Papers can be installed as a plug-in for JOSM where the traces can be made.

(b) Set-up Instructions

1. Go to Field Papers website and search your location.
2. Zoom in so that the maps will be a sufficient scale when printed.
3. Add as many tiles as you need to cover a neighbourhood.
4. Save the URL that is provided so that you can retrieve and share the map: http://www.fieldpapers.org/atlas.php?id=s7rc4xx9#15/43.3586/-80.3161
5. Print PDF to take into the field and mark up.
6. When you are done editing, scan or photograph the tiles and upload the images back to Field Papers.
7. Note down the URL of your page snapshot: http://www.fieldpapers.org/snapshot.php?id=5b4xxg3d#16/43.3562/-80.3224
8. Install the Field Papers plug-in for JOSM by going to “Edit - Preferences”. You will have to restart the program.
9. Go to menu “Field Papers” and paste in the URL. The picture you took will be located in the correct location on your map.

OSMAnd

(a) Description

OSMAnd is an application on Android phones that works similar to a GPS unit in that it can save waypoints and track where you are going. Phones have a shorter battery life and are more fragile than GPS units, but the real advantage is that they are more widely available.

(b) Set-up Instructions

1. Download free application from Google Play and install on your phone.
2. Go to “Settings - Data Management - download or update offline data” to add maps (select “World Base Map” and “Congo-democratic-republic africa” for download).
3. Go to menu “Where am I” to locate yourself. Your position should show up as a blue dot.
4. Go to menu “Settings - Navigation - General” to select preferred language, language of names in maps, and unit of measure (kilometers/meters).
5. Go to menu “Settings - Plugins - Logging services & Sleep Mode” to activate tracking. Make sure to uncheck this setting after you are done your journey so that your phone isn’t connecting to the internet more than it has to.
6. Go back one menu and configure the “Logging services” settings.
7. Select the pedestrian option and select “Log track to GPX file”.
8. To see the track as you walk you can go to menu “Settings - Map layers - GPX tracks”.
9. Tricks for extending battery life are to go to the home page before putting in sleep mode while tracking is set, and if in a remote area, turn on airplane mode so that the phone isn’t continuously searching for signals. Airplane mode can be found under phone settings.
10. Upload the gpx files to the computer using a MicroSD adapter or plugging the phone into the computer’s USB port. Favourites are in the main folder as a single gpx file and the tracks are located in a “tracks” folder.
11. After uploaded onto the computer the waypoints can be deleted by going to the menu “favourites” folder and selecting the trash bin and then the items you want to delete. Tracks can similarly be removed.
ODK Collect

(b) User Instructions

1. To add a waypoint, tap the screen while still holding a finger on the screen (similar to a right click). A location box will come up with a Latitude and Longitude for the location you clicked. Click on the box and pick the “Add to favourites” option.
2. Fill in an ID (similar to GPS device) using the keyboard and click “Add”. Note that the icon will locate itself at the center of the screen that you are at when you take the action of adding a favourite.
3. Another way to add a favourite is to go to menu “Use locations - Add to favourites”. Using this method will locate the tag at the center of the screen.
4. In your notebook fill in the following information that must correspond with each ID number:
   If a street: ID, Name, Type (highway, major road, residential road, footpath), Condition (very good, good, average, bad, very bad), Paving (asphalt, gravel, dirt)
   If a POI: ID, Name, Type (commercial, recreational,, Address (if applicable)
5. When you are done collecting data, return to the hub and submit the phone and your notes to the map editors.

JOSM

(a) Description

JOSM is a free software that is used for offline editing of OpenStreetMap (OSM). OpenStreetMap is an open source online map that can be edited or downloaded by any registered member. The easiest way to describe it is to call it the “Wikipedia” of mapping. There are now millions of people who contribute and I recently signed up because I learned it would be a valuable tool in generating a globally positioned map of Beni. JOSM allows you to select an area that you want to download from OSM and then has the option to put a tiled Bing satellite image behind it. Then using editing tools it is possible to add to the map by tracing new elements such as roads, buildings, or water-bodies, or adjusting existing lines and information. I am using JOSM to trace the roads and creeks to form a preliminary base map. One might ask why I am tracing the roads of a place I have never been to and what if I make errors. The reason I am doing it is because I need to create a base map that I can add to once I go to Beni. If I do not create a base map, I would have nothing for the mapping participants to even follow or know where to go or what neighbourhoods to explore. They will use this information as a base but will then add to it and correct any errors by physically being there. That means that OSM will have errors for a small amount of time, but will soon be made accurate as we gallivant around Beni and document refinements and edits. The mapping participants will be able to collect informa-
tion beyond just the tracings by documenting data such as road names, road types, paving types, and what condition they are in. They will also be mapping other things such as buildings and places that are Points Of Interest (POIs) for the community. While the line information can be shared with OSM, we have the choice of whether or not to add the detailed information or keep it for our own use. JOSM always encourages people to upload the content back to OSM, but what is nice about the program is that you can always wait until the information is accurate before uploading, or choose to upload only the elements you want to contribute to the public map. Another great feature of JOSM is that it can export the information as gpx tracks that are compatible for download onto Garmin devices or GPS Android applications for use in the field. JOSM can also export as geoJson files that can be used in coding or to import the same elements with their data into QGIS, an open source Global Information System (GIS).

