OUTCOME EVALUATION OF CLIMATE ADAPTATION MEASURES IMPLEMENTED IN DURBAN CITY, SOUTH AFRICA

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June, 2020

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ABSTRACT

The impact of climate change such as severe storms, flooding, extreme temperature, and increased drought have negative consequences on the lives and wellbeing of the communities. The impacts are expected to be severe for cities in the Global South with high social vulnerability due to poor socio-economic conditions and physical infrastructure. In response to climate change impacts and high social vulnerability, the cities in the Global South have developed and implemented climate adaptation measures. However, a review of the literature suggests that few studies have been undertaken in the Global South to evaluate the outcomes of climate adaptation measures in terms of equity and reducing social vulnerability. Therefore, a study was undertaken in Durban, South Africa to establish whether the outcomes of the climate adaptation measures contributed to reducing or exacerbating social vulnerability. The study involved an assessment of the spatial distribution of social vulnerability to identify the vulnerable communities; mapping the spatial distribution of the adaptation measures to establish whether they were accordingly, equitably distributed; and an assessment of the consequences of the adaptation measures to establish the effectiveness, co-benefits and the risk of maladaptation. The results show a very high social vulnerability for densely populated areas (wards) located closer to the city center, which mainly comprised informal settlements and former township areas; and a high social vulnerability for the areas located in the periphery of the city, which are mostly rural. Further, four of the five projects evaluated were generally equitably distributed as they targeted areas with high social vulnerability. The project which was not equitably distributed mostly targeted areas with low social vulnerability. In terms of effectiveness, four of the five projects achieved the objectives, which contributed to increasing the adaptive capacity and reducing the exposure of the vulnerable community. One project was not effective in reducing the exposure of the vulnerable community to flooding as indicated in its objective. All the projects generated co-benefits which contributed to increasing the adaptive capacity, and to a less extent reducing the sensitivity of the community. However, a high risk of maladaptation was observed in one project, which focused on reducing the exposure of the vulnerable community to flooding. Moderate risk was observed in two projects, which focused on reducing sensitivity. Further, the results indicate maladaptation outcomes for two projects related to the increase in the cost of land closer to the project area and the negative effects of effluents from solid waste storage facilities which were located closer to houses and communal ablution blocks.

Keywords: Climate Change, Climate adaptation measures, social vulnerability, effectiveness, equity, co-benefits, maladaptation.

ACKNOWLEDGMENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Background and justification

Climate Change, which is defined by IPCC (2014, p. 5) as the "change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for a long period, typically decades or longer", poses a serious challenge to the human environment. The effects of climate change such as severe storms, increased flooding, extreme temperature, rise in sea level, and drought are expected to increase and adversely affect the lives and well-being of the people. For example, severe storms and increased flooding result in damage to housing and public infrastructure (UN-Habitat, 2011); drought leads to water scarcity and hunger due to crop failure; and extreme temperature results in health problems in children, old people and those with poor health (Breil, Downing, Kazmierczak, Makinen, & Romanovska, 2018).

The impact of climate change is expected to be severe, particularly in the Global South, where the level of social vulnerability is high due to high poverty levels, and poor housing and public infrastructure (Anguelovski, Chu, & Carmin, 2014; IPCC, 2014). Social vulnerability, in this case, refers to the measures of exposure, sensitivity, and adaptive capacity of the community to the impact of climate change (Kazmierczak, 2015). Adaptive capacity refers to the ability of the community to prepare, respond and recover from the impact of climate change; Sensitivity is the susceptibility of the community to the impact of climate change; and exposure is the extent to which the community is exposed to the impact of climate change (e.g. flooding, heatwave, severe storms).

Given the above, adaptation, which is defined by IPCC, (2014, p 5) as "the process of adjusting to actual or expected climate and its effects", has been recognised as an important strategy to mitigate climate change impact and reduce social vulnerability (Mimura et al., 2014; Sherman & Ford, 2014; Ford et al., 2015). In the Global South, many cities have started implementing adaptation measures in response to the impact of climate change and high social vulnerability (Ford et al., 2015). For example, the cities of Cape Town and Durban in South Africa have implemented climate adaptation measures in response to the impact of severe storms, flooding, and high levels of poverty among the residents (Roberts, 2010; Ziervogel & Parnell, 2014). The cities of Surat in India (Anguelovski et al., 2016), and Medellin in Colombia (Chu, Anguelovski, & Roberts, 2017),

are also examples of cities in the Global South that have implemented climate adaptation measures. However, recent studies undertaken in the Global South, have shown that most of the climate adaptation measures do not take into consideration the needs of the vulnerable and marginalised groups (Ford et al., 2015; Chu et al., 2017). It is also not clear whether the outcomes of climate adaptation measures reduce or exacerbate social vulnerability. As indicated by IPCC (2014), most of the assessments of climate adaptation measures done have focused on vulnerability, planning process, and the impacts. Therefore, an in-depth study was needed to establish whether the outcomes of the climate adaptation measures implemented enhance the well-being of the vulnerable community by reducing social vulnerability or exacerbate their vulnerability. Durban city was selected as a case study as it is known as a frontrunner in implementing adaptation measures in a city of the Global South. It is envisaged that the research will contribute knowledge to the body of science in terms of the effectiveness, equity, and the risk of maladaptation of the climate adaptation measures implemented in the Global South. The findings of research will also provide information to the local municipality in Durban city that can be used to strengthen the current climate adaptation measures or to design new ones.

1.2.   Research problem

Durban city is located on the eastern coast of South Africa. It has a high population growth with the majority of the people unemployed and poor (Roberts & O'Donoghue, 2013; eThekwini Municipality, 2018). The city experiences severe storms and flooding during the rainy season, which causes damage to housing, public infrastructure, and loss of life (IOL, 2017). In response to the effects of climate change and high poverty levels, Durban implemented climate adaptation measures to reduce the vulnerability and increase the adaptive capacity of the community (Roberts, 2010; Anguelovski et al., 2014; Martel & Sutherland, 2019). However, a review of scientific literature on the climate adaptation measures in Durban city suggests that no comprehensive research was undertaken to evaluate whether the adaptation measures were equitably distributed and the outcomes helped to reduce or exacerbate social vulnerability. Most of the studies focused on adaptation and governance issues (Martel & Sutherland, 2019); integration of adaptation initiatives into municipal strategic activities (Chu et al., 2017); planning process for climate adaptation plans (Anguelovski et al., 2014), and challenges and potentials of climate adaptation initiatives (Roberts & O'Donoghue, 2013). Therefore, there was a knowledge gap in terms of the effectiveness, equity, and the issue of maladaptation (negative consequences) of the climate adaptation measures implemented in Durban city.

1.3.   Research objective

The main objective of this research is to establish whether the outcomes of climate change adaptation measures implemented in Durban city reduce or exacerbate social vulnerability

1.3.1.   Specific objectives

i.   To assess the spatial distribution of social vulnerability to climate change in Durban city

ii. To map the spatial distribution of climate change adaptation measures implemented in Durban city

iii. To assess the consequences of climate change adaptation measures implemented in Durban city, to the vulnerable and marginalised groups

1.3.2.   Research Questions

To assess the spatial distribution of social vulnerability to climate change for Durban city

i.   Which factors contribute to the current social vulnerability in Durban city?

ii. What is the current spatial distribution of social vulnerability for Durban city?

To map the spatial distribution of climate change adaptation measures implemented in Durban city

i.   Where are the climate change adaptation measures implemented in relation to the spatial distribution of vulnerable and marginalised groups?

ii. What is the proportion of the target population of climate adaptation measures who are vulnerable and marginalised?

To assess the consequences of climate adaptation measures to the vulnerable and marginalised groups in Durban city

i.   What are the main achievements and non-achievements of the objectives of the climate adaptation measures in relation to social vulnerability?

ii. What are the reasons for the non-achievement of some of the objectives of the climate adaptation measures?

iii. What are the positive consequences (co-benefits) and negative consequences (Maladaptation) of the climate adaptation measures to the vulnerable and marginalised groups?

1.4. Conceptual framework
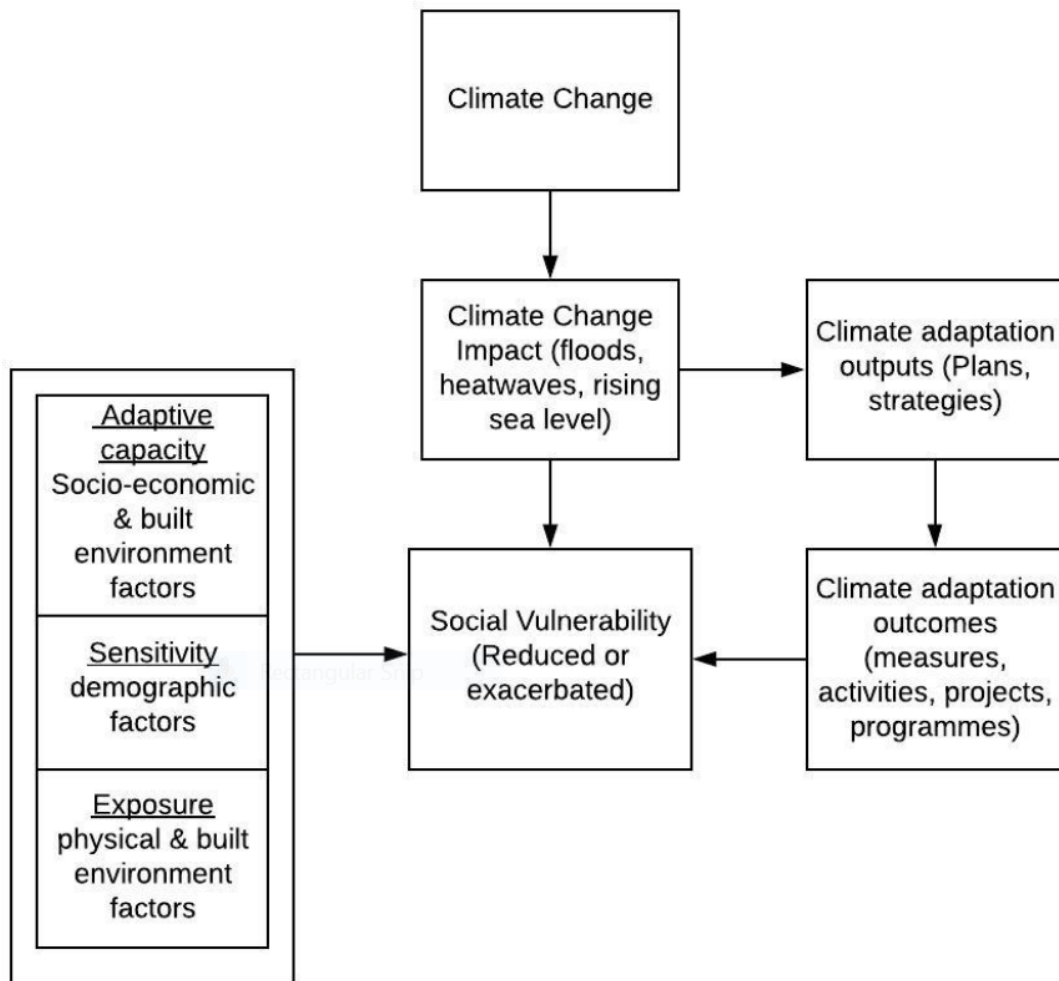
Figure 1. 1: Conceptual framework for outcome evaluation of climate adaptation measures.

