Bachelor Thesis

Operationalizing Social Inclusiveness in Infrastructure Investment Choices in the Developing World

Daniel Robert Lyons-Harrison
4098862

Supervisor

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Dr. Eric Koomen, Vrije Universiteit
Maaike van Aalst, Deltares

Table of Contents

List of Figures

Chapter I: Introduction

Development consulting focuses on identifying and solving problems in the developing world. These problems are usually urgent and tangible. For example, development consultants may be charged with suggesting strategies for increasing cereal production by 3 percent each year in order to ensure food security for the Central African Republic. However, consulting veers into more esoteric territory when the field moves to consider more subjective goals. A good case in point is the emergent debate about what it means to identify 'inclusive interventions'. In development consulting, inclusivity is a new and potentially problematic criterion for judging success. There have been multiple attempts in the past to use qualitative research methods to provide an evaluation of interventions by such researchers as Adger, Kelly, Cross, and Brooks. However these sorties have not succeeded in fabricating a comprehensive overview of either individual measures, or of strategies in aggregate. And on the other end of the spectrum, existing objective frameworks of evaluation have not taken into account the very real merits of the concept of inclusiveness for their analysis and metrics.

The gap left between the qualitative and quantitative camps of development intervention evaluation leaves much to be desired when one wishes to achieve a holistic understanding on the effectiveness of what is widely accepted to be expert recommendations originating from consulting firms in The Global North. This gap has hitherto not been recognized in the community itself, but several other academic fields have encountered and attempted to overcome similar challenges in their own domains. One of the first examples of a field which has adopted a hybrid approach to research is in public health research, but which can be applied to nearly any area of enquiry. According to Morgan, integrating quantitative methodologies with qualitative requires a) choosing a primary method, and then b) choosing to use the secondary method as either a preliminary or "follow up" addition to the original method (Morgan, 1998). Within the course of this work, an attempt will be made to reconcile the positive aspects of tangible and abstract methodologies of evaluation, and produce tools for an integrated framework. It is the sincere hope of the author to advance the capabilities of development consultations is such a way that we may both pursue our actions with a humane passion, and have objective, data-rich evidence and criteria on which to analyse its reliability and validity for decision-making. Providing an appropriate theoretical understanding of the concepts discussed to wit is vital, however, in the creation of task appropriate tools.

To that end, this study begins by defining inclusiveness from an objective standpoint. From there, our understanding of inclusiveness will be utilized to inform broader perceptions of vulnerability and suitability of interventions. Then, novel techniques will be advanced, as an operationalization of two case studies with an eye toward applying that definition in a current real world scenario. These methodological tools, and their eventual application, build on research showcased in the two case studies and employ them in a novel scenario. The lessons learned from relating the results of the case studies to the theoretical goals of the research conclude the thesis, and serve to inform further research on the topic.

What precisely does inclusiveness mean? Pinning down what is encompassed by this concept is the first step on the road to producing a functioning framework to operationalize and employ it. Webster's Dictionary defines inclusiveness as "the quality of including many different types of people and treating them all fairly and equally". This is a fair start to the conversation, but unpacking becomes complex, especially in the context of development studies. While nominally the purpose of international aid programs has been to provide assistance in the economic and social development of countries on the receiving end, it has become apparent to the providers and distributors of aid that the experiences of groups within client countries have not enjoyed the benefits of that aid in a uniform manner.

The theory that the disparities between groups within countries does not matter as much as the disparities countries themselves has been thoroughly discredited by a number of development organizations. According to one OECD report on income inequality, the gaps between countries has dropped on average over the past 30 years, but the average gap between the richest and poorest within countries has grown (OECD, 2015). Research from the World Bank implies broadly that "… within countries, development investments produced unequal benefits (World Bank, 2013 pp.1). Further assessments revealed that groups with certain distinguishing characteristics consistently failed to benefit from a nation's progress."

A marked change in the dialogue surrounding inclusion has hence been seen in the relative importance of addressing the inequalities not only between but also *within* countries. Inclusiveness can then be said to have been extended from the fellowship of nations to the myriad of groups within those nations. From here we are able pinpoint with a greater specificity the type of inclusiveness we wish to address within this study. With the goal of including multiple social groups within what is now recognized as heterogeneous societies, social inclusiveness will be the end to which this research will aspire. Operationalizing social inclusiveness has been summarized by the World Bank in one of its most recent publications, Inclusion Matters (2013), in the form of two new goals, which build on the progress already achieved by the 2015 Millennium Development Goals: firstly, ending extreme poverty in an absolute sense, and secondly, promoting shared prosperity. From these goals, it can be assumed that the first step in consulting on development with these goals in mind is to identify which groups are traditionally excluded, and the mechanisms by which they may be included in the development process.

The groups which are excluded in society vary from setting to setting, and are factors of incredibly complex socio-historic processes. Whether one is entreating the structural subjugation of lower castes in the Indian subcontinent (Madheswaran, 2007) or the legal devices used to disadvantage certain ethnic groups in The People's Republic of China (Maurer-Fazio, 2012)it is clear that all human societies to a greater or lesser degree have a heterogeneous social structure which included privileged and disadvantaged groups. Other commonalities in this framework of exclusion include a definition thereof, which is succinctly put by the World Bank as "Excluded Groups are consistently denied opportunities with which to engage in their larger society" (World Bank, 2013 pp.41). Furthermore, the examples in which exclusion takes place are enumerated. Exclusion may take place in either through "markets, services, or spaces" (World Bank, 2013 pp.43). The reasons why, and the proximate means through which populations are excluded may vary, but is unflaggingly identifiable through socio economic status.

Previous qualitative work has pointed to the differentiation of groups within national contexts based on variables such as gender and ethnicity, but has so far failed to find effective means of operationalizing their findings in a way which lends itself to quantitative analysis (Adger, 2006). Identifying and employing the common denominator between excluded groups is therefore the only way by which to proceed with an operationalizing research. Individuals may be excluded in spite of their socioeconomic status, but groups are without exception differentiated from previously assumed homogenous populations through socioeconomic methods. Local context may change whom this research is directed at helping, but the principle of acknowledging their presence and prioritizing their unique needs remains the same across all possible applications of an operationalized inclusiveness.

How to ensure the total inclusion of all social groups is a topic whose ambition far exceeds the possibility of redress in the space of one research thesis, and even the work of a single researcher of the course of a lifetime. The narrowing of our scope is necessary in order to affect change, even on a small scale. Choosing an appropriate arena to focus the efforts of this thesis was difficult, but reviews of the available literature lead increasingly to the same conclusion: the safety of the most excluded populations in developing countries is being eroded in an increasingly drastic pattern by anthropogenic climate change. "In terms of tackling the consequences of climate change—or adaptation—a social justice perspective emphasizes that those whose lives and livelihoods are most vulnerable to the consequences of climate change and who have contributed the least to its causes should receive preferential support." (World Bank, 2010 pp.10). Logically, it stands to reason that populations who are economically and socially deprived will have greater difficulty when they are made the victims of climactic events. The frequency and intensity of adverse climatic events have been steadily increasing thanks to human activity, largely through emissions of greenhouses gasses. Ironically, those who are doubly disadvantaged, being members of populations who are the least privileged in an international and national sense, are also those who are the least likely to contribute to this tragedy of the commons. In this study then, it is not appropriate to discuss measures which fall under the umbrella of mitigation strategies, which aim to reduce the addition of greenhouse gasses to the atmosphere, but instead adaptation strategies, which help populations to cope with the consequences of climate change. This is due both to the relative ineffectiveness of the former, and the ethical necessity of the latter.

Falling along the same demarcations of the divide between quantitative and qualitative research methodologies, the targeting of adaptation strategies follows one of two schools. (How one defines vulnerability is tantamount to one's views on how the benefits of development aid should be targeted.) Vulnerability may be said to be either **biophysical** or **social** in nature. Once again, the specifics differentiating the two are in how theorists define their terms. Biophysical vulnerability is traditionally situated squarely within the quantitative camp of analysis, and uses traditional, objective measures to assess vulnerability. Biophysical vulnerability refers to the ability of a natural hazard to cause damage to the human system. The strength of the definition is vested in its relationship to natural hazards (Brooks, 2003). Brilliant in its simplicity, a biophysical view of natural hazard vulnerability sees the world in terms of the severity of a hazard, in the amount of damage it is capable of inflicting, and the exposure to assets which are capable of being damaged. Exposure is modified by the sensitivity of a system to a particular hazard, and determines the total vulnerability of the system. Concerned primarily with the outcome of hazard-system contact, this definition is used most frequently in contemporary definitions of hazard impact studies, and consequently by many development organizations and researchers, exemplified by the work done by Jones and de Boer in the Canadian Arctic "Vulnerability is measured by indicators such as monetary cost, human mortality, production costs, [or] ecosystem damage…" (Jones and de Boer, 2003 pp. 394).

Including such stark definitions allows researchers active in this subject area to calculate dollar sums, develop statistical analyses, and eventually inform decisions about aid. But a second, more nuanced definition has been advanced by researchers working in parallel with the quantitative approach. Social vulnerability, much like social inclusiveness, takes into consideration the fact that different populations within a study area have distinguishing characteristics which, in aggregate advantage or disadvantage them. Instead of examining the impacts of natural hazards on outcomes, a social definition of vulnerability looks into the characteristics of the system and its component groups. Vulnerability is the state of the system, which may be impacted by climatic events, but is used to describe how vulnerable the system itself is. "In this formulation, vulnerability is something that exists within systems independently of external hazards. For many human systems, vulnerability viewed as an inherent property of a system arising from its internal characteristics may be termed "social vulnerability" (Adger and Kelly, 1999).

At this juncture, it is important to emphasize the differences between the two approaches. The composition of the system is also important in the biophysical school of vulnerability assessment in that can change the total empirical amount of damage inflicted. However, the biophysical approach assumes that all groups within the assessment experience the same amount when receiving the same amount of damage. In contrast, social approaches distinguish heterogeneous how groups *within* a study area experience the same objectively measured impacts differently, because some of them have inevitably been excluded from the services, markets, or spaces needed to recover from negative impacts. And as previously discussed, these differentiations are often defined by proponents of a social definition as being demographic in nature, pertaining to ethnicity, gender, religion, etc. Finding a way to measure the relationship between these using a metric which can be used to evaluate the situation objectively has been lacking from this approach. This gap is expressed by the IPCC's 5th Assessment Report "Ethical theories based on social welfare functions imply that distributional weights, which take into account different values of money to different people should be applied to monetary benefits of benefits and harms. Such weighting contrasts with much of the practices of cost benefit analysis". Theoretically, there is a recognition that heterogeneous groups in society experience the same event differently based on socio-economic characteristics, but it has yet to be put into practice.

The insights offered through social definitions of vulnerability and inclusiveness can be used in tandem with a biophysical viewpoint if they are suitably operationalized. The way forward is to reduce the heterogeneous characteristics of groups within study areas to socioeconomic status, so that it too may be evaluated objectively. The results of analysis-fusing both schools of thought-will be more socially inclusive than the purely hazard based analysis of the past. At the same time taking into account the diverse groups and interests of the areas under observation. Doing so will be the purpose of this research, and hence leaves us with the goal:

To operationalize the concept of inclusiveness through the combination of an objective assessment of hazards and benefits and the incorporation of socially conciseness ideals. The aim is thus to create new methods for analysis that take into account all the relevant characteristics of study areas, resulting in holistically informed conclusions and recommendations for actions.

To summarize the understanding on which our research is based, and its intent: within development consulting, there is a yet-to-be reconciled gap between researchers who typically use either quantitative or qualitative methods to guide their choice of where to invest development funds. These two schools of thought vary from one another in their definitions of vulnerability, biophysical vulnerability pertaining to the potential for damage to be inflicted by climactic events on human systems, whereas social vulnerability looks into the state of the human system itself, and evaluated how different segments of the system in question are effected by a given disaster based on their distinguishing characteristics. In order to further the cause of social inclusiveness, the strengths of both must be used to operationalize the concept. Traditionally, most studies undertaken into climate change adaptation investments have used solely quantitative analytics to arrive at conclusions. Including a social element to the standard workflow is the key to achieving inclusiveness, and can be mostly readily accomplished through conveying information of differentiating characteristics through socioeconomic status, despite the fact that exclusion can take any form, and is heavily situation dependant. In the following chapters, pilot studies which exhibit the ability to do just such a thing will be offered, and whose suitability will then be analysed in conclusion.