There is an online editor called iD that essentially does the same thing as JSOM, but it edits in OSM directly. I like JSOM for the ability to wait, its exporting capabilities, and also because work can be done offline, a key thing to think about when working with technology in a developing country where internet can be spotty and expensive. I'll be bringing all of these programs over on a USB key to avoid any need for downloading big files from the web. One may also ask why I am not just editing this information in QGIS, a program that is capable of doing the same thing. The reason I have decided to use JSOM is because its connection with OSM allows me to use really helpful tools such as this website that formats base map img files of a specified area from OSM for Garmin devices. Editing in JSOM is also much faster than in QGIS just in the way the interface is designed. QGIS will come into the picture later on when it is time to manipulate the data that we collect to create our own custom maps and corresponding databases. Lastly, JSOM is great for preliminary work because it is valuable to contribute to OpenStreetMap, not only because I am benefiting so much from it as a tool and resource, but also because others will benefit from an open source base map of Beni.
Appendix D: Maps and Metadata of Beni
Table A–01 Road metadata

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Appendices — Maps and Metadata of Beni
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Appendices — Code for Beta Application

Appendix E: Code for Beta Application
The following section includes the code that was developed for the
beta mapping application. The website uses Jquery (https://jquery.
com/), and Openlayers3 (http://openlayers.org/) API’s. The code includes HTML, CSS, and Javascript.

HTML
<!DOCTYPE html PUBLIC “-//W3C//DTD XHTML 1.0 Transitional//EN”>
<html lang=’en’>
<head>
<title>Beni Atlas</title>
<link rel=”stylesheet” href=”stylesheets/ol.css” type=”text/css”>
<link rel=”stylesheet” href=”stylesheets/beniatlas.css”>
<script type=”text/javascript” src=”javascript/jquery.min.js”></script>
<script type=”text/javascript” src=”javascript/ol.js”></script>
</head>
<body>
<script type=”text/javascript” src=”javascript/beniatlas.js”></script>
<script type=”text/javascript” src=”javascript/layerfunctions.js”></script>
<script type=”text/javascript” src=”javascript/buttonfunctionality.js”></script>
<div id=”header”>
<p>
<a href=”index.html”>
<img src=”images/logo_beniatlas.png” alt=”BeniAtlas” style=”top:80px; left: 30px;
position:absolute”>
</a>
</p>
<p>
<ul class=”nobullet” class=”hnav”>
<li class=”hnav-about”><a class=”hnav-menu” href=”about.html”>[About]</a></li>
<li class=”hnav-map”><a class=”hnav-menu” href=”maps.html”>[Maps]</a></li>
<li class=”hnav-blog”><a class=”hnav-menu” href=”blog.html”>[Blog]</a></li>
<li class=”hnav-partners”><a class=”hnav-menu” href=”partners.html”>[Partners]</a></li>
<li class=”hnav-en”><a class=”hnav-menu” href=”english.html”>[EN]</a>/</li>
<li class=”hnav-fr”><a class=”hnav-menu” href=”french.html”>[FR]</a></li>
</ul>
</p>
</div>
<div id=”mapcolumn”>
<div id=”map” class=”map”></div>
<img class=”northarrow” src=”images/northarrow.png” alt=”North Arrow” width=”30px”>
<div id=”infocolumn1”>
<h2 class=”title”></h2>
<p class=”source”></p>
<p class=”description”></p>
<!--<svg width=”20” height=”10”><rect fill=”red” stroke=”#000000” stroke-miterlimit=”10”
width=”20” height=”10”/></svg>-->
<div id=”legend”>
<div id=”legendicons”></div>
<p class=”legend”></p>
</div>
</div>

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CSS

/*------------------------------------*
  GENERAL
  "------------------------------------*/
body {
  padding: 0;
  font-family: "Helvetica Neue", Arial, Helvetica, sans-serif;
  color: #333333;
  font-size: 75%;
  background: white;
  color: #666;
}

#header {
  height: 160px;
  width: 100%;
}

#mapcolumn {
  width: 700px;
  float: left;
}

#map {
  height: 500px;
  width: 100%;
  background: white;
  top: 155px;
  left: 0px;
  z-index: -1;
  float: left;
}

#buttoncolumn {
  width: 140px;
  height: auto;
  padding: 50px;
  background-color: white;
  z-index: 2;
  float: left;
  clear: right;
}

#infocolumn1 {
  width: 300px;
  height: auto;
  padding-left: 50px;
  float: left;
  z-index: -1;
}

#infocolumn2 {
  width: 300px;
  height: auto;
  padding-left: 50px;
  float: left;
}

/*------------------------------------*
  BUTTONS
  "------------------------------------*/
/*negative margin around layer buttons to bring closer together*/
input.layer_button {
  margin-right: -4px;
  margin-top: -4px;
  bottom: -10px;
}

div.method_group {
  padding-left: 10px;
Beni Atlas’
border-style:solid;
border-width:2px;
border-color:red;
}