The conceptual framework in figure 1.1 provides the scope of the study and illustrates the relationships (links) between climate change, social vulnerability, and climate adaptation.

As indicated in the framework, climate change impacts such as floods, heatwaves, and rise in sea level adversely affect communities characterised by a high level of social vulnerability. Social vulnerability in this case is a combination of three dimensions: adaptive capacity, sensitivity, and exposure (Kazmierczak, 2015; Breil et al., 2018). Therefore, high social vulnerability is influenced by low adaptive capacity (e.g. low education level, low-income level, inadequate physical infrastructure), high sensitivity (e.g., a high percentage of female-headed households, a high percentage of children below 5 years, a high percentage of people above 65 years, or a high population of ethnic groups), and high exposure (e.g. high population density, informal housing, proximity flood zones).

The conceptual framework also shows the relationship between climate change impacts and climate change adaption plans/strategies. The framework demonstrates that the effects of climate change necessitate the development of climate adaptation plans aimed at lowering climate change impacts and improving the wellbeing of the vulnerable groups. The climate adaptation plans/strategies result in adaptation outcomes, which are projects or programmes implemented by the local authority. Examples of climate adaptation measures include drainage improvement, road construction, social security programmes, insurance programmes, and low-income housing construction (Anguelovski et al., 2016). Adaptation measures can reduce social vulnerability by reducing the exposure of vulnerable communities to climate change hazards (IPCC, 2014; Breil et al., 2018) (e.g. through improving the drainage system, construction of floodwalls); reducing the sensitivity of the community (e.g. improving access to healthcare); and improving the adaptive capacity of the vulnerable groups (Breil et al., 2018) (e.g. climate change awareness, skills training, or employment creation). On the other hand, the conceptual framework illustrates that climate adaptation measures can also exacerbate social vulnerability through intervention measures that negatively affect the vulnerable community. For example the re-location of the vulnerable community to areas far from job business opportunities.

1.5. Structure of the thesis

This thesis is structured as follows: In chapter two, Durban city, which is the study area for this research, is described in terms of location and management, demographic, and socio-economic characteristics and climate change challenges. In chapter three, a review of literature is presented in terms of climate change adaptation, equity, social vulnerability, and experiences of climate adaptation measures in Durban city. In chapter four, a description of the research methodology is done in terms of research design, data collection, sampling, data analysis, and limitation of the research. In chapter five, the results of the research are presented regarding the assessment of the spatial distribution of social vulnerability, the spatial distribution of climate change adaptation measures, and the assessment of the consequences of climate adaptation measures. In chapter six, the results of the research are discussed regarding the current spatial distribution of social vulnerability, the spatial distribution of adaptation measures, and the consequences of adaptation measures. In chapter seven, the conclusion and recommendations of the research are presented regarding the specific objectives of the research and related research questions.

2.   DESCRIPTION OF THE STUDY AREA

2.1.   Introduction

This chapter describes the city of Durban, which is the study area for this research. The city is described in terms of the location and administration, socio-economic and demographic characteristics, climate change challenges, and experiences of climate adaptation measures

2.2.   Location and management

As indicated in figure 2.1, the city of Durban is located on the eastern coast of South Africa, in the KwaZulu Natal province (Sutherland, Scott, Nel, & Nel, 2018). Further, the city lies within the eThekwini Municipality, which is the local government authority responsible for the management of the city (Sutherland et al., 2018)
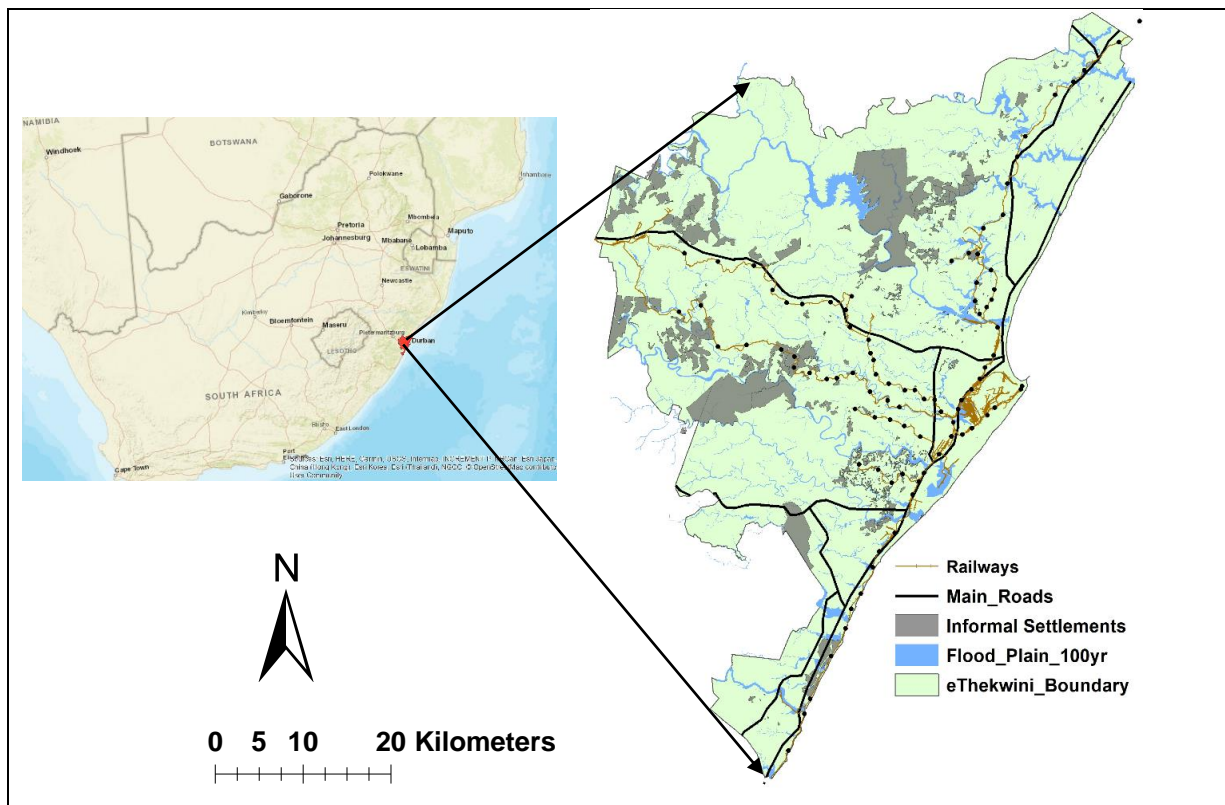
Figure 2. 1: The location of the city of Durban in South Africa. Source: author, 2020.

eThekwini Municipality is divided into the urban and rural areas: the urban area located in the inner part of the city, comprises residential, commercial, and industrial areas; the rural areas located in the periphery of the city, comprises commercial farms, open space, and rural settlements.

Most of the land in the rural area is under the jurisdiction of the Traditional Authorities which is a challenge when it comes to issues of urban planning and management (eThekwini Municipality, 2018).

2.3.   Demographic and Socioeconomic characteristics

According to the eThekwini Municipality (2018), Durban has a total population of approximately 3.8 million people comprising 51% female and 49% male. The city is predominately occupied by the black African people at 74%, followed by the Indian (Asian) people at 17%, the White people at 7%, the coloured people at 3%, and other nationals at 0.4%. The major language that is spoken is IsiZulu (62% of the population), followed by English (26%) (http://www.statssa.gov.za/). The composition of the population gives a reflection of the socio-economic conditions of Durban as the majority of the residents who are unemployed and considered as poor are the Black Africans (Roberts & O'Donoghue, 2013). This is evident from the high poverty level of 42% (Roberts & O'Donoghue, 2013), an unemployment rate of 30% (eThekwini Municipality, 2018; Sutherland et al., 2018). Further, as indicated by eThekwini Municipality, (2018), 8% of the population attained tertiary education, 26% attained secondary education (grade twelve), 29% attained some sort of secondary education, 19% attained primary education and 8% did not attain any formal education. Further, as indicated in figure 2.1, the city has a large number of informal settlements, located on flood plains and hilly areas, and where the majority of the vulnerable community reside (eThekwini Municipality, 2018). These areas are therefore susceptible to flooding and other climate change-related impacts.

2.4.   Climate Change challenges

As indicated by eThekwini Municipality (2018), the location of Durban on the coast makes it vulnerable to the expected rise in sea level due to climate change. Further, it is projected that by 2065, Durban will experiences an increase in the intensity of annual rainfall, and temperatures between 1.5 to 2.5 degrees (Roberts & O'Donoghue, 2013). The expected increase in climate change will result in severe storms, increased flooding, and severe drought. The likely impact on Durban includes damage to infrastructure and high insurance cost due to flooding, an increase in heat stress due to high temperatures, reduced crop yield due to drought, and loss of biodiversity and coastal erosion due to rise in sea level (Roberts & O'Donoghue, 2013; eThekwini Municipality, 2018).

2.5. Experiences of climate change adaptation measures in Durban

Climate change adaptation planning and implementation in Durban started as far back as 2004 (Roberts, 2010). It was mainly driven as a response to the impact of climate change on the vulnerable communities and physical infrastructure (Roberts, 2010; Ziervogel & Parnell, 2014), and also as part of the Durban climate change strategy (eThekwini Municipality, 2014). The success of adaptation in Durban is also linked to co-benefits (e.g. employment creation, business opportunities, skills training) resulting from the implementation of adaptation measures (Roberts, 2010).