The tools which will be developed and applied to these pilot studies comprise two different case studies. By introducing the concepts mentioned hitherto in an applied manner, the possibilities of implementing them on an altogether larger scale can be realized. The proximate means to achieving the ultimate goal of bringing social inclusiveness into account when consulting on infrastructure in the developing world will to be to communicate effectively to policy makers and other stake holders that there is in fact a discrepancy in the impacts of either damages or benefits triggered by climactic events within what were previously seen as homogenous study areas. In both of the case studies, this takes place at the sub national level--one urban, one regional. More than just informing them of the presence of difference, the methods put forth will be shown to be amenable to including an objective, numerical assessment of infrastructure investments. As proposed in the IPCC's report quoted above, this will take the form of a weighting system which modifies the results of more traditional cost/benefit analyses. To show the full range of possibilities to which this proposed novel methodology can be applied, there is one case study concern with weighting damages in the City of Colombo, Sri Lanka, and one with weighting benefits in the Central Cebu Region, The Philippines. Measuring the results of these pilot studies against our proposed goal, and envisioning their further applications will conclude this research.

Chapter II: Flood Damage Projections in Colombo, Sri Lanka

2.1 Introduction

One of the world's great tragedies is that those who are the most vulnerable members of our population are also most often those who find themselves, through a combination of ill fortune and downward economic pressure, living in areas prone to natural disaster. A further tragedy is that these same people are often overlooked in the hard calculus of disaster impact planning and abatement. The proposition that one dollar of damage caused by disaster will impact the lives of a subsistence farmer and an oligarch in an equal manner is a falsehood, and helps enforces the underlying power structures which posited both individuals in such disparate positions in the first place. Under current Flood Impact Assessment strategies, damages are aggregated spatially and demographically, which is one way by which this narrative if furthered. Hence, it is the goal of this chapter to give an overview of some of the germane work being done in the field of spatial economics and human geography which would see the inherent shortcomings in contemporary Flood Impact Assessment bettered and to produce a workable example in a GIS environment to showcase the practical applications thereof. This goal leads logically to the posing of the following research question:

(1) *What possible additions can be made to existing processes within flood risk assessment through the medium of GIS to meet an outcome which produces analysis which takes into due consideration relative Socioeconomic Status of often heterogeneous populations?*

As much as is possible, the new methods discussed will be integrated with the current workflows and conventions in place at the Water, Subsurface, and Infrastructure Research Institute Deltares, and as such, will interact with the problem through the lens of flood impact assessment, one of the primary subjects at the institution.

This chapter is structured as follows. In the first section, Background, the basic theoretical concepts of Flood Impact Assessment, as well as the specific tools which are being used currently at Deltares to implement them in practice will be given. Additionally, an assessment of these tools with respect the degree of the social equitability of their output will be given. In the second section, Novel GIS Analyses, two new tools to help achieve what the author of the report feels is a socially equitable outcome will be described. A new way to interactively visualize data, as well as a new manner by which to describe the direct, tangible damages of flooding which is both demographically and spatially explicit will be proposed. The report will then conclude with a section discussing the implications of the finding and results of the preceding sections, as well as an critique detailing the limitations hitherto.

2.2 Background

2.2.1 Flood Risk Assessment Strategies

Before the tools used by Deltares to describe the impact of flood damage can be discussed in any depth, the methodologies by which they arrive at the flood extent maps, which are crucial inputs for much of the geospatial analysis to come, will be briefly outlined. At its heart, predicting the physical extent of a flood event is a combination of the volume of water added to the system per unit of time, and the topography of the drainage area. The nature of the inputs does depend on the temporal scale of the flood prediction. Real time and medium range (7-10 days) flood predictions rely on the direct measurements of flood forcing meteorological events. The flood predictions made by Deltares and similar organizations which plan for flood mitigation strategies in the long term, as opposed to immediate response options, make what are referred to as Probabilistic Flood Risk Assessments (Dahm et al., 2013). This takes into account the year to year probability of forcing events ranging from near once in a century high or low input amounts to levels mimicking the mean inputs per year. And from there fabricates a range of scenarios with gradually decreasing return periods, beginning e.g. two years, and becoming gradually less likely. The forcing events taken into account in aggregate consist of expected annual sea level, discharge of local bodies of water, and projected volumes of precipitation. The result of this is a series of raster structure datasets showing the flood inundation levels of a catchment area or interconnected catchment areas with a corresponding return period measured in years. How expected amounts of annual damage are derived from the range of projections described under the theoretical framework of Probabilistic Flood Risk Assessment will be described in the following section (Dahm et al., 2016).

2.2.2 Flood Impact Assessment Tool

At this point, the first GIS tool used in the workflow associated with this project comes into action. The Flood Impact Assessment Tool, or FIAT, is the in house software at Deltares used to describe the economic consequences of flood events. This is one manifestation of a broader range of techniques used in flood impact modelling. Similar probabilistic methods have been proposed by Aerts, Moel, and others in previous publications, which can predict the extent of floods at different probabilities, or "return Periods" (Aerts et al, 2013). However, this stage of the workflow departs from the strict probabilistic modelling techniques found in the meteorological and hydrological forecasting methods, and moves to an expected annual damage (EAD) figure instead. The reason for this is that to make effective policy recommendations, an average expected sum needs to be compared with the initial capital investment and upkeep costs of mitigation infrastructure and strategy investments. A dollar amount "saved" can be easily calculated by comparing the total investment costs over the lifetime of the investment and the Expected Annual Damage, this process is commonly referred to as a Cost Benefit Analysis.

Flood Inundation Maps with absolute occurrence rates mentioned in the above section are used as one of the inputs for FIAT, and are overlaid with a polygon file showing the built environment of the study area through the spatial positions of building footprints. In an ideal situation, the polygon file would accurately describe each and every building within an urban area, its primary use, its condition, and if applicable, the number of persons living there. Using such attribute data, amounts of damage can be calculated per raster cell by comparing the number of buildings affected to the amount of damage which can be maximally inflicted upon it. Maximum amounts of damage are calculated based on the aforementioned attribute data of building polygons. Damage Raster Maps for each probability are combined statistically into an Expected Annual Damage by overlaying the individual raster files while taking their probability in relation to one another into account (FIAT Wiki, 2016).

2.2.3 Current Capabilities

FIAT's ultimate output of an Expected Annual Damage Raster Map is what is most often used at Deltares for empirically supporting answers to Cost Benefit Analysis for clients in flood sensitive areas. What it leaves to be desired is a capability for a holistic and intersectional understanding of the economic impacts of floods. Spatial distribution of wealth in cities, especially in lower income countries, is heterogeneous in the extreme, which in turn causes sub-sections of populations with varying Socio Economic Status to experience aftermath of disasters differently (Cutter, 2008). Additionally, the data inputs, processes, and outputs are not immensely approachable for policy makers and stake holders who are unfamiliar with GIS and/or Hydrology.

As brief an overview as it is, the preceding sections prime the research question described in the introduction with a suitable degree background information so as to be answered in the context of current practices in flood risk and damage analysis. Exploring both the empirical techniques to describe the relative effects of economic flood impacts of an economically diverse urban living scape and methods to easily and effectively communicate such information will be the purpose of the remainder of this paper, and will hopefully answer the research questions successfully. As the primary project pertaining to flooding events, the case study of Colombo, Sri Lanka, will be used as a subject and example for the novel GIS products proposed below.

2.2.4 Case Study

Colombo is the largest city and financial capital of the island nation of Sri Lanka, with a metropolitan population of more than three quarters of a million people. The Metropolitan Colombo area has a high potential for harmful flood events due to its geographic position at the mouth of a monsoon fed river drainage system. This already substantial risk is aggravated by the rapid urban growth, coupled with unplanned patterns of human settlements and land use. In addition the increasing population and unplanned development have led to encroachment of canal reserves, reclamation of wet lands, and spread of settlements in to high flood hazard areas.

The consultation of Deltares has been focused on minimizing Colombo's exposure to flooding events by identifying areas which are likely to experience damage, and then recommending cost appropriate interventions. Standard best operating practice in these cases includes interventions such as "improving the drainage systems, creating extra storages, enlarging the conveyance and outfall capacities as well improvement to flood early warning, formulation and implementation of necessary policies for land use management, building control, etc." (Grehels, 2017) It is also essential to line up strategic support for implementation of the above mentioned strategies by the development agencies. What is sought to be accomplished through this essay is to apply a more nuanced identification method, one which takes into account the Socioeconomic Status of those affected, and to recommend a retargeting of interventions if the outcome is significantly different than the traditional method, which only takes into account the dollar amount at risk.

2.3: Novel GIS Analyses

2.3.1 3D Visualization

Effective communication with policy makers is imperative when researchers attempt to make their finding not only known, but understood. Within the field of scientific communication, the use of electronic media has become more and more widespread over the last 15 years (Feldman, 2001). Specifically, within the Spatial Sciences, new forms of communication have been developed to go beyond the standard cartographic representations of data. Examples of this include interactive geocoding, and real time navigation services (Sui, 2001). Studies conducted by Camara and Raper have proved the increased communicative efficacy of "new" Geospatial media. One of the examples sighted was of virtual reality, where users were able to interact with a GIS environment, so as to experience the same information as would be available on a map in a more engaging manner (Camara and Raper, 1999).

To that end, we decided that a novel method, in this instance 3D, would be beneficial in conveying our message to policy makers and other stake holders. This was mentioned as being an especially helpful tool in literature on the topic (Kling et al., 2000). Building on the virtual reality example above, this would add an additional layer of interaction for the user. This was accomplished by liaising with the Serious Games Department at Deltares in order to construct a virtual environment where our geospatial socioeconomic could be visualized in an engaging manner. Rendered in Unity Game Engine, a popular software suite used by game designers to produce games like "Pokémon Go!", this is the first impression which both policy makers and wider audiences will see regarding the spatial distribution of relative socioeconomic status and other attribute data across the urban space of Colombo. Interactive, different flooding scenarios can be seen overplayed with a 3D model of the built environment, in which different economic indicators can be chosen to be represented visually by colour on a building by building basis. Participants will give a more than cursory overview of the situation in the field of the geo-spatial overlap of flooding and Socioeconomic Status. The end product can be either downloaded as a complete entity, wherein users may boot the simulation on a personal computer, or it may be shown to a wider audience via screen capture software.

Method

As will be seen in the successive methods section, there sometimes is something left to be desired when it comes to the cartographic representation of spatially referenced data. Even with flawless technique, the medium of the two dimensional, static map has essentially not developed since the introduction of statistics, and their resulting visualizations to Geography in the 18th Century (Firendly, 2001). In order to fully utilize information technology in this discipline, all of its capabilities should be put into practice, which in this study took the form of an interactive, 3D environment. This allows us to see out information in finer detail, and allows the user to interact with the data in an extremely user friendly way, without requiring any technical training. The steps implemented to achieve the 3D environment of Colombo are as follows.

1. Investigated Data provided by Sri Lankan Census Bureau, searched for data sets which would are at the most specific level of detail (GN District), and serves to further the inquiry of the research question, specifically what datasets would provide credible proxies for income and/or expenditure of residents.

2. The dataset containing information for the “Number of Households with Access to Electricity as their primary cooking fuel” was selected for a number of reasons. It was a linear, ratio variable which could be logically construed with the consumptive patterns of households. Cooking is a basic need, but cooking with electricity is not. Households with higher incomes would then choose to upgrade to a sufficient electricity subscription, and invest in appropriate equipment as one of their first purchases of luxury goods.
3. Data Cleaning and interpolation. The number of households with access to electricity as a primary means of cooking is cross referenced with the number of households per district to determine the proportion of households, and ergo residents (Derived through dividing number of dwellings by GND population), who have access to such resources. Also, there were several districts for which no data had been recorded by the census bureau. A nearest neighbour sampling method was employed to make a continuous coverage of all GNDs with all polygons.
4. Building Footprint Dataset consolidation. At this point, a building footprint dataset was introduced as a layer to the GIS environment. Buildings which were residential in nature were selected, and exported as a separate layer. The Spatial Intersect toolbox was then used to ascribe the proportion of electricity using individuals to the individual building polygons from the GND layer. 3 Natural classes emerged here. Low adaptation to electric cooking >2%, middling adaptation 2-15%, and high adaptation, anything above 15%, most often in the homogenous range of 80% and upwards.
5. Further Class consolidation within Building Footprint dataset. One of the other economic attributes which was chosen to be shown in the 3D Environment was whether or not the buildings were part of an informal settlement, or “shanty”. Achieved by consolidating the “remarks” category into 5 broad classes, one of which was shanties. This step was performed to correct for recording errors, i.e. spelling “shanty” as “santy”, and for the sake of the visual clarity of the finished product.
6. 3-D Rendering in the Unity Game Engine. Building Polygons are rendered in LOD1, or LOD3 for several landmark sights, and are coloured on either a sliding scale, or categorical basis depending on the type of variable. Users are able to navigate the environment, and interactively change which of the datasets they wish to be seen. All of this is done on the fly.