.ol-zoom .ol-zoom-in{
  border-radius:4px 4px 0 0
}

.ol-zoom .ol-zoom-out{
  border-radius:0 0 4px 4px
}

/*------------------------------------*
  TEXT
 `------------------------------------*/

p.buttons {
  font-family: "Myriad Pro";
  font-size: 110%;
  font-weight: bold;
  color: black;
  z-index: 1;
}

p.legend {
  padding-left: 35px;
  padding-bottom: 10px;
  line-height: 170%;
}

p.copyright {
  position:absolute;
  top:1750px;
  left:460px;
}

p.white {
  color:white;
}

ul.nobullet {
  list-style-type:none;
  margin:0;
  padding:0;
}

ul.hnav {
  list-style-type:none;
  margin:0;
  padding:0;
  overflow: hidden;
  z-index: 1;
}

li.hnav-about {
  position: absolute;
  top:180px;
  left:94px;
  z-index: 1;
}

li.hnav-map {
  position: absolute;
  top:180px;
  left:245px;
  z-index: 1;
}

li.hnav-blog {
  position: absolute;
  top:180px;
  left:389px;
  z-index: 1;
}
Javascript

//**********************************************************************
//VIEWS//
//**********************************************************************

var world = new ol.View({
  projection: 'EPSG:4326',
  center: [0, 0],
  zoom: 1.5,
  minZoom: 1.5,
  maxZoom: 1.5
});

var drc = new ol.View({
  projection: 'EPSG:4326',
  center: [23.65, -3.02],
  zoom: 5,
  minZoom: 5,
  maxZoom: 5
});

var nkivu = new ol.View({
  projection: 'EPSG:4326',
  center: [28.69, -0.60],
  zoom: 7.4,
  minZoom: 7.4,
  maxZoom: 7.4
});

var beni_r = new ol.View({
  projection: 'EPSG:4326',
  center: [29.53, 0.42],
  zoom: 9,
  minZoom: 9,
  maxZoom: 9
});

var beni_c = new ol.View({
  projection: 'EPSG:4326',
  center: [29.46, 0.50],
  zoom: 13,
  minZoom: 13,
  maxZoom: 16
});

var beni_q = new ol.View({
  projection: 'EPSG:4326',
  center: [29.46, 0.50],
  zoom: 13,
  minZoom: 13,
  maxZoom: 16
});

//**********************************************************************
//SOURCES//
//**********************************************************************

var worldSource = new ol.source.GeoJSON({
  url: 'data/admin_world.geojson',
  projection: 'EPSG:4326'
});

var drcSource = new ol.source.GeoJSON({
  url: 'data/admin_drc.geojson',
  projection: 'EPSG:4326'
});

var drcdivSource = new ol.source.GeoJSON({
  url: 'data/admin_drc_div.geojson',
  projection: 'EPSG:4326'
});

var nkivuSource = new ol.source.GeoJSON({
  url: 'data/admin_nkivu.geojson',
  projection: 'EPSG:4326'
});
Beni Atlas

url: 'data/admin_nkivu.geojson',
projection: 'EPSG:4326'
});

var nkivudivSource = new ol.source.GeoJSON({
//NORTH KIVU DIVIDED ADMIN SOURCE
url: 'data/admin_nkivu_div.geojson',
projection: 'EPSG:4326'
});

var beni_rSource = new ol.source.GeoJSON({
//BENI REGION ADMIN SOURCE
url: 'data/admin_beni_r.geojson',
projection: 'EPSG:4326'
});

var beni_c_roadsSource = new ol.source.GeoJSON({
//BENI ROADS SOURCE
url: 'data/roads_test.geojson',
projection: 'EPSG:4326'
});

var beni_c_roadspSource = new ol.source.GeoJSON({
//BENI PRIMARY ROADS SOURCE
url: 'data/roads_primary.json',
projection: 'EPSG:4326'
});

var drc_coSource = new ol.source.GeoJSON({
//DRC CONFLICT SOURCE
url: 'data/conflict_drc.geojson',
projection: 'EPSG:4326'
});

var drc_cuSource = new ol.source.GeoJSON({
//DRC CONFLICT SOURCE
url: 'data/culture_drc.geojson',
projection: 'EPSG:4326'
});

var beni_c_cuSource = new ol.source.GeoJSON({
//BENICITY CULTURE SOURCE
url: 'data/culture_test.geojson',
projection: 'EPSG:4326'
});

var beni_qSource = new ol.source.GeoJSON({
//BENI QUARTIER BOUNDARIES SOURCE
url: 'data/quartiers_test.geojson',
projection: 'EPSG:4326'
});

//////////////////////////////////////////////////
//STYLES//
//////////////////////////////////////////////////

//GREY FILL STYLE
var greyStyle = new ol.style.Style({
fill: new ol.style.Fill({
color: '#D8DAD9',
}),
stroke: new ol.style.Stroke({
color: 'white',
width: 0.5
})
});

//BLACK OUTLINE STYLE
var outlineStyle = new ol.style.Style({
stroke: new ol.style.Stroke({
color: 'black',
width: 1
})
});

//BLACK OUTLINE 2 STYLE
var outline2Style = new ol.style.Style({
stroke: new ol.style.Stroke({
color: 'black',
width: 2
})
});
//POINT STYLE CONFLICT
var drc_coStyle = new ol.style.Style({
    image: new ol.style.Circle({
        radius: 4,
        fill: new ol.style.Fill({
            color: '#94ABB7',
        }),
        stroke: new ol.style.Stroke({
            color: 'rgba(20,130,150,0.8)',
            width: 1
        })
    })
});

//culture drc style
var drc_cuStyle = new ol.style.Style({
    stroke: new ol.style.Stroke({
        color: '#F062A4',
        width: 1
    })
});