The climate-smart community pilot project is one of the climate adaptation measures that focused on community awareness of climate change, community vulnerability assessment, and the improvement of livelihood of the vulnerable groups (Roberts, 2010; Anguelovski et al., 2014)). Another project was the community reforestation project, which was aimed at mitigating the emission of GHGs (during the 2010 FIFA world cup), improving the livelihood of the local community, and protecting the local rivers from invasive species and disposal of solid waste (Roberts, 2010). The project recorded several achievements such as the creation of employment for the local people and reforestation of the landfill. The Green Roof Pilot project is another climate adaptation project implemented in Durban (Roberts, 2010). The main objective of the project was to reduce high temperatures inside buildings and to reduce surface water runoff. The initial results indicate a significant reduction in high temperatures and stormwater runoff. The Water Harvesting Pilot project was implemented to assess the technologies that were available in South Africa (Roberts & O'Donoghue, 2013). The project was implemented at a school in a peri-urban area. The results indicated a reduction in the stormwater runoff and flooding at the school and provided water for crop irrigation and drinking. The Aller River Pilot project was implemented in partnership between the municipality and the eThekwini Conservation forum (Martel & Sutherland, 2019). The objectives of the project were to improve the wellbeing of the poor communities, improve the management of rivers in eThekwini, and to enhance climate change resilience. The initial results of the project indicate an improved relationship with the community and the creation of WhatsApp groups for river monitoring. The Palmiet River Rehabilitation project's main objectives were the rehabilitation of the wetlands and the river banks (Martel & Sutherland, 2019). The key success of the project was that it established a working relationship between the residents of Quarry road west informal settlements, the climate change experts from the local university, and the local Municipality.

The key lesson learned from the review above is that besides the community reforestation project, most of the projects were implemented on a pilot basis and therefore not widely distributed. Further, most of the projects focused on river rehabilitation, stormwater reduction, reforestation, and a few on the improvement of the livelihood of the community. Therefore, none of the projects directly focused on increasing the adaptive capacity or reducing the sensitivity of the local people.

3. LITERATURE REVIEW

3.1. Introduction

This reviews the literature on climate change adaptation, equity, and social vulnerability. The chapter is divided into three sections: the first section deals with the definitions and concept of adaptation to climate change; the second part focuses on social vulnerability to climate change, and the third section deals with equity in climate adaptation.

3.2. Adaptation to Climate Change

Climate Change scientists have acknowledged that mitigation alone cannot reduce the impact of climate change particularly in the Global South, where poverty levels are high. Therefore, IPCC and many scholars have acknowledged the importance of climate adaptations as complimentary to climate mitigations (Mimura et al., 2014; McManus, Shrestha, & Yoo, 2014; Ford et al., 2015). Climate adaptation is defined by (IPCC, 2014, p 5) as "the process of adjustments to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human interventions may facilitate adjustments to expected climate and its effects". This research adapts this definition and defines adaptation as measures undertaken by the local government authority (municipalities) in response to or anticipation of the impact of climate change by reducing community vulnerability and enhancing their adaptive capacity.

According to McManus et al. (2014), climate change adaptations can be divided into two main categories, autonomous and planned adaptations: autonomous adaptations is undertaken by individuals, communities, or the private sector without guidance from government policies or strategies; while planned adaptations are undertaken by the local or national governments based on the climate change policy or strategies. This research focuses on planned adaptation, which is undertaken by local governments in anticipation or response to the impacts of climate change (UN-Habitat, 2011; Hughes, 2013). The role of the local government or municipalities, in this case, is to develop and implement adaptation measures in response, for example, to damage to public infrastructure (roads, drainages, bridges) or water scarcity affecting the livelihood of the local people or urban poverty(Ford et al., 2015; UN-Habitat, 2011). Climate adaptation measures can also generate employment opportunities, improve access to health, and provide social security, which ultimately improves the adaptive capacity of the local people (Ford et al., 2015).

Municipalities also implement adaptation measures in anticipation of the increased incidents of flooding or severe weather conditions (e.g. storms). For example, the construction of dikes to protect the population against the anticipated increase in flooding.

Climate change adaptation measures not only create benefits but can also create maladaptation (Barnett & O'Neill, 2010; Weiland et al., 2015), which is defined by Barnett & O'Neill (2010, p 211) as "action was taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increasing the vulnerability of other systems, sectors or social groups". According to Barnett & O'Neill (2013), climate adaptation measures implemented to reduce exposure to the impact of climate change tend to create a high risk of maladaptation; while those implemented to reduce sensitivity to climate change impacts tend to create a moderate risk of maladaptation; and climate adaptation measures implemented to increase adaptive capacity tend to have a low risk of maladaptation.

3.2.1. Criteria for evaluating the outcomes of climate adaptation measures

Evaluation of climate change adaptation measures can be categorised as process evaluation and outcome evaluation criteria (Weiland et al., 2015; Klostermann et al., 2018). The process evaluation criteria focus on the assessment of the process used to formulate climate change adaptation measures (e.g. institution capacity, community participation, decision making, barriers); while the outcome evaluation criteria focus on whether the outcomes of climate adaptation measures implemented reduce or increase the social vulnerability of the target community (Klostermann et al., 2018). This research focuses on the outcome evaluation criteria explained in the subsequent paragraphs.

There is no standard criterion for evaluating the outcomes of climate adaptation measures. It is based on the context in which adaptation measures have been implemented (Weiland et al., 2015). Two frameworks on outcome evaluation criteria are presented in this section. The first framework indicated in Table 3.1, is based on the study by Sherman & Ford (2014) which was undertaken to evaluate the performance of climate adaptation projects implemented in developing countries. The seven criteria provided in the framework are based on the current criteria used in the evaluation of climate change adaptation measures. The application of evaluation criteria was based on the quantitative data in relation o the performance of the adaptation projects.

Table 3. 1: Project performance criteria

Project performance indicator	Criteria
Effectiveness	Achievement of project outcomes within stated timeframe and scales; clear benefits from the project
Efficiency	Physical, human, and time-resource efficiency; transaction costs
Equity	Project emphasis on ensuring that marginalised populations/individuals are included in the project; project site identification as a vulnerable area
Legitimacy	Local perceived importance of project theme(s); transparency in implementation, community participation/acceptance; communication with stakeholders
Flexibility	Iteration of project implementation, including tailoring project activities and methods to the local context
Sustainability	Likelihood of intervention actions/benefits extending beyond the initial project period; local commitment, capacity, and funding for the project; foreseeable future environmental or social consequences as a result of the intervention
Replicability	Potential to scale up intervention and implement the project in another site; inherent transferability of the project

Source: Adopted from Sherman & Ford (2014)

Another framework for evaluating the outcomes of climate adaptation measures, which is indicated in Table 3.2, was developed by Weiland et al. (2015). The effectiveness, efficiency, and equity criteria are based on the same principle as explained in Table 3.1 above. Side-effects focus on the positive consequences (co-benefits) and negative consequences(which are also known as Maladaptation) of climate adaptation measures. The framework was developed based on scientific literature and project documents on the evaluation of climate adaptation and was further refined based on the feedback from the stakeholders.

Table 3. 2: BASE evaluation criteria for climate adaptation (BECCA)

Category	Subcategory/criteria	Explanation
Effectiveness	General description	The extent to which the intended outcome(s) has (have) been achieved. In terms of preventing climate change damage (e.g. reducing impacts, reducing exposure, enhancing resilience, or enhancing adaptive capacity, reduction in economic losses). A further specification

		might be considered effectiveness also in terms of cost-effectiveness
Efficiency	General description	A measure of how economically funds, expertise, time, etc. are converted into results. The measure should consider if the (economic and non-economic) benefits gained from adaptation measures exceed the (economic and non-economic) costs of its implementation, against the policy objectives used in the analysis. Actions should also be weighted based on the risks involved, their long-term cost-effectiveness, and market compliance.
Equity	General description	Equitable distribution of benefits as widely as possible with attention to most vulnerable groups
	Proportion of beneficiaries	Supporting the broadest possible range and number of beneficiaries (example for measurement: number of beneficiaries of the adaptation measures with respect to the total population from the given location which is or will be experiencing the problem that requires adaptation)
	Attention to the most vulnerable groups	Attention and priority towards supporting most vulnerable groups (example for measurement: attention received by the most vulnerable population group within the target population (e.g. children, elderly, handicapped)
Side effects	General description	Side effects are (usually unintended) positive and negative, outcomes of the adaptation measures for other social, environmental or economic objectives (e.g. to help reduce social inequality, to decrease energy demand, to help to raise the resilience of ecosystem services, etc)
	Negative side effects (or maladaptation)	The negative side effects (also referred to as maladaptation) are indirect, negative outcomes set off by the adaptation measures outside of their target area
	Positive side effects (Co-benefits)	Positive side effects (ancillary effects) are additional beneficial outcomes delivered by the adaptation measures but not aimed at in the first place (e.g. new employment opportunities, innovation knock-on effects, and new market potential, social capital accumulation).
Acceptability	General description	The adaptation measures are culturally, socially, environmentally, and politically acceptable. They are accepted by those affected and by stakeholders
Coherence	General description	The measures are not in conflict with other adaptation efforts and coherent with existing or planned policies on the local, regional, and national levels.

| Robustness | General description | Adaptation measures are considered robust to uncertainties if they can maintain their effectiveness under different climatic and socio-economic development scenarios. |
| | Regret/No-regret strategies | Positive effects are even reached without climate change. No-regret measures are interventions with positive outcomes for development even in situations in which the uncertainty surrounding the future impacts does not allow for better targeting of the policy responses. |

Source: Adapted from Weiland et al. (2015)

3.3. Social vulnerability to climate change

Social vulnerability to climate change comes from the vulnerability concept (Breil et al., 2018) which is defined by IPCC (2014) as "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt". Based on the above definition, this research considers social vulnerability as a combination of exposure, sensitivity, and adaptive capacity to the impact of climate change (Kazmierczak, 2015; Owusu & Nursey-Bray, 2018). Sensitivity refers to the susceptibility of the community (or system) to the impact of climate change. Sensitivity is influenced by demographic factors such as age, gender, race and ethnicity, and health issues (Kazmierczak, 2015). Adaptive capacity is the ability of the community to prepare, respond, and recover from the impact of climate change. Adaptive capacity is determined by socioeconomic factors (Reckien, 2018), and the built environment factors (physical infrastructure) (Holand, Lujala, & Rod, 2011). Exposure is determined by the physical and built environment factors such as housing type, population density, and flood zones, which increase the impact of climate change on the community (IPCC, 2014; Kazmierczak, 2015).