Results

The 3-D environment was successfully completed, and made available to the entirety Deltares through the internal intranet system. This has afforded persons working both inside of the

Colombo project and in other departments a look into data on the spatial distribution of income in the urban living scape of our case study city. Stemming from this, a greater appreciation for the work being undertaken within the larger inclusiveness movement within the company was achieved.

Also, a video of the environment has been shown in multiple workshops in the city of Colombo itself, to both policy makers and stake holders. This took place within the context of a presentation in combination with all of the existing work undertaken by the team working on the Colombo consultancy project, ranging from the flood damage raster maps mentioned in the FIAT section above, to the possible infrastructure and strategy interventions conceived by engineers and economists. The seriousness not only of the flood exposure to the city at large, a fact already keenly understood by the members of the local government, but also of the spatial confluence of flood damage and poverty. This will be described in greater detail in the following sections. Perhaps most tellingly, the financial representatives of the World Bank were impressed by the information presented in the environment. The importance of inclusiveness may have made an inroad in this instance, because not only were the decision making parties of the Colombo flood intervention case reached by this novel method of communication, but so were representatives of an organization which handles and bankrolls interventions around the world. Even if the significance were to be lost on local authorities, this product effectively made the case for the importance of inclusiveness on a larger scale. A copy of the 3D Environment may be requested by contacting the author.

2.3.2 Tabular and Cartographic of FIAT Post Processing Equity Weighting

Available data concerning the Expected Annual Damage projections for the Colombo study area is combined and reinterpreted with the spatial SES data visualized previously to reflect the variable effect of economic damage experienced by Colombo's residents. Tools already discussed in the Current Capabilities section were used as input in this process, and where subjected to novel post processing techniques in order to produce an analysis which would bring to the fore the interaction of spatial distributions of poverty and flood exposure. Spatial instance of economic deprivation were identified by looking at the consumptive data at the GND level, the most specific available, and this was then compared to national data of income distribution to find an approximation of income per GND. These approximations was then used as an input for equations which resulted in an "Equity Weight", which was used to modify the gross damage done to each GND. In principle, this allows us to quantify the damage done to each district in a way which takes

SES into account, thus allowing a more accurate assessment of the impact of flood damages to areas which are heterogeneous in the economic capacity to overcome natural disasters.

Methods

Initial Flood Impact Assessment

1. A FIAT model was run for the Colombo Study area so that the primary Expected Annual Damage raster could be introduced into the project's workflow. Flood extent projections overplayed with the GND boundaries of Colombo, as well as an inset map of the study area's position within a broader geographic context can be seen in Appendix II.
2. Gross damage done to each GND was then calculated by running a Zonal Statistics analysis using the GND polygon layer and EAD raster layer. Cartographic representation of the result may be found below in figure 1, alongside tabular output of the 5 highest damaged GN Districts, table 1.

Identifying and Defining Heterogeneous Segments of Colombo's Population

3. Deriving a spatial distribution of income in Colombo from the data available to us was the next step in the equity weighting process. The consumptive patterns described by the adoption rate of electric cooking equipment were broken into quintiles, and compared to the distribution of income in Sri Lanka as a whole. With a data concerning the income distribution of Sri Lanka, it is possible to show per quintile what the average income per capita is. The equation below shows how the average income for each quintile was derived.

$$CN^{Q} = (AN^{C} * Q_{S})/Q_{p}$$

Where:

CN^{Q} is the Per Capita Quintile income

AN^{C} is the Aggregate Income of Colombo (constant)

Q_{S} is the Quintile share of income

Q_{p} is the Quintile Population (constant)

Describing Flood Damages as a Function of Socioeconomic Status

4. The total income for each GND was calculated by multiplying the population of each district (ii) by the average income for the SES class derived in the previous step. This information is then compared to the gross Expected Annual Damage from step 1, and damage as a percentage of total income can then be calculated. A choropleth map showing this in

addition to the spatial distribution of income quintiles is to be found following the gross damage map below, figures 2 and 3.

$$AN^G = CN^Q * D^G * H$$

Where:

AN^G is the total income per GND

D^G is the population density of the GND of residents/household

H is the number of households

5. Seeing flood damage visualized via relative damage in proportion of income lost can be helpful to see how heavily a district is affected by projected Expected Annual Damage, but it is not the most effective option in this a CBA, because it does not allow us to see how much damage saved in direct relation to SES. Hence, we calculate Equity Weights (EW) to modify the gross damage caused to each district as a function of its SES. EWs are calculated by looking at the relative utility of an additional unit of income, in this case 1000 Sri Lankan Rupees, normalized for relative SES. Marginal utility is calculated by equation iii below, which is then applied to an equation to calculate the equity weight of damage for each income group (iv). The equations are taken from the paper of Jarl Kind et al (2016). The results and equity weights for each income quintile can be seen below in table 2.

$$U(\delta Y) = U(Y_1) - U(Y_0)$$

In Which Utility is Calculated By

$$U(Y) = \frac{Y^{1-\gamma}}{1-\gamma}$$

Where

$U(\delta Y)$ is the marginal utility of an additional unit of income

$U(Y_1)$ is the utility of average quintile income plus 1000 SLR

$U(Y_0)$ is the utility of average quintile income

γ is the elasticity of income (1.2)

iv. $\omega_{yi} = \frac{U(\delta Y)_Q}{U(\delta Y)_M}$

Where

ω_{yi} is the equity weight

$U(\delta Y)_Q$ is the quintile marginal utility of income

$U(\delta Y)_M$ is the median utility of income

6. EWs are then applied to gross Expected Annual Damage sums per GND to calculate Equity Weighted damage for each polygon. A map showing this spatial distribution would be redundant, because of figure 3, which shows damage as a proportion of income shows an identical distribution. But a map showing the difference between each district's Equity Weighted Expected Annual Damage and its Gross Expected Annual Damage is included to clarify the relationship between the two metrics, and concludes the series of maps below in figure 4. Continued within table 1, a modified ranking of most damages districts is offered, as well as their change in rank (if available) from the first portion.

Results

The end products of the Post-Processing of existing outputs described and illustrated in the previous section provides the user with an array of additional sets of data to influence decision making for proposed mitigation strategies. Social vulnerability is easily conveyed to the audience cartographically by mapping the proportion of lost income of districts projected to be victims of flood events (Figure 3). Furthermore, analytical capability is created by applying equity weights to Gross Expected Annual Damage (Figure 4) amounts for districts, showing the impact of flood damage to residents as a function of their Socio-Economic Status relative to other enumerations in the same study area. Competing mitigation strategy scenarios can then be compared in a cost benefit analysis not only with the total dollar amount by which they decrease Expected Annual Damage, but also the sum of equity weighted damage they prevent.

For the data used in this example, one would not expect to see a massive change in results between mitigation scenarios chosen, due to the fact that the majority of flood damage happens in districts within the bottom two income quintiles of the city. However, many of the competing strategies being considered (Deltares, 2016) do not target the most heavily affected regions of the city. Therefore, the true seriousness of this spatial combination seen by the reinforcement of the pattern portrayed by gross Expected Annual Damage when compared to equity weighted Expected Annual Damage is of grave importance. The fact that the majority of economically deprived residents, as spatially described by income quintiles, and the majority of flood related damage, described by gross Expected Annual Damage, are spatially highly correlated is an extremely worrying fact. In the maps below, it can be seen that a flood plain can be identified by observing the highly concentrated cluster of damaged neighbourhoods in the North of the map, and that a similar clustering of low income neighbourhoods can be observed in a corresponding zone on the following map. And finally, the degree to which damages are worsened by economic deprivation can be seen in the final map of the difference between gross and equity weighted Expected Annual Damage, hopefully conveys the seriousness of the situation in a suitably concrete manner. Making a socially equitable choice will be that much harder to avoid.

GND	Expected Annual Damage	GND	Equity Weighted EAD	Change in Position
Megoda Kolonnawa	392721,4	Kittampahuwa	818878	+1
Kittampahuwa	353721	Kotuvila	814132	+1
Kotuvila	351671	Maha Buthgamuwa C	784108	+1
Maha Buthgamuwa C	338701,7	Megoda Kolonnawa	553934	-3
Welewatta	317099,4	Sedawatta	544895	N/A

Table 1: Rank Ordering of GNDs before and application of Equity Weights

Table 2: Equity Weight Tabulations

Income Category	Category Mean (Annual) Income	Mean Income Plus 1000 SLR	Utility of Mean Income	Utility of Greater Income	Marginal Utility	Equity Weight
1	135942.7	136942.7	0.47022	0.46953	0.000689	2.315036
2	205690.4	206690.4	0.43284	0.43242	0.00042	1.410504
3	274129.2	275129.2	0.40868	0.40838	0.000298	1
4	384641.1	3856411	0.38191	0.38171	0.000198	0.666426
5	869322.5	870322.5	0.32444	0.32436	7.46E-05	0.250714