//POINT STYLE CULTURE
var beni_c_cuStyle = new ol.style.Style({
    image: new ol.style.Circle({
        radius: 4,
        fill: new ol.style.Fill({
            color: '#F768A1',
        }),
        stroke: new ol.style.Stroke({
            color: 'rgba(20,130,150,0.8)',
            width: 1
        })
    })
});

///////////////////////////////////////////////////<FONT STYLE FUNCTIONS///<
///////////////////////////////////////////////////<LAYERS///<
/////////////////////////////////////////////////////////
var worldLayer = new ol.layer.Vector({
  source: worldSource,
  style: greyStyle
});

var drcLayer = new ol.layer.Vector({
  source: drcSource,
  style: outlineStyle
});

var drcdivLayer = new ol.layer.Vector({
  source: drcdivSource,
  style: greyStyle
});

var nkivuLayer = new ol.layer.Vector({
  source: nkivuSource,
  style: outlineStyle
});

var nkivudivLayer = new ol.layer.Vector({
  source: nkivudivSource,
  style: greyStyle
});

var beni_rLayer = new ol.layer.Vector({
  source: beni_rSource,
  style: outlineStyle
});

var beni_rdivLayer = new ol.layer.Vector({
  source: beni_rSource,
  style: greyStyle
});

// ADMINISTRATIVE BENI POINT LAYER

// quartier boundaries layer
var beni_qLayer = new ol.layer.Vector({
  source: beni_qSource,
  style: quartiertextStyleFunction
});

// roads layer
var roadsLayer = new ol.layer.Vector({
  source: beni_c_roadsSource,
  style: (function() {
    var route_principale = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: 'black',
        width: 6
      })
    })];
    var route_secondaire = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: 'grey',
        width: 4
      })
    })];
    var route_tertiare = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: 'grey',
        width: 2.5
      })
    })];
    var route_sentier = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: '#D8DAD9',
        width: 1.5
      })
    })];
    var route_service = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: '#D8DAD9',
        width: 2
      })
    })];
  })
});
var route_pieton = [new ol.style.Style({
  stroke: new ol.style.Stroke({
    color: '#938B6A',
    width: 1
  })});
]
]
var route_default = [new ol.style.Style({
  stroke: new ol.style.Stroke({
    color: '#D8DAD9',
    width: 1.5
  })});
]
]
return function(feature) {
  if (feature.get('type') == 'route_principale') {
    return route_principale;
  } else if (feature.get('type') == 'route_secondaire') {
    return route_secondaire;
  } else if (feature.get('type') == 'route_tertiare') {
    return route_tertiaire;
  } else if (feature.get('type') == 'route_sentier') {
    return route_sentier;
  } else if (feature.get('type') == 'route_service') {
    return route_service;
  } else if (feature.get('type') == 'route_pieton') {
    return route_pieton;
  } else {
    return route_default;
  }
};

//inner roads layer
var roadsLayer2 = new ol.layer.Vector({
  source: beni_c_roadsSource,
  style: (function() {
    var route_principale2 = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 3
      })});
    ]
    var route_secondaire2 = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 1.5
      })});
    ]
    var route_tertiare2 = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })});
    ]
    var route_default2 = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        width: 0
      })});
    ]
    return function(feature) {
      if (feature.get('type') == 'route_principale') {
        return route_principale2;
      } else if (feature.get('type') == 'route_secondaire') {
        return route_secondaire2;
      } else if (feature.get('type') == 'route_tertiare') {
        return route_tertiare2;
      }
    };}

//primary roads layer
var roads_primaryLayer = new ol.layer.Vector({}
source: beni_c_roadsSource,
style: new ol.style.Style({
  stroke: new ol.style.Stroke({
    color: 'grey',
    width: 3
  })
})
});

// roads infrastructure layer
var beni_c_inLayer = new ol.layer.Vector({
  source: beni_c_roadsSource,
  style: (function() {
    var condition_bonne = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: 'blue',
        width: 2
      })
    })];
    var condition_mediocre = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: 'yellow',
        width: 2
      })
    })];
    var condition_mauvaise = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: 'red',
        width: 2
      })
    })];
    var condition_default = [new ol.style.Style({
      stroke: new ol.style.Stroke({
        color: '#D8DAD9',
        width: 1
      })
    })];
    return function(feature) {
      if (feature.get('condition') == 'condition_bonne') {
        return condition_bonne;
      } else if (feature.get('condition') == 'condition_mediocre') {
        return condition_mediocre;
      } else if (feature.get('condition') == 'condition_mauvaise') {
        return condition_mauvaise;
      } else {
        return condition_default;
      }
    };
  })();
});

// conflict drc layer
var drc_coLayer = new ol.layer.Vector({
  source: drc_coSource,
  style: drc_coStyle
});