Therefore, communities with low adaptive capacity, high sensitivity, and high exposure are more vulnerable to the impact of climate change. For example, Reckien et al. (2017) indicated that socially vulnerable communities are adversely affected by the impact of climate because they settle in areas that are densely populated, poor physical infrastructure and basic services, and areas located in high-risk zones. Further, it is argued that women, particularly those living in informal settlements, are more vulnerable to climate change impacts because they are more exposed to climate hazards such as heat and floods

3.4.   Equity in climate adaptation

As municipalities implement adaptation measures, there is a need to take into consideration equity issues if the measures are to be successful (Reckien et al., 2017). Equity in climate adaptation can be categorised in terms of procedural equity and distributive equity (McManus et al., 2014; Reckien et al., 2017). According to McManus et al. (2014), procedural equity entails the involvement of the most vulnerable groups or the community (the poor, women, ethnic groups) in the planning and implementation process of climate adaptation measures. This means the involvement of the vulnerable groups in the identification and selection of the intervention measures for climate adaptation. On the other hand, distributive equity means that the outcomes of climate adaptation measures are fairly distributed by ensuring that the benefits reach the most vulnerable groups in the community. This entails implementing climate adaptation measures that target vulnerable communities such as creating employment or business opportunities, reducing exposure to flooding or heatwave, improving access to health facilities, or making land available for housing to the poor that is affordable and free from climate change hazards (Reckien et al., 2017). Ford et al. (2015) give an example of equity in adaptation in Nepal, where the mini hydro-power generation initiative targeted women in terms of participation (procedural equity) and increasing their adaptive capacity (outcome equity). However, the study indicates that generally, adaptation measures implemented in the Global South cannot be considered socially equitable because they do not consider the needs of the most vulnerable groups such as women, the elderly, children, and indigenous communities.

4. RESEARCH METHODOLOGY

4.1.   Introduction

This chapter focuses on the research methodology in terms of the research design, data collection, sampling, data analysis, and limitation of the research.

4.2.   Research design

This research used a case study approach to acquire in-depth information about the study area and climate change adaptation measures that have been implemented in Durban city. The study employed both quantitative and qualitative methods in terms of data collection and analysis. The research design matrix indicated in Table 4.1, shows the three specific objectives of the research and the related research questions. For each research question, the data requirement, data sources, data collection and analysis methods, and expected results are briefly explained.

Table 4. 1: Research design matrix

Research Questions	Data requirement	Data sources	Data collection method	Data analysis method	Expected results
Specific Objectives 1: To assess the spatial distribution of social vulnerability to climate change in Durban city					
Which factors contribute to the current social vulnerability in Durban city?	Factors that influence social vulnerability	Scientific (journals) publications on social vulnerability	Online library search and literature review	Content analysis	List of confirmed factors that influence social vulnerability
What is the current spatial distribution of social vulnerability in Durban city?	Socio-economic & demographic factors (census statistics)

Spatial data (physical infrastructure & physical environment factors) | Department of statistics, South Africa (Stats South Africa, 2011) website

eThekwini (Durban city) Municipality website | A search of the websites | Social vulnerability analysis using ArcMap software | GIS map showing the spatial distribution of social vulnerability in Durban city |

Specific objective 2: To map the spatial distribution of climate change adaptation measures implemented in Durban city					
Where are the climate change adaptation measures implemented in relation to the spatial distribution of vulnerable and marginalized groups	Names of settlements where climate adaptation measures have been implemented Shapefiles showing the location of adaptation measures	eThekwini Municipality planning or non-governmental organisations (NGOs) Municipality officials and other key informants	Interviews with Municipality officials and other key informants	Spatial data analysis using ArcMap software Qualitative analysis using Atlas.ti 8.4 software	GIS map showing the spatial distribution of climate adaptation measures
What is the proportion of the target population of climate adaptation measures are vulnerable and marginalised	Number of beneficiaries (direct & indirect) of the adaptation measures Population for the wards and settlements (target areas)	Municipality and NGO officials Stats South Africa & eThekwini municipality websites	Interviews with Municipality and NGO officials A search of the websites	ArcMap software Quantitative data analysis using Microsoft excel	Percentage of vulnerable & marginalised groups who are target beneficiaries of adaptation measures
Specific objectives 3: To assess the consequences of climate adaptation measures to the vulnerable and marginalised groups in Durban city					
What are the achievements and non-achievements of the objectives of climate adaptation measures	Views of key informants and climate change experts on achievements and non-achievements of climate adaptation measures	Municipality officials, non-governmental organisations (NGOs) officials and Climate change experts from UKZN	Interviews with Municipality officials, NGO officials, climate change experts from UKZN	Qualitative data analysis using Atlas.ti 8.4 software Quantitative analysis using Microsoft excel	Matrix table showing achievements & non-achievement of adaptation measures Bar graphs showing the outcome vulnerability
What are the reasons for the non-	Views of key informants climate change	Municipality officials, non-governmental	Interviews with municipality	Qualitative data analysis	Matrix table showing the reasons for

achievements of some of the objectives of the climate change adaptation measures	experts on reasons for non-achievements of objectives	organisations (NGOs) and climate change experts from UKZN	officials, NGO officials, climate change experts from UKZN	using Atlas.ti 8.4 software	non-achievements of the objectives
What are the positive consequences(co-benefits) and negative consequences (maladaptation) of the climate adaptation measures to the most vulnerable community	Views of key informants and local community regarding the co-benefits and the risk of maladaptation of climate adaptation measures	Municipality officials, non-governmental organisations (NGOs) Local community (vulnerable & marginalised groups)	Interviews with municipality officials, NGOs, climate change experts from UKZN FGD with community representatives (CBOs)	Qualitative data analysis using Atlas.ti 8.4 software Qualitative data analysis based on pathways Maladaptation framework	Matrix table showing the co-benefits of climate adaptation measures Bar graphs showing the outcome vulnerability Matric table based on pathways Maladaptation framework

4.3. Selection of the study area

Durban city was selected as a study area for this research because it is one of the cities in the Global South that has developed and implemented climate adaptation measures. The city also has high poverty levels and its location makes it more susceptible to climate change-related impacts such as severe storms, flooding, and a rise in sea level.

4.4. Primary Data

This section describes the sampling techniques and the data collection methods that were used for primary data. As indicated in Table 4.1, primary data was used to assess the achievements and non-achievements of the objectives, the co-benefits, and maladaptation (negative consequences) of climate adaptation measures implemented in Durban city.

4.4.1. Sampling

Purposive and snowball sampling (non-probability sampling) methods were used for the selection of key informants and community members as explained in the following subsections

4.4.2. Purposive sampling

Purposive sampling (Alan, 2016) was used because the research targeted specific departments at the eThekwini Municipality (Environmental Planning and Climate Protection Department; Coastal, Stormwater, and Catchment Management Department; and Human Settlements Unit) which were directly involved in the implementation of climate change adaptation measures. The names of the departments and the physical address were identified through the contact person from eThekwini Municipality. Google maps were used to find the physical location of the offices. Purposive sampling was also used to select NGOs involved in climate adaptation projects or programmes. These are Kloof Conservancy, Green Corridors Green Spaces, and South Durban Community Environmental Alliance (SDCEA), and Community Organisation Resource Centre (CORC) of Slum Dwellers International (SDI). The offices were located using Google maps.

The selection of NGOs was based on the suggestions from the contact person and interviewees. The Kloof Conservancy was suggested by the interviewee from the University of KwaZulu Natal (UKZN), the SDCEA was suggested by the second interviewee (contact person) from UKZN, Green Corridors Green Space was suggested by the interviewee from the Aller river project, and CORC/SDI was selected based on previous engagement with the author. The Kloof Conservancy and the Green Corridors Green Space were selected as they were involved in the implementation of adaptation measures in partnership with the Municipality. The SDCEA was more involved in advocacy and monitoring work related to climate change in Durban. The major limitation in the selection of the NGOs was the issue of bias, particularly for CORC/SDI and SDCEA, as it was based on previous engagement with the author and contact person respectively. However, all of them were confirmed by the contact person from the Municipality as actively involved in issues of climate change and with communities in Durban.

4.4.3. Snowball sampling

Snowball sampling method (Hughes, 2013; Anguelovski et al., 2016; Alan, 2016) was used to select key informants and the community members from the study area. This method was used due to the lack of a complete list of key informants. The advantage of this method was that the interviewees were able to suggest key people who were actively involved in climate adaptation

initiatives in Durban. Therefore, the quality of the data that was collected was good and more reliable. Before the fieldwork, an initial list of 8 key informants from the eThekwini Municipality, UKZN and NGOs, was compiled with the help of the contact persons from the eThekwini Municipality and the UKZN. The key informants who were listed for the interview were those involved in the implementation or monitoring of climate adaptation measures implemented by the eThekwini Municipality or in partnership with the NGOs. All the eight key informants were contacted for the interviews, three of them agreed. appointments were made, and were later interviewed. Further, eight key informants and six community members (FGD) were interviewed based on the suggestions of other interviewees. Therefore, a total of 18 key informants were contacted for possible interviews, and six participants for FGD. Out of the 18 who were contacted, a total of ten (eight face to face and two skype) were interviewed as indicated in Table 4.2. Three interviews were conducted with eThekwini municipality officials: two interviews were conducted with officials from the Department of Environmental Planning and Climate Protection, and one from the Human Settlement Unit. Three other officials who were contacted for interviews declined because of busy schedules. Two academic staff from the University of KwaZulu Natal involved in climate change issues in Durban City were also interviewed. Five representatives of local NGOs were interviewed: Two from Kloof Conservancy, one from Green Corridors Open Spaces, and two from SDCEA, and two other representatives of NGOs declined to be interviewed. One self-administered questionnaire was done with the Municipality official from the Department of Coastal, Stormwater and Catchment Management (the official was not available during the time of the fieldwork), and a focus group discussion (FGD) was done with 6 community members from Clermont residential areas. Six participants were selected because it was a manageable number in terms of facilitation and time, and it allowed time to get many views from the participants (Alan,2016). Five FGDs were planned for the five projects which were selected, however, this could not be done due to limitations such as language barrier, challenges to mobilise the community as the contact person was a busy, and inadequate time during the fieldwork..