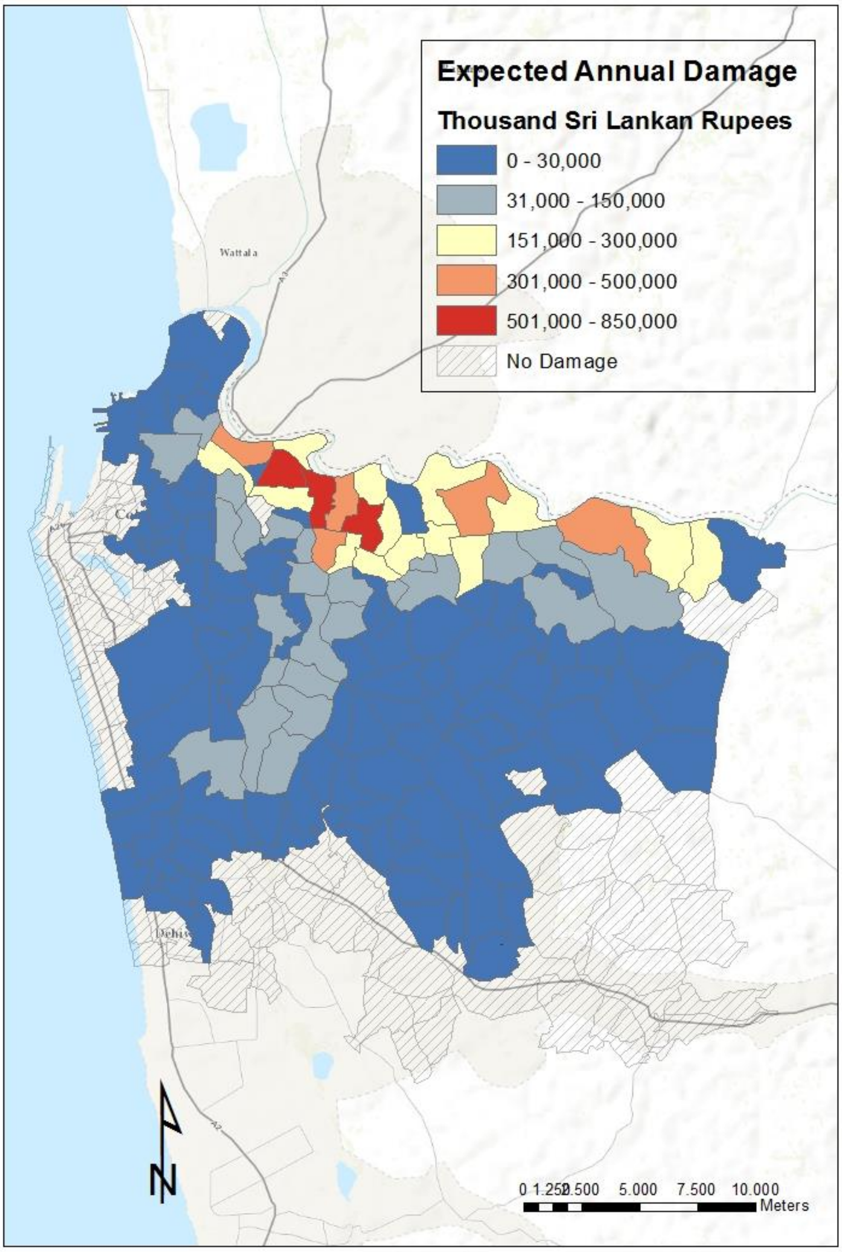

Figure 1: Expected Annual Damage Projected per Grama Niladari District

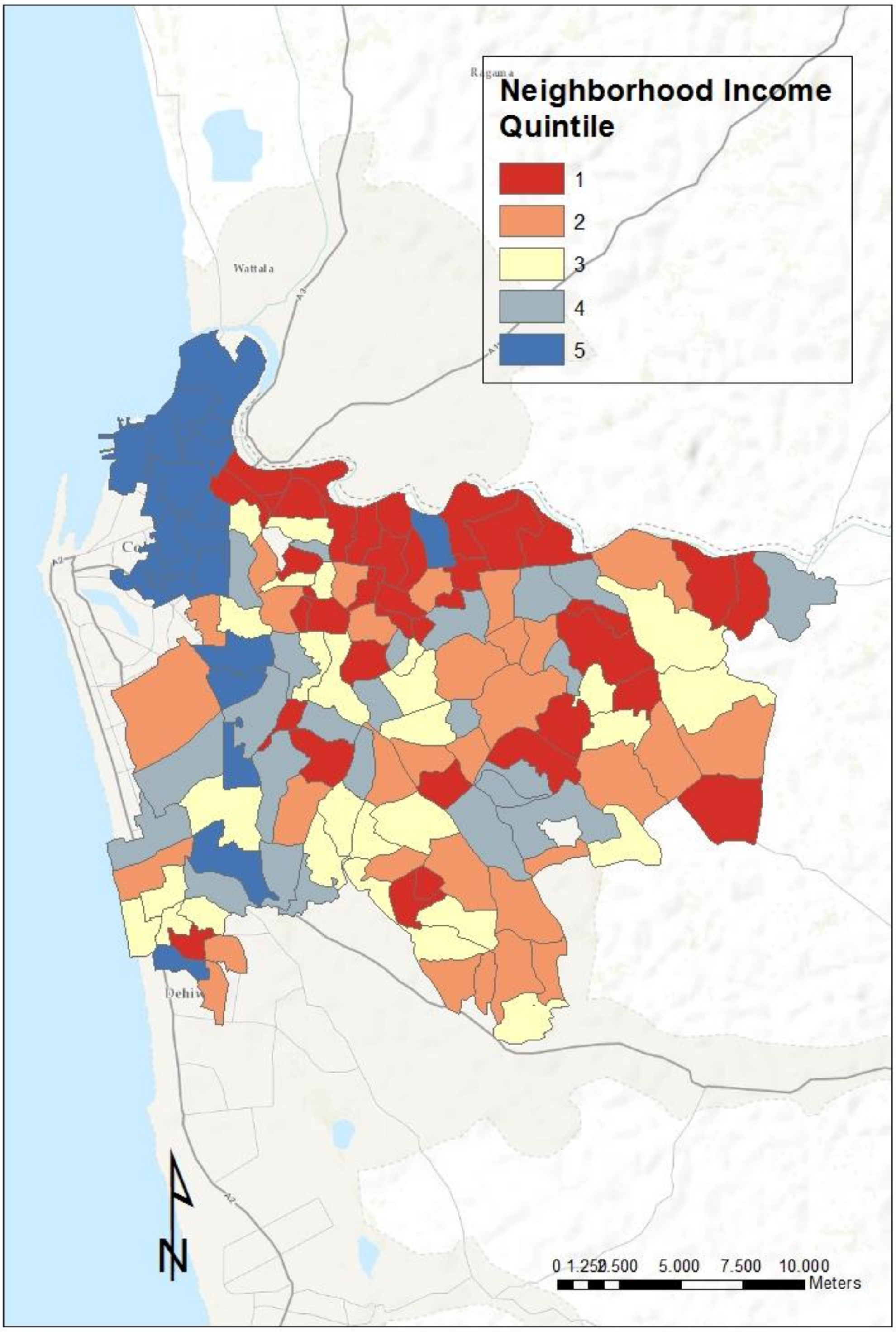

Figure 2: Income Quintile Rank per Grama Niladari District

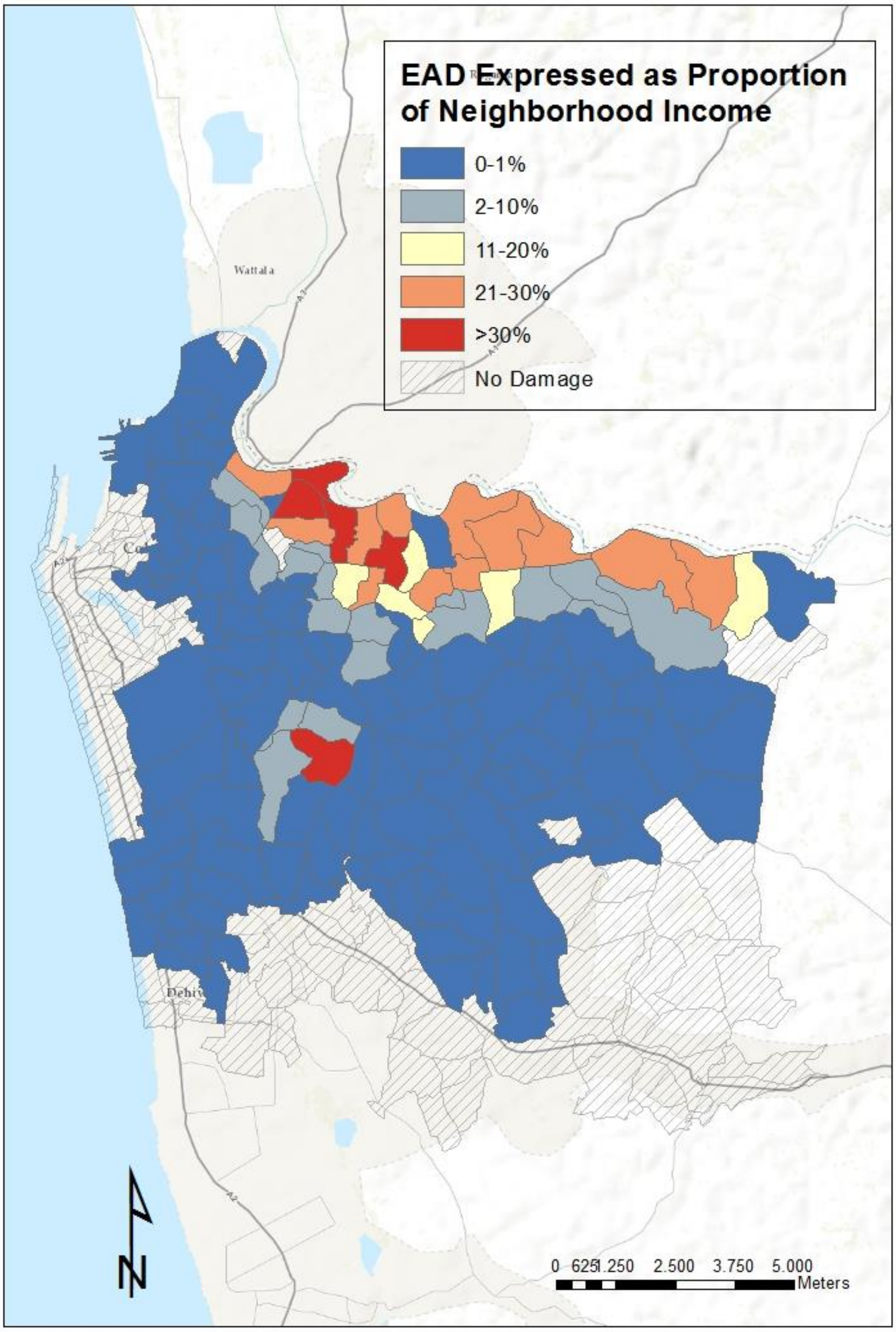

Figure 3: The Proportion of Grama Niladari

District Annual Income Projected to be Lost Due to Flooding

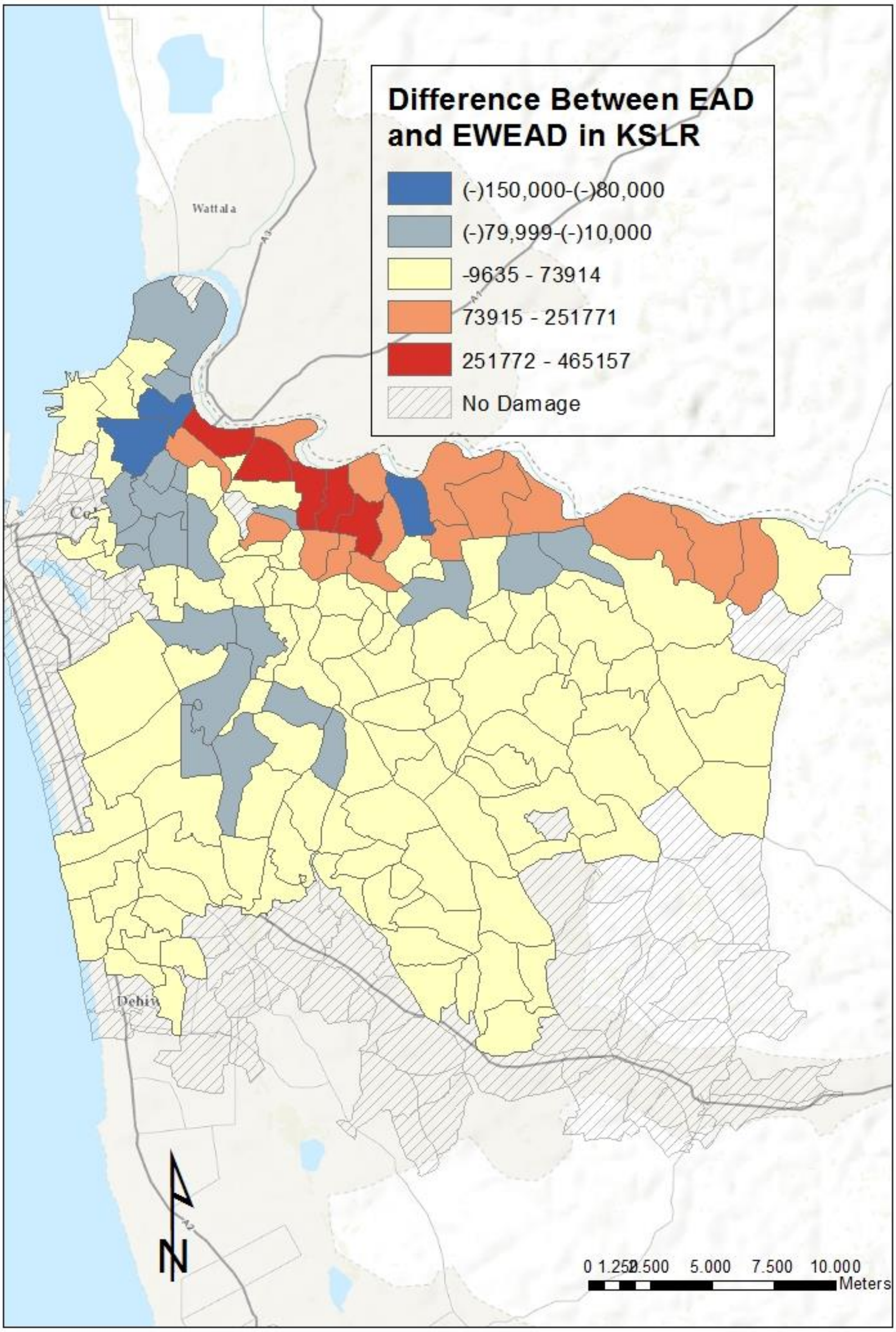

Figure 4: The Difference of 1000s of Sri Lankan Rupees Between Gross Estimated Annual Damage and Equity Weighted Estimated Annual Damage

2.4: Conclusion

2.4.1 Discussion

Following the research question "What possible additions can be made to existing processes within flood risk assessment through the medium of GIS to meet an outcome which produces analysis which takes into due consideration relative Socioeconomic Status of often heterogeneous populations?", this section of the report will question exactly to what extent value has been added to Flood Impact Assessment capabilities of Deltares by the introduction of GIS analyses appended by this paper to the existing workflow. Beginning with the rendered 3D environment, value added can already be identified relatively early in the flood risk, damage, and mitigation projection process.

One of the most difficult tasks can be effectively conveying spatially referenced Socio Economic Data to persons in decision making positions regarding the manner by which the effects of natural disasters are addressed. This often falls to the city fathers or other local administrative officials in the absence of a strong, central disaster relief agency. And whilst a simple overlay of vulnerable locations and expected flood extents can show much of the same information, a more content rich and interactive environment will have a higher impact, and a greater chance of gaining traction not only with audiences of decision makers, but also ones with a wider variety of stakeholders. Following the propositions of Kling and McKlim (2000) the 3D Environment constitutes a method appropriate to the situation to introduce an innovative way to convey spatial information, and therefore communicate with the audience more effectively. In this way, the seriousness of the spatially uneven impact of natural disasters can be effectively visualized and communicated.