// conflict world layer
var world_coLayer = new ol.layer.Vector({
  source: worldSource,
  style: (function () {
    var defaultStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#D8DAD9',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    var veryhighStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#011D1D',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    return function(feature) {
      if (feature.get('condition') == 'veryhigh') {
        return veryhighStyle;
      } else {
        return defaultStyle;
      }
    };
  })();
});
stroke: new ol.style.Stroke({
    color: 'white',
    width: 0.5
  })
});

var highStyle = [new ol.style.Style({
    fill: new ol.style.Fill({
      color: '#A8A8A8',
    }),
    stroke: new ol.style.Stroke({
      color: 'white',
      width: 0.5
    })
  })];

var mediumStyle = [new ol.style.Style({
    fill: new ol.style.Fill({
      color: '#7F7F7F',
    }),
    stroke: new ol.style.Stroke({
      color: 'white',
      width: 0.5
    })
  })];

var lowStyle = [new ol.style.Style({
    fill: new ol.style.Fill({
      color: '#565656',
    }),
    stroke: new ol.style.Stroke({
      color: 'white',
      width: 0.5
    })
  })];

var verylowStyle = [new ol.style.Style({
    fill: new ol.style.Fill({
      color: '#2D2D2D',
    }),
    stroke: new ol.style.Stroke({
      color: 'white',
      width: 0.5
    })
  })];

return function(feature) {
  if (feature.get('p2013rate') == 'veryhigh') {
    return veryhighStyle;
  } else if (feature.get('p2013rate') == 'high') {
    return highStyle;
  } else if (feature.get('p2013rate') == 'medium') {
    return mediumStyle;
  } else if (feature.get('p2013rate') == 'low') {
    return lowStyle;
  } else if (feature.get('p2013rate') == 'verylow') {
    return verylowStyle;
  } else {
    return defaultStyle;
  }
};
});

// culture world layer
var world_cuLayer = new ol.layer.Vector({
  source: worldSource,
  style: (function () {
    var defaultStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#D8DAD9',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    var veryhighStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#AC1283',
      })
    })];
    var highStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#A8A8A8',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    var mediumStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#7F7F7F',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    var lowStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#565656',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    var verylowStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#2D2D2D',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    return function(feature) {
      if (feature.get('p2013rate') == 'veryhigh') {
        return veryhighStyle;
      } else if (feature.get('p2013rate') == 'high') {
        return highStyle;
      } else if (feature.get('p2013rate') == 'medium') {
        return mediumStyle;
      } else if (feature.get('p2013rate') == 'low') {
        return lowStyle;
      } else if (feature.get('p2013rate') == 'verylow') {
        return verylowStyle;
      } else {
        return defaultStyle;
      }
    }
  })();

// world layer
var worldLayer = new ol.layer.Vector({
  source: worldSource,
  style: (function () {
    var defaultStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#D8DAD9',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    var veryhighStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#AC1283',
      })
    })];
    var highStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#A8A8A8',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    var mediumStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#7F7F7F',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    var lowStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#565656',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    var verylowStyle = [new ol.style.Style({
      fill: new ol.style.Fill({
        color: '#2D2D2D',
      }),
      stroke: new ol.style.Stroke({
        color: 'white',
        width: 0.5
      })
    })];
    return function(feature) {
      if (feature.get('p2013rate') == 'veryhigh') {
        return veryhighStyle;
      } else if (feature.get('p2013rate') == 'high') {
        return highStyle;
      } else if (feature.get('p2013rate') == 'medium') {
        return mediumStyle;
      } else if (feature.get('p2013rate') == 'low') {
        return lowStyle;
      } else if (feature.get('p2013rate') == 'verylow') {
        return verylowStyle;
      } else {
        return defaultStyle;
      }
    }
  })();

```javascript
var veryhighStyle = [new ol.style.Style({
    fill: new ol.style.Fill({
        color: '#D53491',
        stroke: new ol.style.Stroke({
            color: 'white',
            width: 0.5
        })
    }),
});

var highStyle = [new ol.style.Style({
    fill: new ol.style.Fill({
        color: '#F768A1',
        stroke: new ol.style.Stroke({
            color: 'white',
            width: 0.5
        })
    }),
});

var mediumStyle = [new ol.style.Style({
    fill: new ol.style.Fill({
        color: '#F99AB1',
        stroke: new ol.style.Stroke({
            color: 'white',
            width: 0.5
        })
    }),
});

var lowStyle = [new ol.style.Style({
    fill: new ol.style.Fill({
        color: '#FCC6C6',
        stroke: new ol.style.Stroke({
            color: 'white',
            width: 0.5
        })
    }),
});

var verylowStyle = [new ol.style.Style({
    fill: new ol.style.Fill({
        color: '#FCC6C6',
        stroke: new ol.style.Stroke({
            color: 'white',
            width: 0.5
        })
    }),
});

return function(feature) {
    if (feature.get('cu_rating') == 'veryhigh') {
        return veryhighStyle;
    } else if (feature.get('cu_rating') == 'high') {
        return highStyle;
    } else if (feature.get('cu_rating') == 'medium') {
        return mediumStyle;
    } else if (feature.get('cu_rating') == 'low') {
        return lowStyle;
    } else if (feature.get('cu_rating') == 'verylow') {
        return verylowStyle;
    } else {
        return defaultStyle;
    }
};

// culture drc layer
var drc_cuLayer = new ol.layer.Vector({
    source: drc_cuSource,
    style: drc_cuStyle
});

var beni_c_cuLayer = new ol.layer.Vector({
    source: beni_c_cuSource,
    style: beni_c_cuStyle
});
```
```javascript
var worldGroup = new ol.layer.Group({
    layers: [worldLayer, drcLayer]
});

var world_coGroup = new ol.layer.Group({
    layers: [world_coLayer, drcLayer]
});

var world_cuGroup = new ol.layer.Group({
    layers: [world_cuLayer, drcLayer]
});

var drcGroup = new ol.layer.Group({
    layers: [drcdivLayer, nkivuLayer]
});

var drc_coGroup = new ol.layer.Group({
    layers: [drcdivLayer, drc_coLayer, nkivuLayer]
});

var drc_cuGroup = new ol.layer.Group({
    layers: [drcdivLayer, drc_cuLayer, nkivuLayer]
});

var nkivuGroup = new ol.layer.Group({
    layers: [nkivudivLayer, beni_rLayer]
});

var beni_rGroup = new ol.layer.Group({
    layers: [beni_rdivLayer]
});

var beni_cGroup = new ol.layer.Group({
    layers: [roadsLayer, roadsLayer2]
});

var beni_c_inGroup = new ol.layer.Group({
    layers: [beni_c_inLayer]
});

var beni_c_cuGroup = new ol.layer.Group({
    layers: [roadsLayer, roadsLayer2, beni_c_cuLayer]
});

var beni_qGroup = new ol.layer.Group({
    layers: [roadsLayer, roadsLayer2, beni_qLayer]
});

var beni_q_inGroup = new ol.layer.Group({
    layers: [beni_c_inLayer, beni_qLayer]
});

var beni_q_cuGroup = new ol.layer.Group({
    layers: [roadsLayer, roadsLayer2, beni_c_cuLayer, beni_qLayer]
});

itime:

//INTERACTIONS/
//CHANGE TO RED WHEN CLICK
var selectInteraction = new ol.interaction.Select({
    layers: [beni_qLayer, drcLayer, nkivuLayer],
    style: new ol.style.Style({
        stroke: new ol.style.Stroke({
            color: 'blue',
            width: 3,
        }),
        fill: new ol.style.Fill({
            color: 'rgba(0,0,255,0.1)',
        })
    }),
});
```