Table 4. 2: List of key informants and community members interviewed during the research

No.	Date of the interview	Position of the interviewee	Department & organisation
Face to face interviews			
1.	13/01/2020	Manager of the Durban Research Action Partnership (DRAP)	Environmental Planning and Climate Protection Department, eThekwini Municipality

2.	14/01/2020	Project officer, climate change infrastructure and development	South Durban Community Environment Alliance (SDCEA)
3.	14/01/2020	Air Quality/GIS & Youth Development Officer	South Durban Community Environment Alliance (SDCEA)
4.	21/01/2020	Project Manager	Kloof Conservancy (Aller River Pilot Project)
5.	21/01/2020	Community Liaison Officer	Kloof Conservancy (Aller River Pilot Project)
6.	23/01/2020	Climate Change Expert	Built Environment and Development Studies, UKZN
7.	24/01/2020	Area Coordinator, iQhaza Lethu Programme	Human Settlement Unit - Planning and Research, eThekwini Municipality
8.	24/01/2020	Project Coordinator	Green Corridors Green Spaces Projects
	Skype Interviews		
9.	4/02/2020	Postdoctoral Researcher	Durban Research Action Partnership (DRAP), UKZN
10.	17/02/2020	Senior Manager, Restoration Ecology Branch	Environmental Planning and Climate Protection Department
	Self-administered Questionnaire		
11.	10/03/2020	Senior Manager, Catchment Management	Coastal, Stormwater and Catchment Management Department, eThekwini Municipality
	Focus Group Discussion		
12.	21/01/2020	Six Ecological Champions (Eco-Chaps)	Aller River Pilot project, community beneficiaries

Source: author (2020)

4.4.4. Interviews

Face to face interviews were held with officials from the Municipality, NGOs, and Climate Change Experts from UKZN, during the fieldwork from 13th to 24th January 2020. Two skype interviews were conducted after the field trip with Municipality official and a Climate Change Expert from

UKZN. Face to face and skype interviews were conducted using an interview guide. An interview guide was used to allow interviewees to express themselves and therefore get more views for a particular question. Skype interviews were used because some key informants from the Municipality and UKZN were not available during the period of the fieldwork. A day before the interview, the interview guides, the introductory letters (appendix 4.1), and the informed consent forms (appendix 4.2.) were sent through email to the key informants. Before the commencement of the interview, interviewees were requested to read through and sign the informed consent forms, and requests were made for permission to record the interviews, which were granted. The interviews took approximately 45 minutes and were digitally captured using a voice recorder

Two separate interview guides were used: one for the Municipality officials (appendix 4.3), and another for the NGO officials and Climate Change Experts (appendix 4.4). The interview guides had a similar outline, the major difference was the phrasing of the questions. The interview guides contained three sections: Introduction, personal information, and climate adaptation measures. The introduction section contained brief information about the interviewer and the purpose of the research. The personal information section contained general questions about the interviewees and their role in climate adaptation issues. The main purpose of this section was to get the interviewees relaxed and more engaged in the interview. The section on climate adaptation measures contained questions on the type of adaptation measures implemented in Durban city, the target areas where the adaptation measures were implemented, the achievements of the objectives and reasons for non-achievement, co-benefits and negative consequences. The main objectives of the questions under this section were to get the views of the interviewees regarding the effectiveness (achievements & non-achievements of the objectives) of climate adaptation measures; whether the adaptation measures considered the vulnerable community (equity issues); and to establish the co-benefits and negative side effects of the adaptation measures to the vulnerable community.

4.4.5. Focus group discussion

A focus group discussion (FGD) was conducted with members of the community who were beneficiaries of the Aller River project on 21st January 2020. The FGD was done as a form of triangulation of the information (views) collected from interviewing key informants. The participants were suggested by the interviewee from the Aller River project. The group was working for the Aller river project as ecological champions (Eco-Champs). It comprised of six youths: four females and two males. The discussion was conducted using an FGD guide and

digitally captured using a voice recorder. Before the start of the discussion, the informed consent form was explained to the participants and then signed. The permission was also sought from participants to record the interview. The FGD guide contained five sections as follows: introduction, general/introductory questions, achievements of adaptation measures, co-benefits, and negative consequences. The introduction section had the same information as the interview guide for key informants. The general questions section contained general information on the effects of climate change. The idea was to test the knowledge of the participants in climate change issues and to get them involved in the discussion. The achievement of the adaptation measures section contained questions on the adaptation measures implemented by the Municipality in their communities. The purpose of the questions was to get community perception regarding the effectiveness of the adaptation measures. The co-benefits section involved questions on how the participants and members of their household benefited from the adaptation measures. The objective of the questions was to establish whether the adaptation measures benefited vulnerable communities or not. The section on negative consequences had questions related to the maladaptation outcomes of adaptation measures on the local community. The detailed FGD guide is found in appendix 4.5.

4.4.6.   Self-administered questionnaire

As indicated in Table 4.2, a self- administered questionnaire was sent to the Municipality official from the Department of Coastal, Stormwater, and Catchment Management on 10th March 2020. The interviewee also signed the consent form and returned it together with the questionnaire. The self-administered questionnaire was used because the interviewee was not available during the period of the fieldwork. The questionnaire used the same outline and content as the interview guide. Some questions were open-ended and others were closed questions (see appendix 4.6).

4.5.   Secondary data

Secondary data was used for the assessment of the spatial distribution of social vulnerability in Durban city. Data collection involved reviews of scientific literature (journals) to select factors that influence social vulnerability in Durban city. As indicated in Table 4.3 (see appendix 4.7 for detailed description and justification), twenty factors were selected with regards to adaptive capacity, sensitivity, and exposure to climate change. The demographic and socio-economic factors were selected based on the study on social vulnerability in cities in South Africa by Apotsos (2019). The selected factors were compared to similar studies done in Finland by Kazmierczak (2015) and the USA by Cutter, Boruff, & Shirley, (2003) and Reckien (2018). The built environmental factors

were selected based on the study done in Norway by Holand et al. (2011) and as suggested by Shirley, Cutter, & Boruff (2003). The physical environmental factor (flood plain) was selected based on the social vulnerability study done in Finland by Kazmierczak (2015).

Table 4. 3: List of selected factors that influence social vulnerability in Durban city

Dimension	Indicators	Description	Contribution to social vulnerability
Sensitivity			
Demographic factors	Children under 5 years old	Percentage of children under the age of five years	Positive (+)
	65 years old and above	Percentage of residents who are 65 years and above.	Positive (+)
	Female-headed households	Percentage of households where the head of the household is female.	Positive (+)
	Black population	Percentage of black people	Positive (+)
	Non-Citizens	Percentage of residents who are not citizens of South Africa	Positive (+)
Adaptive capacity			
Socio-economic factors	IsiZulu language	Percentage of residents who speak IsiZulu	Positive (+)
	IsiXhosa language	Percentage of the residents who speak IsiXhosa language.	Positive (+)
	Other African languages	Percentage of residents who speak other African languages.	Positive (+)
	Sign language	Percentage of residents who use sign language due to difficulties in talking.	Positive (+)
	Low income	Percentage of persons between the ages of 25 and 65 years old earning less than eight hundred Rands (R800) per month.	Positive (+)
	Unemployment	Percentage of persons aged between 25 and 65 years who are not employed	Positive (+)
	Low education	Percentage of residents who are 20 years old and above who have not completed primary education	Positive (+)
	Informal employment	Percentage of people employed in low-skilled jobs(e.g. Informal business)	Positive (+)

Built environment factors	Proximity to clinics	Measures the nearest distance to the clinics	Negative (-)
	Proximity to health posts	A measure of the nearest distance to the health posts.	Negative (-)
	Proximity to rail stations	A measure of the nearest distance to the rail station.	Negative (-)
	Proximity to public transport routes	A measure of the nearest distance to the public transport routes	Negative (-)
Exposure			
Built environment factors	Population density	The ratio of population to the total area (square km) of the spatial unit (ward).	Positive (+)
	Informal dwelling	Percentage of housing that is informal	Positive (+)
Physical environment factor	Proximity to flood hazards	A measure of the nearest distance to the flood zone.	Positive (+)

Source: Shirley; Holand et al. (2011); Kazmierczak (2015); (Reckien, (2018); Apotsos (2019);

As indicated in Table 4.4, data for socioeconomic and demographic factors (based on 2011 census) were downloaded from the statistics South African website (http://www.statssa.gov.za/) and WaziMap websites (https://wazimap.co.za/profiles/province-KZN-kwazulu-natal/). Spatial data in the form of physical infrastructure (ward boundaries, public bus stops, roads, railway stations, clinics) and physical environment factors (flood zones) were downloaded from the eThekwini municipality website http://gis.durban.gov.za/datadownloads/showdocs.asp.

Secondary data was also used in the analysis of the spatial distribution of adaptation measures in Durban city, and to determine the proportion of vulnerable and marginalised communities who were beneficiaries of adaptation projects. Data in the form of shapefiles for the location of climate adaptation measures (projects) was collected from eThekwini Municipality officials; while data on the population of the target settlements (Planning Units) was downloaded from eThekwini websites.

Table 4. 4: Summary of secondary data collected during the research

Type of data	Scale	Sources of data	Data format
Scientific papers		web of science, science direct/Elsevier, SpringerLink	PDF documents

		Journals, Scopus, and other online sources	
Climate change adaptation documents		eThekwini Municipality - Environmental Planning & Climate Protection Department; UKZN - built environment; & Aller River Project – Kloof Conservancy	PDF documents
Socioeconomic statistics	Ward level	2011 census data (Stats South Africa website or WaziMap websites)	Excel file
Population density, housing type	Ward level	2011 census data (Stats South Africa website or WaziMap websites)	Excel file
Fixed Clinics, health posts	Ward level	eThekwini Municipality website	Shapefile
Railway stations, Public transport routes, roads, ward boundaries	Ward level	eThekwini Municipality website	Shapefile
Flood plaine_100yr, rivers	Ward level	eThekwini Municipality website	Shapefile
Location of Sihlanzimvelo projects	Settlement level	eThekwini Municipality - Coastal, Stormwater, and Catchment Management Department.	Shapefile
Planning Units	Settlement level	eThekwini Municipality website	Shapefile

4.6. Data preparation

Primary data in the form of digitally recorded interviews (face to face and skype) were transcribed into text (word documents) using Amberscript translation software. The transcribed data were also checked manually to edit the documents (checking spellings and sentences that were not clear). Editing of some documents took more than 1 hour due to incomplete sentences or words wrongly transcribed. Data from focus group discussion (FGD) was transcribed manually because the discussion was recorded in an open office, therefore it contained background noise. Data from a self-administered questionnaire was not transcribed as it was already in text form. Secondary data in the form of census statistics, downloaded in CSV format (excel documents) were cleaned up to remove some variables that were not needed for the analysis. The documents were then converted

to dbf format for use in ArcGIS analysis. The scientific papers and other documents (PDF) were saved into the Mendeley watch folder for content analysis using Mendeley desktop software.