As seen and illustrated above in the case study of Colombo, economically deprived populations are concentrated in areas which are most prone to damage from floods (Figures 1 and 2), an important pattern to recognize when looking into mitigation strategies. However, visualizing this information does not convey all of the information needed for policy recommendations. An empirical method grounded in the principals of welfare economics to interpret the financial dimension of flood damages adds on to improved visualization (Figure 4). In Equity Weighting not only are patterns recognized, but future actions in the form of mitigation strategies are capable of being judged in a socially equitable manner. This was achieved by applying a methodology which adds an empirical tool to assess damage inflicted by natural disasters in a manner which takes into account the relative Socioeconomic Statuses of separate geographic enumerations within a study area into account. The end result of adding this to the toolkit of consultant and policy makers is to add the capability to judge an intervention, either strategic or infrastructure, by the projected damage that it saves, as well as its equity weighted counterpart. This tool is in essence a simplified version of the theoretical equity weighting procedure proposed by Jarl Kind (2016), which can be applied in a more rapid deployment in relatively data poor environments.

2.4.2 Limitations

There are naturally a number of limitations whenever geospatial analysis is conducted in an environment with less than perfect information. While often the case for any exercise outside of the hypothetical, is especially true for environments where data is either heavily interpolated, or otherwise inaccurate. The capitol of Sri Lanka is one such case. Beginning with the house footprint polygon dataset, discrepancies can be easily identified if the attribute data is observed in even a cursory depth. One particularly glaring inaccuracy came across during the course of this analysis was the presence of “aggregated” polygons. For instance, some especially large polygons, which would be assumed to be commercial in nature, are actually denoted as something along the lines of “100 Houses” or the like. This proves problematic for several steps in the analysis where it is assumed that the polygons are each individual housing units, which may have accounted for up to 5% of units not being counted, and therefore misallocating population figures to specific GNDs.

Beyond inaccuracies in data collection, there were to a certain extent methodological failings in the design of the analysis. Environmental fallacy was especially detrimental to the integrity of the results, as at several moments, the characteristics of district level polygons were ascribed to individual enumerations, e.g. assuming the city of Sri Lanka has the same GDP per capita and GINI coefficient as the entirety of Sri Lanka. Finally, the largest and most spurious assumption employed by the author to perform the analysis was the prediction of income quintiles by census data of one particular hallmark of consumption. This departs greatly from the detailed required household income data proposed by Kind et al. when the mathematical concept of equity weighting was first proposed. Overall, the methods outlined and proposed herein can be applied to scenarios like Colombo which have a dearth of traditional household income data to allow a socially holistic assessment of the financial impact of flood, or any other disaster.

Chapter III: Water Provision in The Central Cebu Region, Philippines

3.1: Introduction

The effects of climate change do not always take the form of an overwhelmingly obvious natural disaster which has increased in either its frequency or intensity, such as the example of Sri Lankan flooding in the previous case study. Other, more subtle perturbations inflicted on human systems through climactic means can be just as devastating, while at the same time eliciting less attention from observers. Interacting with gradually applied climatic pressures are the economic and population growth of the developing world--rates of which far outstrip countries in the Global North because of the globalization of the world market place, and the transition from high birth rate and high mortality rate demographic models to low birth and mortality rates. Mediating between these two is a period of development where birth rates remain high, but death rates have decreased. This is known as the third stage of demographic development (Chesnais, 1992) and is forecasted to characterize most if not all countries in the Global South for the remainder of the coming century. A larger number of people competing for finite natural resources poses a great enough threat to an equitable distribution of resources, but this is compounded by the aforementioned economic development. More persons with an ever-increasing want for goods and services only increase the need for a meditated effort to ensure an equitable distribution of those resources.

Like so many areas of development studies, the pall of climate change hangs over the economic reality of the situation. In the following chapter, it will be shown how the twin threads of an expanding population and of extensive economic development will combine to produce a greater water demand for the study area of Central Cebu. Beyond that, there is another factor which lends an additional element of urgency to the process of providing the residents of the region with a greater supply of drinking water. Groundwater resources face threats from both a reduced recharge rate, and salinization from a rising global sea level (Kundzewicz, 2007). Surface water is also threatened by a cycle of flood and drought characterized by increasing periodization and intensity. When the accelerating water requirements of residents in the Central Cebu Region are seen in light of a generally more insecure access to water, the need to invest in water provisional infrastructure becomes only more important. Accomplishing this goal in a socially equitable manner is paramount to prevent an inequality of one of life's most important resources in an area already characterized by substantive inequality in access to other resources (Estudillo, 1997).

As has been shown in the preceding chapter, we cannot create an operational plan of action from which to include socially inclusive thinking if we regard the objects of our enquiry as monolithic structures. The problems cannot be addressed with interventions which target the client as a whole, without taking into account the heterogeneous nature of groups which compose it. At odds with this insight, however, is then problem of how to measure the benefits of adaptation-oriented interventions in developing countries where the effects of climate change are aggravated by demographic and economic development. In this second case study, the provision of water to a city in the Global South has been selected, as it complements the nature of the previous example in both subject matter, Freshwater Services, and geography. This second study offers a new area were the theory of equity weighting can be put into practice, evaluating benefits as opposed to cost. Building upon the work done in Colombo, we are able to find an appropriate research question for the second phase of this research.

How can the marginal benefits of additional units of water be quantified for different socioeconomic groups so that the distribution of provisional infrastructure is completed in a socially equitable manner?

In answering this research question, the second case study will be structured in the following way. Firstly, the manner by which infrastructure recommendations are made in the standard Deltares workflow will be outlined. How this has been applied to a particular partner organization, namely the government of the Philippines, will then be discussed. Following a review of this standard approach, we apply a modified method that keeps goal of social inclusiveness in mind. Preliminary results from the new socially inclusive method will follow, and any novel findings we develop, will form a penultimate sub-section of this chapter, including a discussion on how they depart from the more traditional analysis. The case study concludes with a consideration of how this line of enquiry can then be further developed in the future.

3.1.2 Cebu: Methodology and Study Area

In stark contrast to the often complex methodology for forecasting flood damage, the method employed by Deltares and other firms like it to determine the appropriate strategy of investing in resource supplying infrastructure is remarkably simple and straightforward. Firstly, a demand gap is calculated for a fixed number of time steps. Trends in the demand of water are analysed based on previous data points, and are hence extrapolated into the future. Simple regression analysis is performed with regards to population growth, under the assumption that the demand for water will increase proportionately. The scale at which this is performed varies, but the number of enumerations in most projects does not exceed ten, severely limiting the precision of any subsequent studies. The total demand for water is then compared to the available resources in the region, or sub regions if applicable, and any shortages are then identified. Shortages are then addressed by investing in a number of water providing infrastructure projects. Additional units of water supplied through these investments are assumed to be applied equally over the entire study area, or enumerations. Cost effectiveness, which is the dollar amount required to provision an additional unit of water, most often measured in Million Cubic Meters (MCM), and time to completion are the metrics used to select appropriate interventions. In principle, a number of infrastructure investments are chosen in ascending cost per unit until the demand gap is met. Constraining this is the rapidity of which water is needed, possibly tipping in favour options which have a higher cost per unit, but that have a more immediate benefit.

The process broadly outlined above has been followed in the work performed by Deltares for the Central Cebu region. Cebu is an island province of the Philippines, and one of its most densely populated. The province consists of the Island of Cebu itself, plus several hundred outlying islands of varying size and importance. The majority of the province's population resides in a series of conurbations on the central region of the main island, and the largest of the outlying islands, Mactan. In addition to extrapolating water demand from purely population growth projections, the existing studies conducted in the Central Cebu region have included local economic development as a compounding factor for increasing water demand. Water demand is associated primarily with the prevalent mechanism through which water is supplied to households. In the most economically deprived of households, water must be purchased from vendors, or be collected from groundwater sources. These are referred to as Service Level One (L1) households, and surveys performed by local partners have revealed that on average, such households only consume between 10 and 15 litres of water per person per day (Deltares, 2017). Slightly higher on the economic ladder, Service Level Two (L2) households have access to wells or an analogous water providing mechanisms within easy walking distance of their homes. In rural regions, such households consume on average 25 litres of water every day per person and nearly 40 in urban areas. And on the top end of the spectrum, Service Level Three (L3) households have access to water in the convenience of their own homes, and consume 120 litres per day per household member in rural regions and up to 175 in urban regions.

As it stands currently, there are a number of intervention strategy timelines on offer to stakeholder in the Central Cebu region which will cover the needs of the region for the foreseeable future. In combination with the baseline methodology and the local economic development projections, the intervention portfolios for the Central Cebu Region also take into account socioeconomic impacts, such as provision of employment, as well as ecological impacts including flooding from damming or habitat destruction. All of the intervention portfolios include a mixture of groundwater and surface water measures to meet demand gaps, the only differences being the timing of various interventions, and the geographic locations of the investments. The study area has been so far enumerated into three separate geographic entities, encompassing the Western Conurbation of Toledo, Central Highlands, and the Eastern Conurbation of Cebu City. The key assumption of existing investment portfolio options, however, is that all beneficiaries will experience the utility water in an equal manner. The selling price collected by the Metropolitan Cebu Water District (MCWD) is 12.60 Philippine Pesos per litre and this value has been used in each study to determine benefit, as this is the freely determined market price. But as has been stressed repeatedly in this research, groups do not experience the development interventions in a uniform manner, whether this be damage prevented, or benefits added. The remainder of this case study will therefore be dedicated to finding a method to differentiate between groups within the Central Cebu region with regards to additional utility of additional units of water.

3.2: Methods

3.2.1 Scenario Formation

The first step in identifying a method for group identification is to see how water demand develops in a number of scenarios. Previous intervention portfolios were constructed under the assumption that demand would grow in Central Cebu along pre-existing trends in population growth and economic development. Reports from local partners describe this as no longer an accurate method to construe future demand, and instead insist on a number of scenarios to be constructed, to reflect the uncertainty of future reality. So in addition to adding an additional criterion for consultants to use in the decision making process, the work presented here will also be used in the reformation of existing investment portfolios along the renovated lines of scenario consideration, as opposed to trend analysis.

There are two dimensions through which we have constructed scenarios for water demand in Central Cebu for the coming century, resulting in 4 unique scenarios. The first dimension is Global Economic Development (GED). Two broad outcomes of GED have been identified as having impacts of note on this case study in the form of population growth. If GED were to be high, it is assumed that there would be a greater urbanizing pressure introduced to the Philippines, and ergo Central Cebu. And as one of the more urbanized regions of the Philippines (Gonzales, 2004), it is expected that it will be poised to receive a high number of internal migrants. And conversely, it is expected that the population of the region will increase to a lesser extent in low GED scenarios, mostly from natural demographic development. The second dimension along which scenarios in this case study is constructed is that of Local Economic Development (LED). The two ends of this spectrum are largely dependent on whether or not The Philippines are able to capitalize on GED, and whether or not there is GED in the first place. As this case study concerns itself with water provisional infrastructure, the way LED manifests in the scenario building process is the proportion of Barangay (neighbourhood level unit) populations which fall into the above mentioned L1/2/3. In high LED scenarios, a greater percentage of Barangay populations will migrate to higher service levels, whereas more will remain at lower levels under low LED conditions.

3.*2.2 Scenario Fabrication*

(1) Baseline

Going from a series of hypotheticals of possible scenarios to implementable geospatial datasets requires us to start from a baseline datasets of Barangay specific data detailing population figures and service level breakdowns, in addition to an appropriately enumerated shapefile containing polygons representing Barangays in a GIS environment. Research has already been done within Deltares in combination with local partners surveying the population and service level of proportion of each Barangay in the study area in 2010. These figures were attributed to a shapefile recovered from Philippine Geoportal agency, a clearinghouse operated by the National Philippines Government to consolidate all geospatial data for the country. And as with many projects of this nature, there was considerable consternation in importing the demographic and service level data derived by Deltares into a shapefile originating from a different organization. There was agreement between the two sources on the number of enumerations, but not on the spelling thereof. Considerable time was therefore taken by the author in order to properly import attribute data in the spatially referenced Barangay file.

In the end, a solid baseline shapefile was produced, and was used as a starting point for the remainder of the speculative scenarios. Below, in figure 7, the spatial distribution of water demand intensity can be seen; this is fabricated by calculating total water demand and normalizing it for area. The figure is compared to the size of the area because it becomes more efficient to focus infrastructure investments over smaller geographic areas[i]. Total water demand is tabulated by multiplying the proportion of a Barangay's population in a certain service level by the mean per capita water consumption for that service level. This is then done for the remaining two service levels, and hence aggregated. The binary urban/rural status of the Barangay is also taken into account in this calculation due to the fact that the same service level designation has different implications for total water demand dependant on where the particular user lives. The demands of the three service levels are summarized below in table 3 for reference. An overview of how the intensity metric is calculated is also offered in the form of equation 3.