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//change to blue when hover
var selectPointerMove = new ol.interaction.Select({
layers: [beni_qLayer, drcLayer, nkivuLayer],
style: new ol.style.Style({
  stroke: new ol.style.Stroke({
    color: 'red',
    width: 3,
  }),
  fill: new ol.style.Fill({
    color: 'rgba(255,0,0,0.1)',
  })
})
});

$(document).ready(function() {
  map.addEventListener('click', function() {
    var featuresExtent = ol.extent.createEmpty();
    selectInteraction.getFeatures().forEach(function(feature) {
      ol.extent.extend(featuresExtent, feature.getGeometry().getExtent());
    });
    map.getView().fitExtent(featuresExtent, map.getSize());
  });
});
Javascript: Button Functionality

```javascript
$(document).ready(function() {
    var method = 'aggregate'; // sets aggregate as default method
    var scale = 'beni_c'; // sets beni city as default place
    var layer = 'none'; // sets no default layer

    document.getElementById("method_aggregate").src = "images/method_aggregate_on.svg"; // turns aggregate button on as default
    document.getElementById("place_beni_c").src = "images/place_beni_c_on.svg"; // turns beni city button on as default

    $('div.method_group').on('click', function(event) {
        document.getElementById("method_aggregate").src = "images/method_aggregate_off.svg"; // turns aggregate button off if it was on
        document.getElementById("method_collect").src = "images/method_collect_off.svg"; // turns collect button off if it was on
        document.getElementById("method_play").src = "images/method_play_off.svg"; // turns play button off if it was on

        switch(event.target.id) {
            case "method_aggregate":
                document.getElementById("method_aggregate").src = "images/method_aggregate_on.svg"; // turns aggregate button on as default
                method = 'aggregate'; // sets aggregate as method
                aggregateFunction();
                if (scale == 'world') {
                    worldFunction();
                    if (layer == 'layer_co') {
                        world_coFunction();
                    } else if (layer == 'layer_cu') {
                        world_cuFunction();
                    } else {
                        world_noneFunction();
                    }
                } else if (scale == 'drc') {
                    drcFunction();
                    if (layer == 'layer_co') {
                        drc_coFunction();
                    } else if (layer == 'layer_cu') {
                        drc_cuFunction();
                    } else {
                        drc_noneFunction();
                    }
                } else if (scale == 'nkivu') {
                    nkivuFunction();
                    nkivu_noneFunction();
                } else if (scale == 'beni_r') {
                    beni_rFunction();
                    beni_r_noneFunction();
                } else if (scale == 'beni_c') {
                    beni_cFunction();
                    if (layer == 'layer_in') {
                        beni_c_inFunction();
                    } else if (layer == 'layer_cu') {
                        beni_c_cuFunction();
                    } else {
                        beni_c_noneFunction();
                    }
                } else if (scale == 'beni_q') {
                    beni_qFunction();
                    if (layer == 'layer_in') {
                        beni_q_inFunction();
                    } else if (layer == 'layer_cu') {
                        beni_q_cuFunction();
                    } else {
                        beni_q_noneFunction();
                    }
                }
                break;
            case "method_collect":
                document.getElementById("method_collect").src = "images/method_collect_on.svg";
                method = 'collect';
                collectFunction();
        }
    });
});
```
if (scale == 'world') {
    worldFunction();
    world_noneFunction();
} else if (scale == 'drc') {
    drcFunction();
    drc_noneFunction();
} else if (scale == 'nkivu') {
    nkivuFunction();
    nkivu_noneFunction();
} else if (scale == 'beni_r') {
    beni_rFunction();
    beni_r_noneFunction();
} else if (scale == 'beni_c') {
    beni_cFunction();
    if (layer == 'layer_in') {
        beni_c_inFunction();
    } else if (layer == 'layer_cu') {
        beni_c_cuFunction();
    } else {
        beni_c_noneFunction();
    }
} else if (scale == 'beni_q') {
    beni_qFunction();
    if (layer == 'layer_in') {
        beni_q_inFunction();
    } else if (layer == 'layer_cu') {
        beni_q_cuFunction();
    } else {
        beni_q_noneFunction();
    }
}
break;
case "method_play":
document.getElementById("method_play").src = "images/method_play_on.svg";
    method = 'play'
    playFunction();
if (scale == 'world') {
    worldFunction();
    world_noneFunction();
} else if (scale == 'drc') {
    drcFunction();
    drc_noneFunction();