4.7. Data analysis

Data were analysed with respect to the outcome evaluation criteria indicated in Table 4.5. Quantitative data analysis was based on the equity criteria in terms of the spatial distribution of climate adaptation measures; and qualitative data analysis was based on the effectiveness, co-benefits, and maladaptation criteria in relation to the climate adaptation measures.

Table 4. 5: Outcome evaluation criteria for the assessment of climate adaptation measures

Project outcome indicators	Description and justification
Effectiveness	Measures the achievements of the objectives of the climate adaptation measures (projects) in terms of reducing exposure, sensitivity, and increasing adaptive capacity to climate change. This criterion was used to establish whether the climate adaptation measures achieved (or did not achieve) the objectives and whether the measures contributed to the reduction of social vulnerability.
Equity	Measures whether climate adaptation measures consider the vulnerable and marginalised groups or target areas considered vulnerable to climate change impacts. This criterion was used in this research to establish whether the climate adaptation measures implemented in Durban city targeted vulnerable and marginalised groups; and the proportion of vulnerable and marginalised groups who were target beneficiaries of climate adaptation measures.
Positive consequences (Co-benefits)	Measures the unintended socio-economic benefits of the climate adaptation measures to the vulnerable and marginalised groups. groups. This criterion was used in this research to establish whether the climate adaptation measures created socioeconomic benefits to the vulnerable and marginalised groups.
Negative consequences (Maladaptation)	Measures the unintended negative adverse effects of climate adaptation measures to the vulnerable and marginalised groups. The assessment of negative consequences was based on the maladaptation outcomes criteria. This criterion was used to assess whether the adaptation measures disproportionately affected the lives of the vulnerable and marginalised groups. The assessment was also done using the risk of maladaptation framework, which analysis maladaptation using the tree dimension of social vulnerability (increasing adaptive capacity, reducing sensitivity, and reducing exposure).

Source: adapted from Barnett & O'Neill (2010); Barnett & O'Neill (2013); Sherman & Ford (2014); Weiland et al. (2015)

4.8.   Quantitative data analysis

Data analysis focused on the spatial distribution of social vulnerability to identify communities that were vulnerable and marginalised; the spatial distribution of adaptation measures was done to identify the target areas, and the beneficiaries of adaptation measures were done to determine the proportion of the vulnerable community who were beneficiaries.

4.8.1.   Social vulnerability analysis

The social vulnerability was analysed using the social vulnerability index (SoVI). The "additive normalization approach without weighting" (Reckien, 2018, p. 1442). This approach was used because it is applicable at any scale (ward or neighbourhood) (Dumenu & Obeng, 2016), it is easy to explain to the community the influence of indicators to social vulnerability, and it uses verified indicators contributing to social vulnerability for the specific study area (Reckien, 2018). Other methods that can be used to calculate SoVI are principal component analysis (PCA) or reduction approach (Holand et al., 2011; Reckien, 2018; Apotsos, 2019), the hierarchical approach, and the fuzz normalisation approach (Reckien, 2018).

As indicated in figure 4.1, the indicators for exposure (flood plain, informal housing, population density), sensitivity (age, gender, race), and adaptive capacity (low income, unemployment, low education, public infrastructure) were normalised (min-max) by converting to the scale of 0 to 1 (Kazmierczak, 2015; Reckien, 2018) using equation [1] (Kazmierczak, 2015; Dumenu & Obeng, 2016). The output indicator scores for adaptive capacity, sensitivity, and exposures indices were added together to form a SoVI (Kazmierczak, 2015; Reckien, 2018).

Indicator score = [value-minimum value]/[maximum value -minimum value]   [1]

After calculating the SoVI, bivariate correlation analysis was used to check the demographic and socio-economic indicators that were negatively or not significantly contributing to SoVI at 0.01 level of significance. Factors such as non-citizens, informal employment, IsiXhosa language were identified and removed. The final SoVI was thereafter calculate using the same method as above.
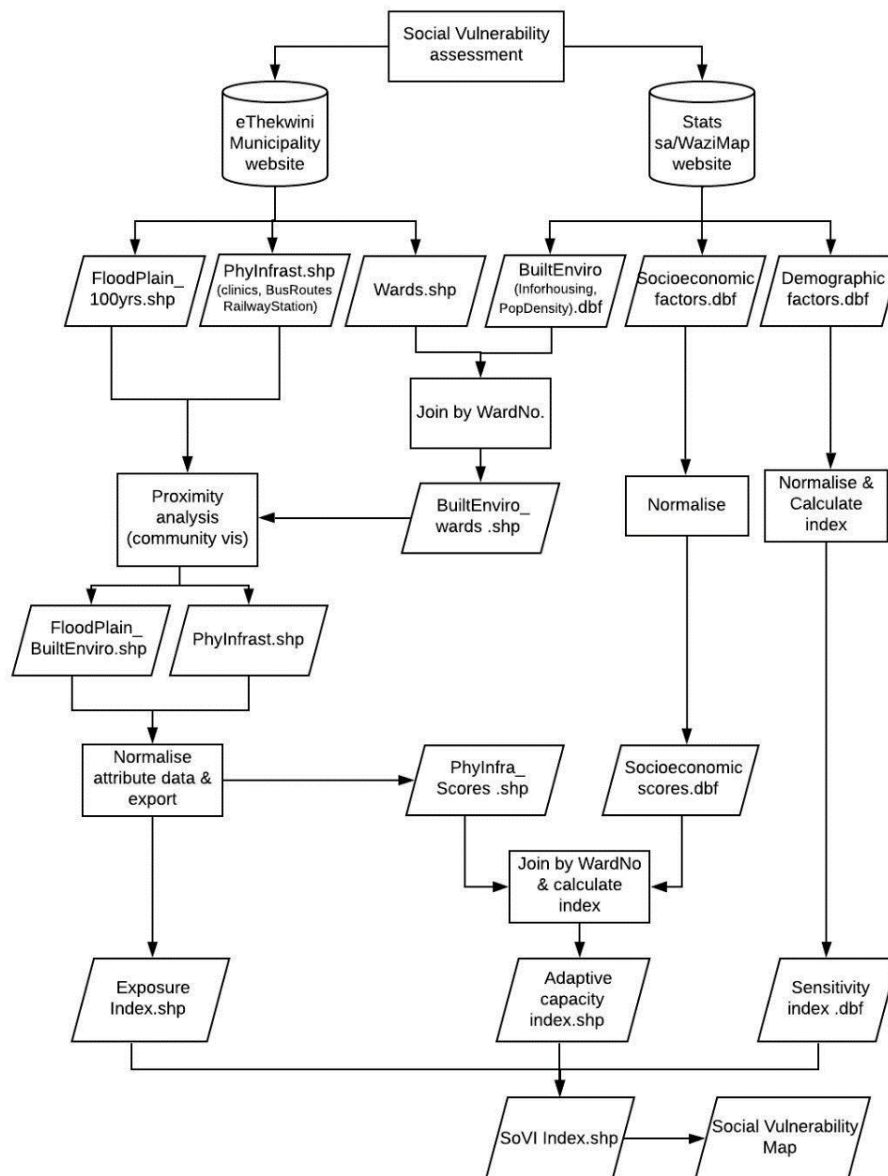
Figure 4. 1: Flow chart showing the step by step analysis of social vulnerability

4.8.2. Analysis of the spatial distribution of adaptation measures

The target areas (settlements) for climate adaptation measures implemented in Durban city were identified during the interviews as well as collected as shapefiles (e.g. Sihlanzimvelo project). The analysis was done as follows: First, the target settlements were selected from the planning unit attribute table using the ArcMap tool – "Selection, select by attribute". After selection by attribute, a new layer was created from the selected settlements using the ArcMap tool –"Selection, create layer from selected feature". An overlay was done on the social vulnerability map to visualise the target areas.

4.8.3. Analysis of the beneficiaries of climate adaptation measures

The calculation of the beneficiaries of climate adaptation measures was based on the actual (direct) and targeted (indirect) beneficiaries. The direct beneficiaries were calculated based on the number of job opportunities created by climate adaptation measures. Descriptive statistics analysis (using excel) was used to quantify the percentage of the beneficiaries and create a bar graph.

The target beneficiaries, in this case, is the proportion of the target population who are vulnerable to climate change impacts. The target population is the population of the settlements where climate adaptation measures were implemented. The target population of the settlements was not available, and therefore, it was calculated based on the population density of the wards (from 2011 census) and the shape area of the target settlements using ArcMap software. This was based on the assumption that the population density for all the settlements located within a specific ward is the same. The population of the vulnerable community was, therefore, calculated from the population of the settlements located in the wards with high social vulnerability.

As indicated in figure 4.2, the Planning Unit layer (wards shapefile) was divided into 0.25 square km polygons using a 500m*500m grid net from ArcMap. This was done to help determine the area of the settlements that were located in vulnerable wards. Second, the target settlements were created from the planning unit shapefile and intersected with the wards layer (shapefile) to calculate the population of the target areas using population density from the wards. An overlay of the target settlements on the social vulnerability map was done, to identify the target populations (polygons) that were vulnerable. The population of the vulnerable community was therefore calculated from the polygons (target settlements) located in areas (wards) with medium to very high social vulnerability. Microsoft Excel was used to calculate and visualise (using bar graphs) the percentage of the vulnerable community from the total population of the target settlement.

Figure 4. 2: Calculating the percentage of vulnerable communities from the target population.

4.9. Qualitative data analysis

The analysis of the qualitative data focused on the three aspects of the outcome evaluation criteria. These are the effectiveness (i.e. achievements and non-achievements of the objectives), co-benefits, and maladaptation (negative consequences for vulnerable groups) of climate adaptation measures.