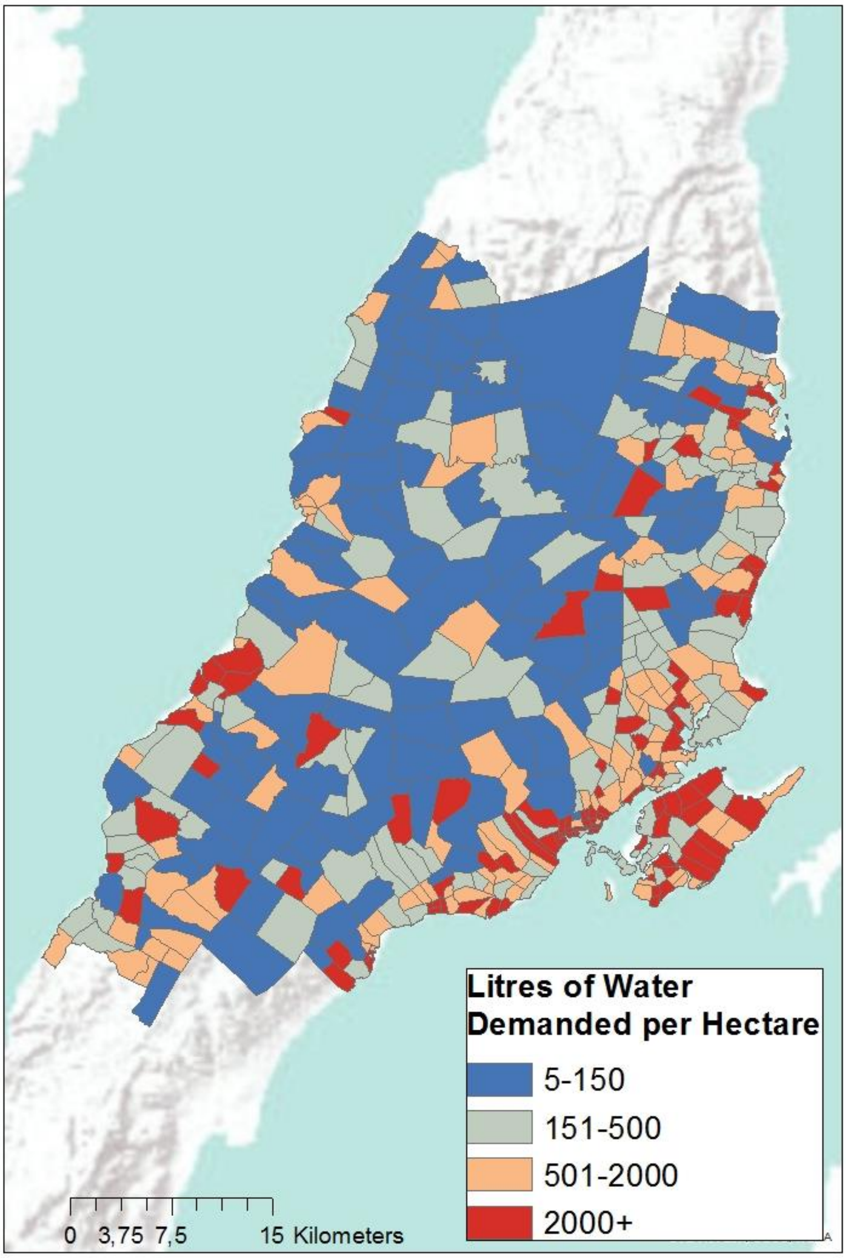

Figure 7-Water Demand Intensity In the Central Cebu Region in 2010

Service level	Range and Mean Water Demand (MWD) In litres per day per person		
	Urban	Rural	
	Urban	Poblacion	Rural
Level I	10-15 (13)		
Level II	30-40 (35)	15-25 (20)	
Level III	150-175 (162.5)	120-130 (125)	100-120 (110)

Table 3: Mean Water Demand of Urban and Rural Consumers in Central Cebu per Service Level

Equation 3, derivation of Water Demand Intensity:

$$Water\ Demand = (L1\% * L1MWD) + (L2\% * L1MWD_{Urban\ or\ Rural}) + (L3\% * L3MWD_{Urban,Poblacion,or\ Rural})$$

$$Water\ Demand\ Intensity = \frac{Water\ Demand}{Barangay\ Area\ in\ Hectares}$$

(2) Global Economic Development Dimension

Economists within Deltares took into account demographic development vis-à-vis global economic development in the scenario building process, with some input from local partners in the Philippines. Methodologically, it was assumed that Barangays would maintain their proportion of the total population of the Central Cebu Region. Analysts therefore only increased the regional population figure once for every time step, and reattributed the population numbers to the Barangays accordingly. Two trajectories were devised by the in house economists at Deltares, namely those of high and low economic growth. Figure 8 below compares these two trajectories over the timespan of 2000 to 2040 in the form of a line chart.

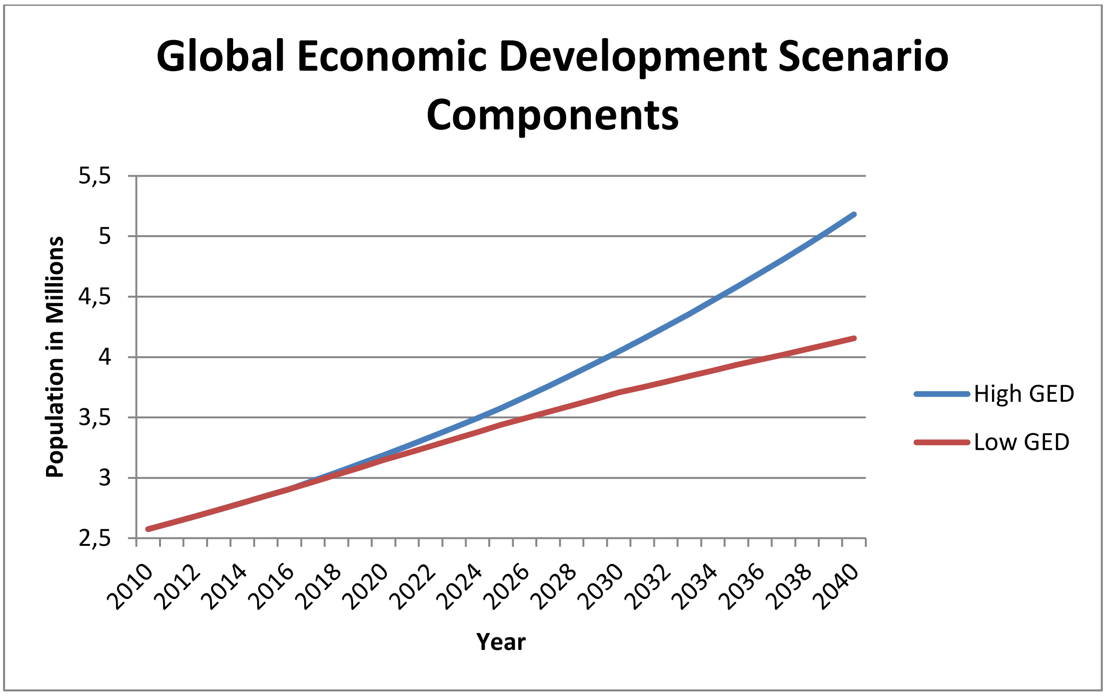

Figure 8-Population Growth in the Central Cebu Region

(3) Local Economic Development Dimension

Apart from a baseline set of scenarios wherein there is no LED, and ergo no migration to higher service levels, there are two trajectories simulated in our research. In the first scenario, there is a gradual level of migration from service level one to service level two, and from service level two to three. This is accomplished by manipulating the data from the baseline scenario so that the proportion of households with L1 decrease by 50% every 5 year time step, and the difference is split between L2 and L3. For example, assuming that a Barangay had a 100% prevalence of L1 in the year 2010, it would be presumed to have a L1 prevalence of 50% in the year 2015, with 25% of households assumed to be L2, and 25% assumed to be L3. How the spatial prevalence of L3 develops over time can be seen in the following series of figures, 9 through 11. In the second scenario, the lofty goal of the Philippine government to completely eradicate L1 prevalence by the year 2020 is used in order to simulate ideal conditions. The truth most likely lies somewhere between these two scenario dimensions, with trends analysis predicting a rough L3 prevalence of 70% by 2020.

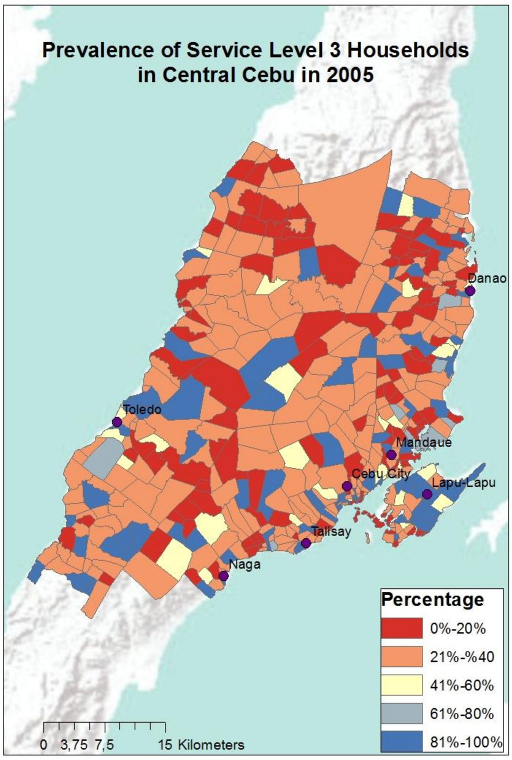

Figure 9

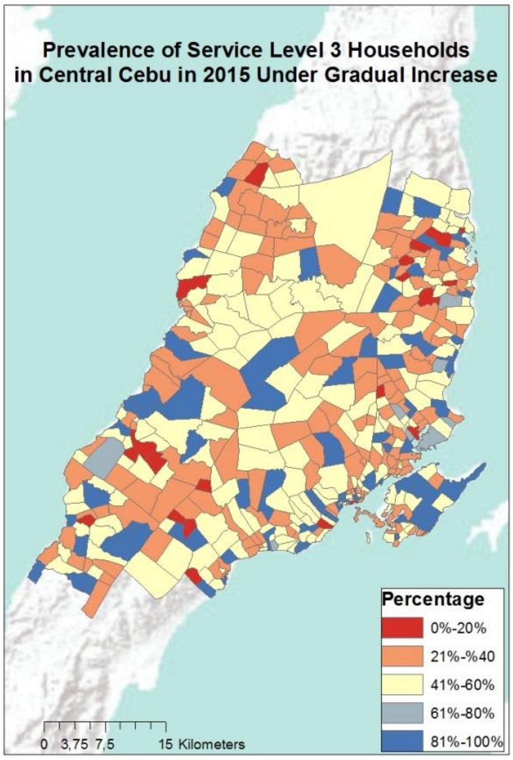

Figure 10

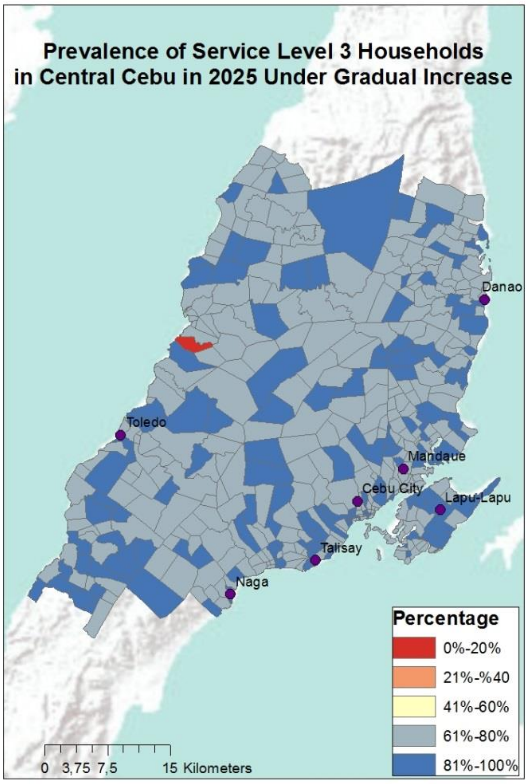

Figure 11

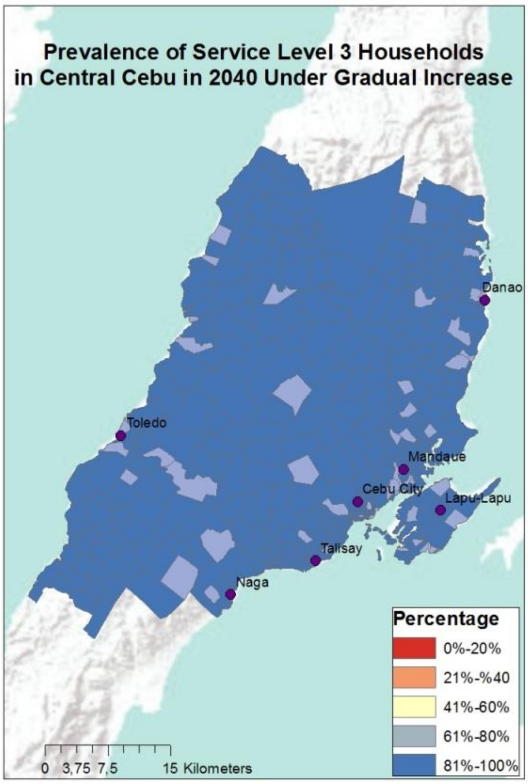

Figure 12

3.3: Results

3.3.1 Identification of Spatial Patterns of Deprivation

Much in the same way as was done in the case study of Colombo, the first step to making socially inclusive infrastructure investments is to find where, geographically speaking, the most vulnerable members of the population are located. That is done in this instance by comparing the results of the different scenarios produced along the two dimensions discussed above. The metric which was chosen to identify the spatial reference to economically-deprived populations in the Central Cebu Region is the additional water generated solely through local economic development. The specific characteristic which is revealed through this particular analysis is the extent to which the residents of a particular Barangay develop their requirements for water over the course of the study timeframe.