} else if (scale == 'nkivu') {
    nkivuFunction();
    if (layer == 'layer_fo') {
        nkivu_foFunction();
    } else {
        nkivu_noneFunction();
    }
} else if (scale == 'beni_r') {
    beni_rFunction();
    if (layer == 'layer_fo') {
        beni_r_foFunction();
    } else {
        beni_r_noneFunction();
    }
} else if (scale == 'beni_c') {
    beni_cFunction();
    beni_c_noneFunction();
} else if (scale == 'beni_q') {
    beni_qFunction();
    beni_q_noneFunction();
}
break;
case "method_play":
document.getElementById("method_play").src = "images/method_play_on.svg";
    method = 'play'
    playFunction();
if (scale == 'world') {
    worldFunction();
    world_noneFunction();
} else if (scale == 'drc') {
    drcFunction();
    drc_noneFunction();
} else if (scale == 'nkivu') {
    nkivuFunction();
    if (layer == 'layer_fo') {
        nkivu_foFunction();
    } else {
        nkivu_noneFunction();
    }
} else if (scale == 'beni_r') {
    beni_rFunction();
    if (layer == 'layer_fo') {
        beni_r_foFunction();
    } else {
        beni_r_noneFunction();
    }
} else if (scale == 'beni_c') {
    beni_cFunction();
    beni_c_noneFunction();
} else if (scale == 'beni_q') {
    beni_qFunction();
    beni_q_noneFunction();
}
break;
document.getElementById("place_beni_q").src = "images/place_beni_q_off.svg";
switch(event.target.id) {
    case "place_world":
        document.getElementById("place_world").src = "images/place_world_on.svg";
        scale = 'world';
        worldFunction();
        if (method == 'aggregate') {
            aggregateFunction();
            if (layer == 'layer_co') {
                world_coFunction();
            } else if (layer == 'layer_cu') {
                world_cuFunction();
            } else {
                world_noneFunction();
            }
        } else {
            world_noneFunction();
        }
        break;
    case "place_drc":
        document.getElementById("place_drc").src = "images/place_drc_on.svg";
        scale = 'drc';
        drcFunction();
        if (method == 'aggregate') {
            aggregateFunction();
            if (layer == 'layer_co') {
                drc_coFunction();
            } else if (layer == 'layer_cu') {
                drc_cuFunction();
            } else {
                drc_noneFunction();
            }
        } else {
            drc_noneFunction();
        }
        break;
    case "place_nkivu":
        document.getElementById("place_nkivu").src = "images/place_nkivu_on.svg";
        scale = 'nkivu';
        nkivuFunction();
        if (method == 'play') {
            playFunction();
            if (layer == 'layer_fo') {
                nkivu_foFunction();
            } else {
                nkivu_noneFunction();
            }
        } else {
            nkivu_noneFunction();
        }
        break;
    case "place_beni_r":
        document.getElementById("place_beni_r").src = "images/place_beni_r_on.svg";
        scale = 'beni_r';
        beni_rFunction();
        if (method == 'play') {
            playFunction();
            if (layer == 'layer_fo') {
                beni_r_foFunction();
            } else {
                beni_r_noneFunction();
            }
        } else {
            beni_r_noneFunction();
        }
        break;
    case "place_beni_c":
        document.getElementById("place_beni_c").src = "images/place_beni_c_on.svg";
        scale = 'beni_c';
        beni_cFunction();
        map.addInteraction(selectInteraction);
        if (method == 'aggregate') {
            aggregateFunction();
            if (layer == 'layer_in') {
                beni_c_inFunction();
            } else {
                beni_c_noneFunction();
            }
        } else {
            beni_c_noneFunction();
        }
        break;
}
} else if (layer == 'layer_cu') {
    beni_c_cuFunction();
} else {
    beni_c_noneFunction();
}
} else if (method == 'collect') {
    collectFunction();
    if (layer == 'layer_in') {
        beni_c_inFunction();
    } else if (layer == 'layer_cu') {
        beni_c_cuFunction();
    } else {
        beni_c_noneFunction();
    }
} else {
    beni_c_noneFunction();
}
break;

case "place_beni_q":
    document.getElementById("place_beni_q").src = "images/place_beni_q_on.svg";
    scale = 'beni_q';
    beni_qFunction();
    map.addInteraction(selectInteraction);
    if (method == 'aggregate') {
        aggregateFunction();
        if (layer == 'layer_in') {
            beni_q_inFunction();
        } else if (layer == 'layer_cu') {
            beni_q_cuFunction();
        } else {
            beni_q_noneFunction();
        }
    } else if (method == 'collect') {
        collectFunction();
        if (layer == 'layer_in') {
            beni_q_inFunction();
        } else if (layer == 'layer_cu') {
            beni_q_cuFunction();
        } else {
            beni_q_noneFunction();
        }
    } else {
        beni_q_noneFunction();
    }
break;
default:
    break;
});