4.9.1. Analysis of the Achievements (and non-achievements) of the objectives

Transcribed interview data in the form of Microsoft documents were analysed using open- coding (Alan, 2016) in Atlas. ti 8.4 software. Codes (phrase) and quotations (sentences) were created to indicate the achievements and the reasons for non-achievements of the objectives of adaptation

measures. Similar codes were grouped under reducing exposure, reducing sensitivity, or increasing adaptive capacity, to indicate the outcomes of climate adaptation measures. The final output results is a matrix table showing the outcome vulnerability (reducing exposure, reducing sensitivity, increasing adaptive capacity) for five climate adaptation measures under consideration Further analysis was done by assigning weights to the codes or quotations in the form of the number of responses. This was done to visualise, through bar graphs, the major factors identified as contributing to the reduction of social vulnerability.

4.9.2.   Analysis of the co-benefits

Similarly, transcribed data were analysed using Atlas. ti 8.4 to identify words (phrase) or sentences indicating the socioeconomic benefits of the adaptation measures to the vulnerable community. The codes and quotations created to represented co-benefits of the adaptation measures were grouped in terms of reducing exposure, reducing sensitivity, or increasing adaptive capacity. The output result is a matric table showing the outcome for each adaptation measures. Further, codes and quotations were given weights in terms of the number of responses. Descriptive analysis using Microsoft excel was done to create graphs showing benefits created by the adaptation measures that help to reduce social vulnerability.

4.9.3.   Analysis of maladaptation

The assessment of the risk of maladaptation of the climate adaptation measures was based on the framework by Barnett & O'Neill (2013) indicated in Table 4.6. The framework is based on the assumption that climate adaptation measures that increase the adaptive capacity of the community carry a low risk of maladaptation, while climate adaptation measures that reduce sensitivity carry a medium risk of maladaptation, and climate adaptation measures that reduce exposure carry a high risk of maladaptation.

Table 4. 6: Framework for the analysis of the risk of maladaptation in climate adaptation

Adaptation strategies	Increasing adaptive capacity	Reducing sensitivity	Reducing exposure
Policies and programmes	Adaptations that can help to increase the adaptive capacity of a system, sector or group	Adaptations that can help reduce the susceptibility of a sector, system or social group to damage	Adaptations that can help to reduce the exposure of a sector, system or group to the impact of climate change
Risk of Maladaptation	Low risk of maladaptation	Modest risk of maladaptation	High risk of maladaptation

Reasons for the risk of maladaptation	• Not emission-intensive of greenhouse gases (GHGs) • Not equitable If targeted at all groups & places • Do not impose high opportunity costs • They do not discourage adaptation by creating dependency • They are all inexpensive relative to hard actions	• Cause temporary increases in the emission of greenhouse gases • Fairly expensive-relocation of settlements or building seawalls • Seawalls create more hazards may encourage more development in flood-prone areas	• Large emission of GHGs • High opportunity cost (economic and environmental cost) • Likely inequalities due to displacement of people • Create dependence & limit future pathways as they could undermine sustainable use of the island

Source: adapted from Barnett & O'Neill (2013)

Further, maladaptation in climate adaptation measures was assessed based on the maladaptation outcome criteria by Barnett & O'Neill (2010) as indicated in Table 4.7. The assessment was done using criterion 2 (highlighted in colour grey) based on the views of the interviewee regarding the negative consequences (maladaptation) of climate adaptation measures on the vulnerable groups.

Table 4. 7: The criteria for assessing maladaptation outcomes in climate adaptation measures

maladaptation outcome	Explanation
Increasing emissions of greenhouse gases	If adaptation actions lead to increased emissions, they may be maladaptive
Disproportionately burdening the most vulnerable	If in meeting the needs of one sector, system or group, adaptation actions increase the vulnerability of those most at risk, they may be maladaptive
High opportunity coast	If economic, social or environmental costs are high relative to alternatives, the adaptation action may be maladaptive
Reduce incentives to adapt	If adaptation actions encourage unnecessary dependence on others, stimulate rent-seeking behaviour penalise early actors, they may be maladaptive
Path dependency	If adaptation actions commit institutions and significant capital to trajectories that are difficult to change in the future, they may be maladaptive

Source: adopted from Barnett & O'Neill (2010).

4.9.4. Limitations

During the fieldwork, It was difficult to access some officials from the municipality due to busy schedules as most of them had just returned from the Christmas holiday. As an alternative, two

skype interviews and one self-administered questionnaire were conducted to collect data from three key informants who were not available during the fieldwork.

At least three focus group discussions (FDGs) were planned but only one was done. The major challenge was the lack of contact persons to organize community meetings. An arrangement was made to engage a research assistant to conduct two more focus group discussions. However, this did not take place due to the outbreak of coronavirus and the lockdown in South Africa.

The use of the wards as a unit of analysis has some limitations because socially vulnerable areas (informal settlements) located in the wards with high adaptive capacity (e.g. Quarry road west informal settlement in ward 23) were hidden on the map. The socioeconomic and demographic data used for social vulnerability analysis is based on the 2011 census, therefore it may not give a true representation of the actual situation on the ground.

5. RESULTS

5.1. Introduction

This chapter presents the results of the research undertaken in Durban city to evaluate the outcomes of climate change adaptation measures. The chapter is divided into three main sections based on the objectives of the study. In the first section results arising from the assessment of the spatial distribution of social vulnerability to climate change for Durban city are presented. In the second section, the results of the analysis of the spatial distribution of climate change adaptation measures are presented. In the third section, the results arising from the assessment of the consequences of climate change adaptation measures to the vulnerable communities are presented.

5.2. Spatial Distribution of Social Vulnerability to Climate Change in Durban

The assessment of the spatial distribution of social vulnerability to climate change was done to identify areas where the most vulnerable communities are located. The first part of the assessment involved identifying factors that contribute to social vulnerability, and the second part involved social vulnerability assessment based on the identified indicators.

5.2.1. Factors that contribute to current social vulnerability in Durban city

Table 5.1 shows the list of factors that were used in the social vulnerability analysis. Initially, twenty factors were identified through the review of scientific literature. After bivariate correlation analysis, three socio-economic factors (non-citizen, informal employment, and IsiXhosa) that did not contribute to SoVI were removed, retaining seventeen. The factors that increase social vulnerability are indicated as "positive (+)" and the factors that reduce social vulnerability are indicated as "negative (-)"

Table 5. 1: List of factors contributing to the current social vulnerability in Durban city

Dimension	Indicators	Contribution to social vulnerability
Sensitivity		
Demographic factors	Children under 5 years old	Positive (+)
	65 years old and above	Positive (+)
	Female-headed households	Positive (+)

	Black population	Positive (+)
Adaptive capacity		
Socio-economic factors	IsiZulu language	Positive (+)
	Other African languages	Positive (+)
	Sign language	Positive (+)
	Low income	Positive (+)
	Unemployment	Positive (+)
	Low education	Positive (+)
Built environment factors	Proximity to clinics	Negative (-)
	Proximity to health posts	Negative (-)
	Proximity to rail stations	Negative (-)
	Proximity to public transport routes	Negative (-)
Exposure		
Built environment factors	Population density	Positive (+)
	Informal of dwelling	Positive (+)
Physical environment factor	Proximity to flood hazards	Positive (+)

Source: Shirley; Holand et al. (2011); Kazmierczak (2015); Reckien (2018); Apotsos (2019);

5.2.2. Current spatial distribution of Social vulnerability in Durban city

The assessment for the current spatial distribution of social vulnerability considered three dimensions of vulnerability: exposure, sensitivity, and adaptive capacity (Kazmierczak, 2015). The results are presented in the subsequent paragraphs.

Exposure to climate change impact

The results of the assessment of the exposure presented in figure 5.1 show high to very high levels of exposure to climate change impacts for wards located near the central business district. These wards are mainly characterised by high population density, poor housing structures (informal housing), and are located near the flood plain (or rivers). Therefore, communities living in these wards are more vulnerable to climate change-related impacts such as flooding or high temperature.
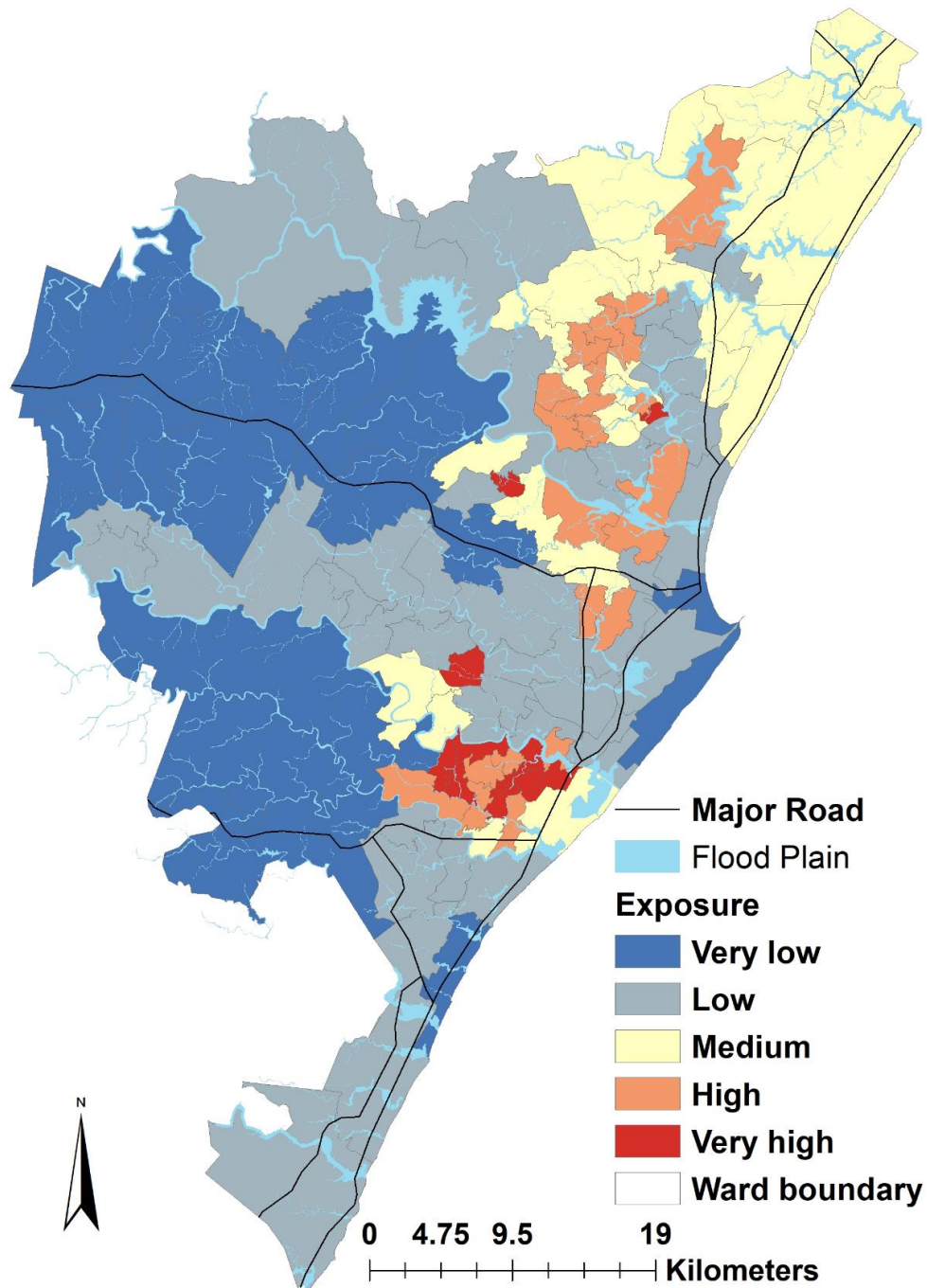
Figure 5. 1: Exposure to climate change impact for different wards in Durban city