Households that are entering into higher service level groupings, which here is used as a proxy for a more general socio-economic status, will have a higher marginal utility of additional units of water than their counterparts who already had access to service level 3. (Their additional demand is bringing them up to par for the standard of consumption of either higher service level.) By performing this value added service, this research provides a suitable answer to the research question stated in the introduction of this chapter. A new layer of information describing the heterogeneous socio-economic characteristics of the study area's residents in terms of spatial distribution is contributed to the decision making process in the Central Cebu Region's infrastructure investment plan.

3.3.2 Derivation of Local Economic Development Generated Water Demand

For the sake of brevity, only one derivation of additional demand will be performed. This example uses the set of scenarios which assumes a high level of global economic development, and the ensuing higher level of demographic development in the study area. A similar analysis performed under the opposite set of scenarios (assuming low economic growth) would show the same spatial distribution of demand generation, but with a lessened effect, and are therefore not especially germane to this research. Furthermore, we have chosen to use the gradual migration to service level 3 scenarios to derive our spatial patterns of additional demand generated because of the nature of recommendations of investment portfolios which are being made to policy makers in Central Cebu. Although it does not follow the trend scenario, a gradual migration is still the most likely to resemble a probable outcome. The derivation itself is a straightforward subtraction of projected Barangay water demand in 2040 under no LED from a scenario of complete LED. This is then compared to the initial water demand, and expressed as a percentage. The resultant map, figure 13, shows the spatial distribution of LED-generated water demand per Barangay in the Central Cebu Region.

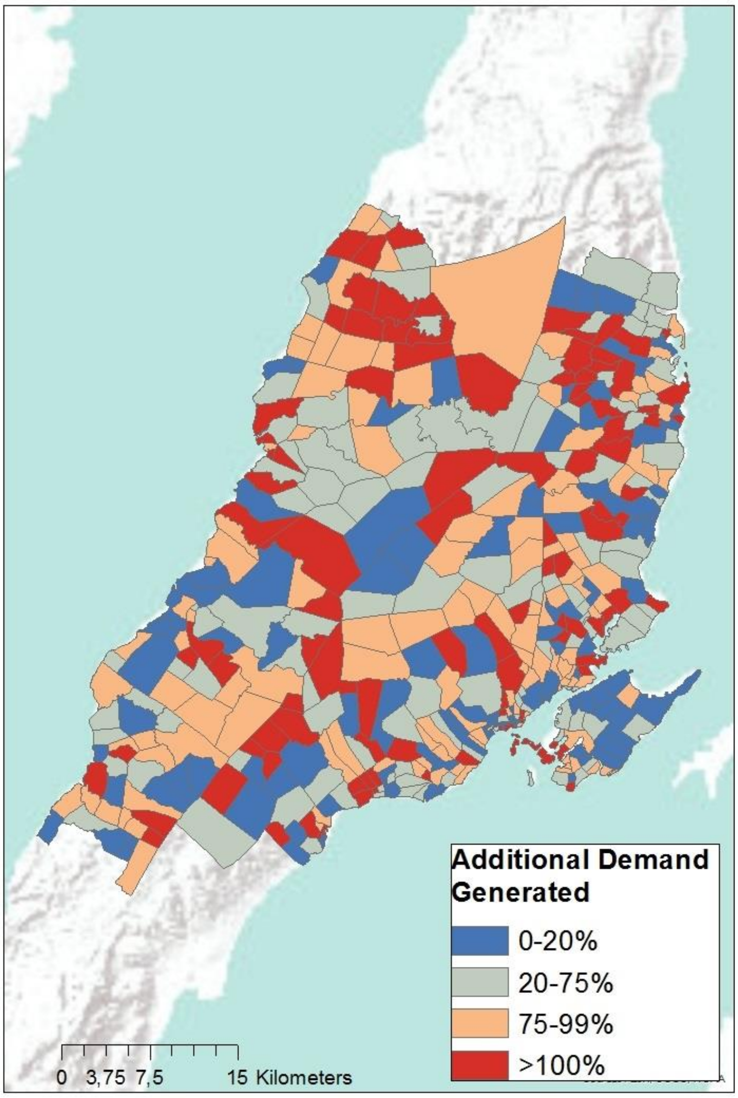

Figure 13: Water Demand Created Through Local Economic Development

3.4: Conclusion

<u>3.4.1 Discussion</u>

The information derived above from the investigations of several dimensions of scenario building can doubtlessly be used to add an additional dimension to the decision making process in

Central Cebu. For instance, by comparing Figures 7 and 13, we are able to see how the underlying assumptions which are being used in this modified process come to light. A clustering of identified water demand in coastal barangays is reversed under the new inclusive mindedness methodology, where we see a more even distribution of water demand identification. So far in the work done by Deltares in the Central Cebu Region, the intensity (per hectare) of water demand has been used as a measure through which to assess the water needs of Barangay-level geographic entities. This unreasonably favours the smaller Barangays in the coastal conurbations consisting of cities such as Toledo and Lapu-Lapu and their surrounding suburban zones. By using gross water demand in the modified workflow proposed in this case study, we are giving a reasonable chance for the very real needs of rural Barangay units in the interior of the island to be heard and understood.

Building on this gross water demand has been modified in such a way so as to highlight the different, and arguably more pronounced needs of newly economically developed Barangays. Through the novel usage of scenario building techniques, the spatial dispersion of water demand generated has been identified purely through local economic development, which is an area which has been highlighted in this research by stakeholders to merit a larger degree of investment than population induced demand. Referring again to figures 7 and 13, we see the breaking if the trend of coastal clustering of demand identification. When demand is viewed through the lens of intensity, coastal elites are favoured, while a more nuanced view is afforded if the same data is extrapolated into the future, and viewed through the more equity conscience lens of LED generated demand growth.

Ideally, the metric identified by this case study, the water demand generated through local economic development derived through scenario comparisons, will be given an equal place among the infrastructure investment options supplied to decision makers. This will not be intended to be an overarching, end-all decision making criterion as the Equity Weighting of Flood Damage was in Colombo. After all, the most important goal in investing in water provisional infrastructure, especially in the face of shrinking resources and burgeoning populations, is to ensure that everyone has enough water to survive. However, by having the percentage of water demand generated by economic growth available to them, policy makers will have feedback to inform their decisions which will help them to create an investment portfolio informed by the concept of social inclusiveness. While this cannot be used to provide precise assessments of the equitability of possible investment portfolios, as the information generated in this pilot study needs to be taken into combination with other data in conjuncture with information regarding things such as ecosystem impacts in addition to water demand, it does show a concrete example of how benefits allocation can be improved by including inclusiveness theory into calculation.

3.4.2 Applications for further research

Identifying LED generated water demand is only the first step in performing analysis comparable to that undertaken in the case study of Colombo (Chapter II), however, there are still several steps in data collection which need to be completed before such a task can be accomplished. The information expressed cartographically in the preceding sections of this chapter can be compared to the FIAT output flood extent raster files of the Colombo case study. By finding where we expect to find the greatest volume of demand generated through economic, rather than demographic development, we have identified the "problem" which needs to be addressed. Apart from this similarity, it is important to note the fundamental differences between this and a flood damage projection. A value judgement has already been introduced into the workflow, by prioritizing the demand needs of developing as opposed to already developed Barangays. The gross demand generated could also have been used as a staging point for further analysis in this case study of the Central Cebu Region, but this would skew unfairly any suggested infrastructure projects to the more densely populated and wealthy Barangays in the coastal conurbations. The author behind this research feels that this is an appropriate value judgement to make, as it will ultimately further our end of informing infrastructure investments so as to be as socially inclusive as possible

At this juncture, the information needed to commission in-equity weighting exercise is currently being either gathered *in situ,* or being calculated by economists specializing in welfare informed economic development. Having been well-received by others within the organization of Deltares as well as stakeholders within and outside Sri Lanka, Equity Weighting was chosen as an appropriate method. Inputs for this include an identification of the spatial distributions of hazards, which in Colombo was Expected Annual Damage caused by flooding, and LED generated water demand in Cebu. Additionally, data about the socio-economic status of the different geographic units in the study area is utilized to calculate equity weights which modify the impact of the phenomenon being invested against. Consisting of proxy consumption data of electricity and national income distribution data in Colombo, a similar effort is being undertaken by local partners in the Philippines. This will then be applied to the selling price of water in the Central Cebu Region, 12.60 pesos, to find the "true" value of water provided by infrastructure investments. As previously mentioned, a certain amount of socio-economic awareness has already been introduced into the workflow for this project by choosing LED generated water demand over gross, but can be supplemented by consumption proxy data and income distribution data for the equity weighting process to introduce a finer and more precise appraisal of the spatial distribution of wealth, and its benefits.

Chapter IV: Reflection

In the two preceding chapters, it has been attempted to bring into the operating practice of the Water and Subsurface Research Institute Deltares' work flows the concept of social inclusiveness. As one of the main areas of interest of the institute is consulting on infrastructure investments in countries in the developing world, two projects currently being undertaken in the developing world were chosen. Firstly, work was carried out for the government of Colombo, Sri Lanka, regarding the evaluation of expected annual flooding damage which accompanies the local monsoon season. This case study was truly a pilot study in the sense that very little had been done either within or without Deltares on the subject of operationalizing social inclusiveness. Taking the lessons learned from the work done in Sri Lanka, a second active Deltares project was nominated to undergo a similar treatment. The Central Cebu Region was chosen due in part to the fact that it concerned itself with the equitable distribution of benefits from infrastructure, as opposed to equitably mitigating damages. In this way, it can be shown that social inclusion can be operationalized in a wider variety of settings than previously thought of. This section will concern itself with evaluating exactly to what extent the cases illustrated in chapter II and III have accomplished the goal posited in chapter I:

To operationalize the concept of inclusiveness through the combination of an objective assessment of hazards and benefits and the incorporation of socially conciseness ideals. The aim is thus to create new methods for analysis that take into account all the relevant characteristics of study areas, resulting in holistically informed conclusions and recommendations for actions.

Evaluating the utility of the research presented herein needs to come from a tripartite perspective, in order to evaluate all of the criteria presented in the goal stated above. Not only do the synthesis of quantitative and qualitative methodologies inherent in an empirically based analysis of social inclusiveness warrant review, but also how the application of equity weighting in Colombo and Cebu conforms to its theoretical basis in the paper by Kind et al, in addition to the observable impacts resulting from the research so far. There were other methods used to interject social inclusiveness into the decision making process, especially in the case of Colombo, but they were ultimately dealt with *in situ*. The closing remarks of this thesis will therefore take the following structure. An evaluation of how quantitative and qualitative approaches to development consulting were integrated into the pilot studies of Flood Damage Assessment in Colombo and Water Provisional Infrastructure in The Central Cebu Region will precede a more general assessment of the practical implementation of Equity Weighting in relation to its theoretical base, which has provided the backbone of the analytical capability of social inclusiveness put forward in this thesis. Following this will be a general reflection of the impacts this research has had on the ground as of yet. Speculation on the future of this area of enquiry, informed by its current effectiveness, will then constitute the final segment of this thesis.