$("div.layer_group").on('click', function(event) {
    document.getElementById("layer_in").src = "images/layer_in_off.png";
    document.getElementById("layer_fo").src = "images/layer_fo_off.png";
    document.getElementById("layer_co").src = "images/layer_co_off.png";
    document.getElementById("layer_cu").src = "images/layer_cu_off.png";
    switch(event.target.id) {
    case "layer_in":
        if (layer !== 'layer_in') {
            document.getElementById("layer_in").src = "images/layer_in_on.png";
            layer = 'layer_in';
            if (method == 'aggregate') {
                aggregateFunction();
                if (scale == 'beni_c') {
                    beni_cFunction();
                    beni_c_inFunction();
                } else if (scale == 'beni_q') {
                    beni_qFunction();
                    beni_q_inFunction();
                }
            } else if (method == 'collect') {
                collectFunction();
                if (scale == 'beni_c') {
                    beni_cFunction();
                    beni_c_inFunction();
                } else if (scale == 'beni_q') {
                    beni_qFunction();
                    beni_q_inFunction();
                }
            }
        }
    break;
    default:
        break;
    }
});
beni_qFunction();
beni_q_inFunction();
}

} else if (layer == 'layer_in') {
document.getElementById("layer_in").src = "images/layer_in_off.png";
layer = 'none';
if (method == 'aggregate') {
aggregateFunction();
if (scale == 'beni_c') {
beni_cFunction();
beni_c_noneFunction();
} else if (scale == 'beni_q') {
beni_qFunction();
beni_q_noneFunction();
}
} else if (method == 'collect') {
collectFunction();
if (scale == 'beni_c') {
beni_cFunction();
beni_c_noneFunction();
} else if (scale == 'beni_q') {
beni_qFunction();
beni_q_noneFunction();
}
}

break;
case "layer_fo":
if (layer !== 'layer_fo') {
document.getElementById("layer_fo").src = "images/layer_fo_on.png";
layer = 'layer_fo';
if (method == 'play') {
playFunction();
if (scale == 'nkivu') {
nkivuFunction();
nkivu_foFunction();
} else if (scale == 'beni_r') {
beni_rFunction();
beni_r_foFunction();
}
}
else if (layer == 'layer_fo') {
document.getElementById("layer_fo").src = "images/layer_fo_off.png";
layer = 'none';
if (method == 'play') {
playFunction();
if (scale == 'nkivu') {
nkivuFunction();
nkivu_noneFunction();
} else if (scale == 'beni_r') {
beni_rFunction();
beni_r_noneFunction();
}
}

break;
case "layer_co":
if (layer !== 'layer_co') {
document.getElementById("layer_co").src = "images/layer_co_on.png";
layer = 'layer_co';
if (method == 'aggregate') {
aggregateFunction();
if (scale == 'world') {
worldFunction();
world_coFunction();
} else if (scale == 'drc') {
drcFunction();
drc_coFunction();
}
}
else if (layer == 'layer_co') {
document.getElementById("layer_co").src = "images/layer_co_off.png";
layer = 'none';
if (method == 'aggregate') {
}
aggregateFunction();
if (scale == 'world') {
worldFunction();
world_noneFunction();
} else if (scale == 'drc') {

drcFunction();
drc_noneFunction();
}
}
break;
case "layer_cu":
if (layer !== 'layer_cu') { //confirming that layer has not been previously clicked

document.getElementById("layer_cu").src = "images/layer_cu_on.png"; //turn button on
layer = 'layer_cu'; //change layer variable to culture
if (method == 'aggregate') {
aggregateFunction();
if (scale == 'world') {
worldFunction();
world_cuFunction();
} else if (scale == 'drc') {

drcFunction();
drc_cuFunction();
} else if (scale == 'beni_c') {
beni_cFunction();
beni_c_cuFunction();
} else if (scale == 'beni_q') {
beni_qFunction();
beni_q_cuFunction();
}
} else if (method == 'collect') {
collectFunction();
if (scale == 'beni_c') {
beni_cFunction();
beni_c_cuFunction();
} else if (scale == 'beni_q') {
beni_qFunction();
beni_q_cuFunction();
}
}
else if (layer == 'layer_cu') { //allows layer to toggle off if has already been clicked

document.getElementById("layer_cu").src = "images/layer_cu_off.png"; //turn button off
layer = 'none'; //change layer variable to none
if (method == 'aggregate') {
aggregateFunction();
if (scale == 'world') {
worldFunction();
world_noneFunction();
} else if (scale == 'drc') {

drcFunction();
drc_noneFunction();
} else if (scale == 'beni_c') {
beni_cFunction();
beni_c_noneFunction();
} else if (scale == 'beni_q') {
beni_qFunction();
beni_q_noneFunction();
}
} else if (method == 'collect') {
collectFunction();
if (scale == 'beni_c') {
beni_cFunction();
beni_c_noneFunction();
} else if (scale == 'beni_q') {
beni_qFunction();
beni_q_noneFunction();
}
}
break;
default:
layer = 'none'
if (scale == 'world') {
worldFunction();
world_noneFunction();
}
```c
}}
```