Firstly we must cast our attention back to the opening remarks of Chapter I: The Inclusiveness Concept, to classify the relationship between qualitative and quantitative analysis present in this thesis. As such, it is now an appropriate moment to assess the novel equity conscious analyses showcased in Chapters II and III in light of Morgan's paradigm of hybrid analysis. Morgan was by no means a Geographer nor an Economist, but his work in public health research paved the way for both quantitative and qualitative methods to be used in tandem. According to Morgan, the way to integrate two epistemologically opposed schools of operation is to nominate one or the other as the primary method, and then use the subordinate method to add onto this analysis either before or after the main analysis is completed. In this way, there is either a preliminary research method which informs a later, central analysis, or a post-processing method is employed after the primary method.

In searching for a precise classification for the analysis performed in Colombo and Cebu, the definitions of hazard inherent to the quantitative and qualitative methods of risk analysis must first be reviewed. In the biophysical school, hazard is inherent to an event, usually climactic in nature. In the social school on the other hand, hazard is endemic to the state of the system to which the event occurred. In our socially inclusive methodology posited in this thesis, both schools were integrated, so that the traditionally quantitative biophysical and qualitative social schools would form components of a unified tradition. The reasons for this of course are to lend a greater credibility and strength to researchers who prioritize socially conscious recommendations for actions, by giving them an objective operationalization of social characteristics. By conforming the ideals of the social school to the methods (objective quantification of characteristics), this research can then be said to use quantitative methods as its primary method, with qualitative as the secondary. Furthermore, the secondary qualitative methods can be said to take the form of a follow up analysis. In both Cebu and Colombo, an objective, event oriented hazard was quantified, (Economically generated water demand and Flood Damage respectively), and was then complimented by post processing which took into account the heterogeneous nature of the socio-economic characteristics of the study areas. This took the form of proxy consumptive data which was then related to national income statistics in Sri Lanka, and will likely follow an analogous path in The Philippines.

How does this hybrid quantitative and qualitative methodology of social inclusiveness compare to the equity weighting described by Kind et al in their paper “Accounting for risk aversion, income distribution and social welfare in cost-benefit analysis for flood risk management”? The method of equity weighting was taken from this paper, but was the first implementation of the theoretical framework outside of the hypothetical. Naturally, there were compromises which needed to be made in order to translate the theoretical precepts to actual on the ground analysis. Primarily, the largest area where bridges needed to be built was in the resolution and quality of data called for in “Accounting for risk aversion”. The consumptive patterns of average income of GN Districts were unavailable from the Sri Lankan Census Bureau, which lead to the usage of proxy data is the analysis presented above. This is only one example of how the equity weighting performed in Chapter II, and proposed in Chapter III was transformed from a data intensive, theoretical concept into a “quick and dirty” analysis able to be applied in data poor environments in the developing world, the primary target area for the practitioners putting equity weighting into effect. On the whole, the equity weighting performed in this thesis provided much of the quality output proposed by Kind et al, if with slightly more assumption and extrapolations, and provides a model for further case studies around the world.

Finally, the present situation of the intended outcome of the entire research behind socially inclusive hazard analysis, informing infrastructure investment options, will be compared to the goal statement of this thesis. Adding an additional layer of information to the decision making process was only ever going to be just that, an additional layer. Other concerns and influences abound when policy makers attempt to determine the most suitable way to spend their infrastructure budget. In a sense, the goal of the research can be construed as being too lofty, and ultimately unachievable. But if understood from a synergistic point of view, the achievements of the research’s outcomes to date have been achieved in a more than satisfactory fashion. In the Colombo case study, the contributions of equity weighted analysis went largely unheeded, and the ultimate investment choices bore little bearing to the socially inclusive output of Chapter II. However, a general level of awareness of the concept of social inclusiveness in the field was raised in financers of the project in Sri Lanka, the World Bank, and in professionals in the field, in Deltares. This has been seen in the reception of the second pilot study in The Philippines. Socially inclusive assessments of investment options have been made part of the decision making process whole sale, even though they have not yet reached their terminal form.

The swift adoption of operationalized inclusiveness bodes well for the theoretical framework created through this thesis, and for the field as a whole. It appears likely that social inclusiveness will remain a pillar of infrastructure investment studies in the future. The spatially referenced nature of the output produced by this methodology lends itself especially well to infrastructure investments in socioeconomically heterogeneous areas, where there is a high degree of geographic segregation of population groups dependant on economic factors. And by integrating quantitative and qualitative aspects of formerly disparate methods of analysis, the holistic nature of socially inclusive analysis operationalizes inclusiveness in such a way as to ensure a greater benefit for stakeholders, policy makers, and investors the world over. In the face of rising income inequality between and within nations and a steadily changing climate, the benefits of socially inclusive analysis will only continue to grow, becoming an increasingly vital component of the development consulting field. Whether it be in preventing damage to the most vulnerable members of the global community through climactic events, or through the provision of benefits through infrastructure. By adopting such methodologies, it is hoped by the author that one day the staggering disparities which currently characterize the international community of nations may be somewhat diminished, or at the very least recognized and addressed with appropriate concern.

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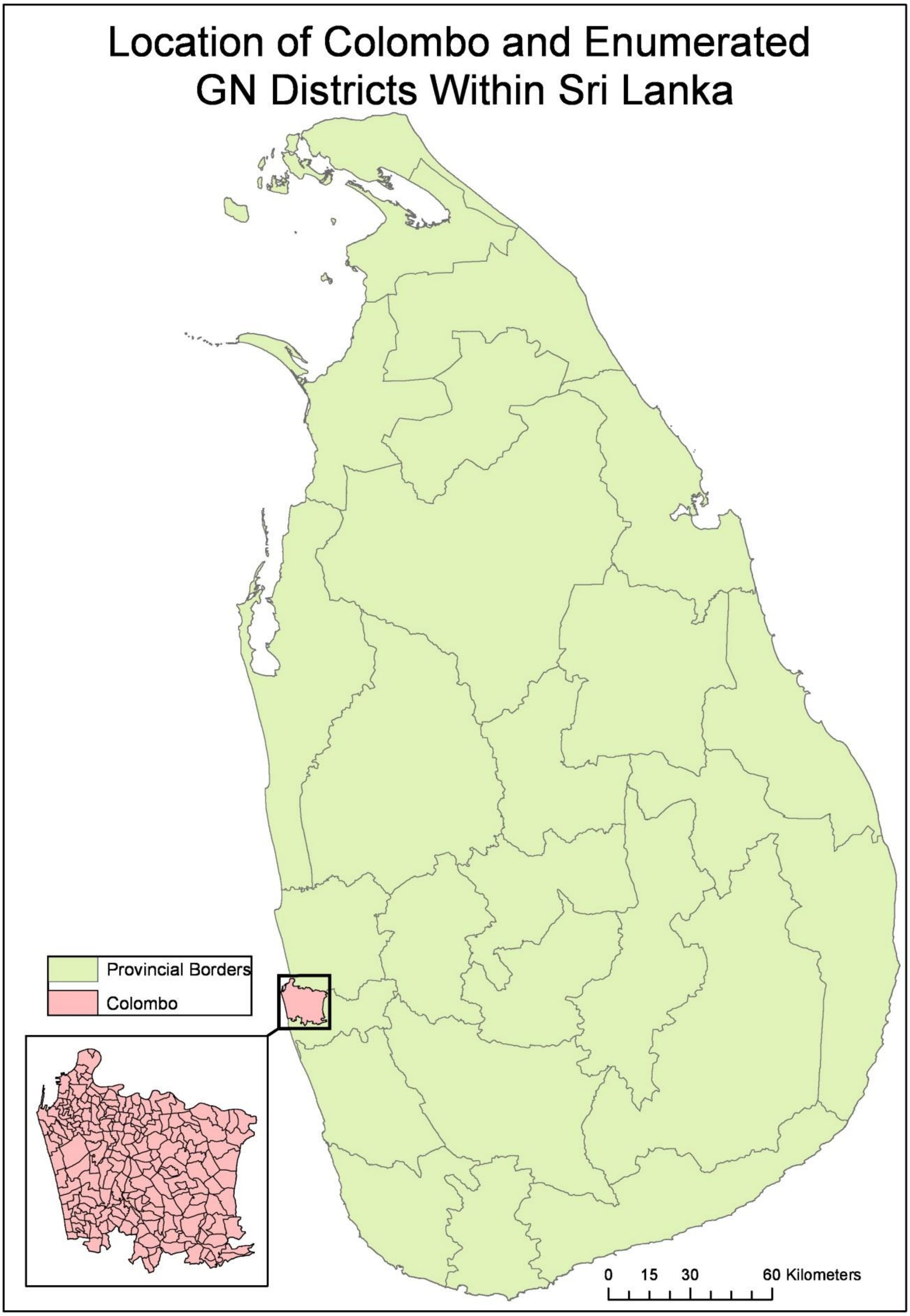
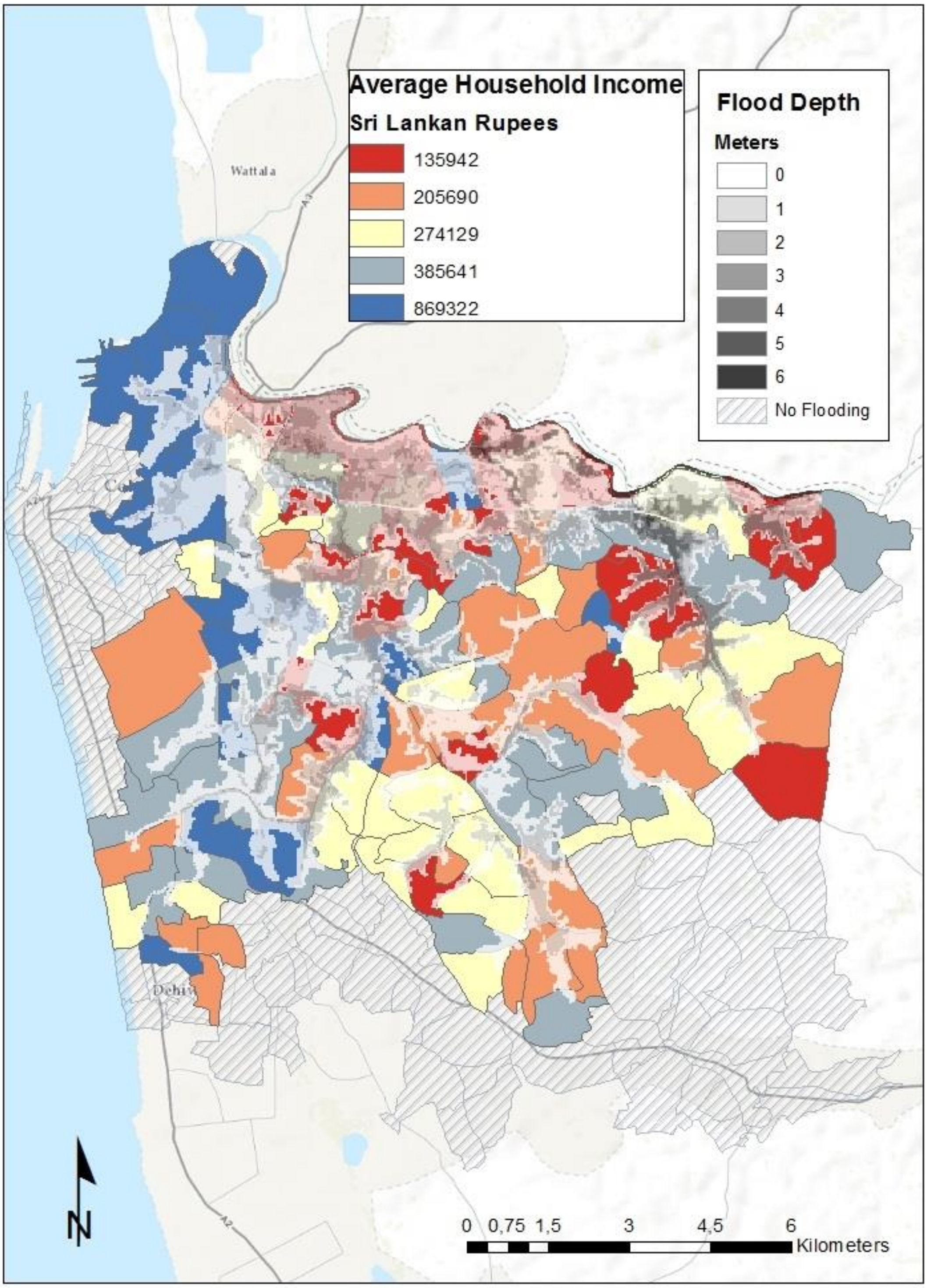
Appendix I: Colombo



Flood Depth for Return Period 100 Years



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