Sensitivity to the impact of climate change

The results of the assessment for sensitivity presented in figure 5.2 show that most of the wards with very high to high levels of sensitivity are those located on the outskirts (rural areas) of the city. A few are located near the CBD towards the southern and northern parts of the city. These wards have a concentration of the most vulnerable groups such as female-headed households, children, old people, and black communities. In general, the results indicate that communities

living in these wards are more susceptible to the effects of climate change (e.g. heatwave, flooding, waterborne diseases)
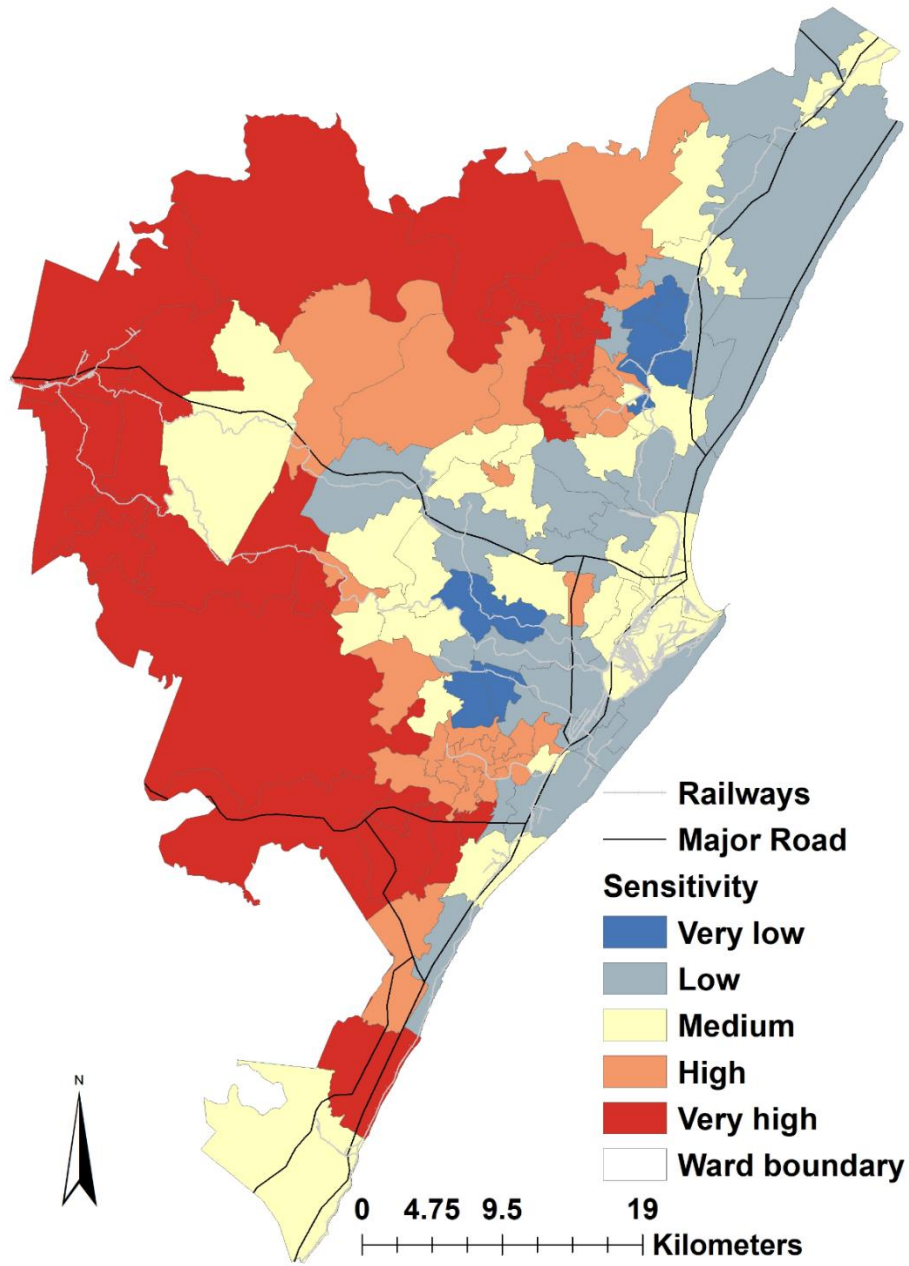
Figure 5. 2: Sensitivity to climate change impact for different wards in Durban city

Adaptive capacity to the impact of climate change

The assessment of adaptative capacity was done to identify communities with low adaptive capacity to the impacts of climate change. The results presented in figure 5.3 show that wards with low to very low-level of adaptive capacity are those located on the outskirts of the city (rural areas) as well as those located towards the southern, northern, western, and southern parts of the city. Further, a few wards located near the central part of the city show low adaptive capacity. Generally,

the results indicate that communities living in these wards have less capacity to respond, prepare, or recover from the impact of climate change due to inadequate income, low education and less access to social facilities (e.g. hospitals, public roads facilities)
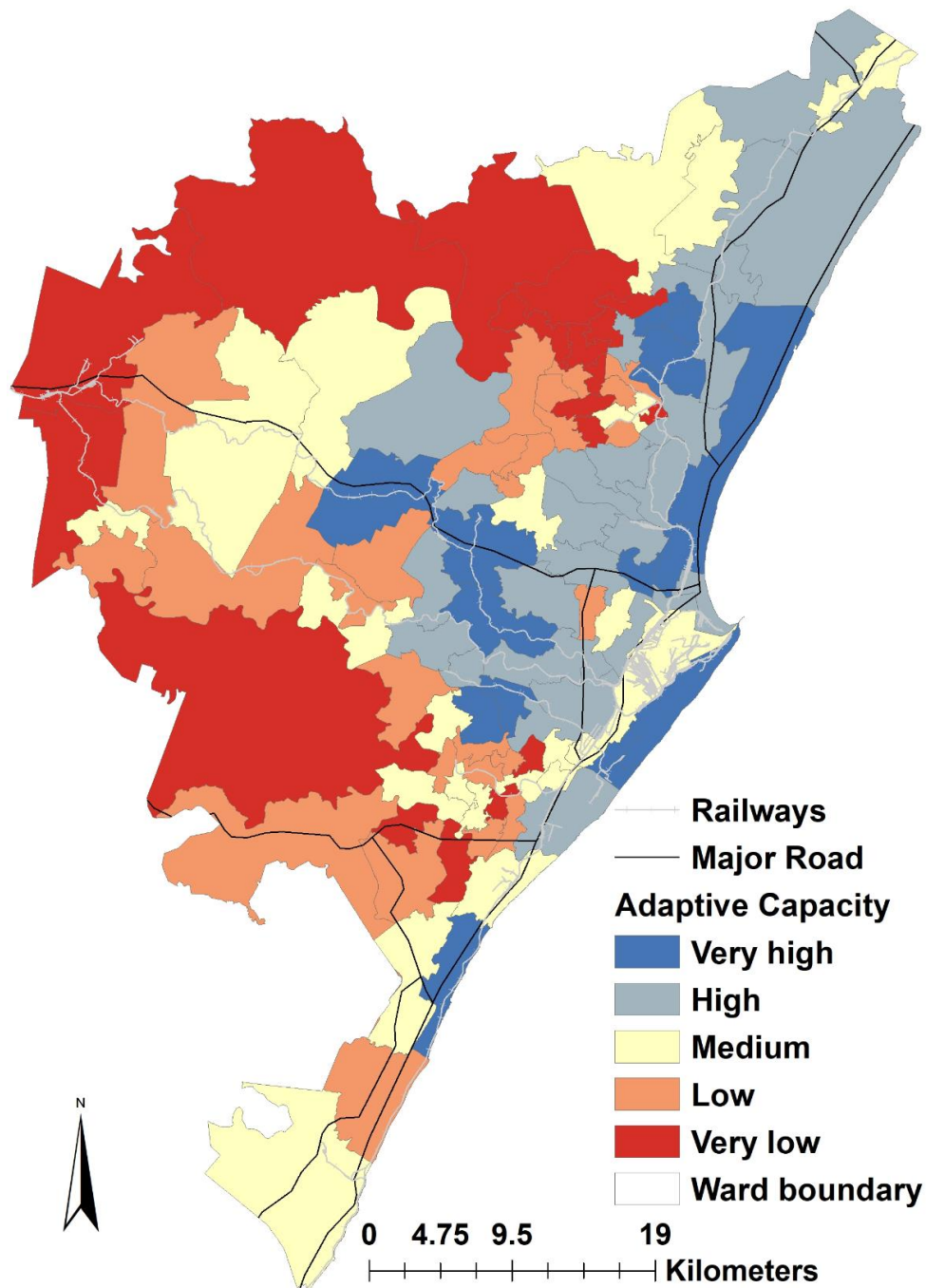
Figure 5. 3: Adaptive capacity to climate change impact for different wards

Social vulnerability to the impacts of climate change

Social vulnerability assessment gives the overall level of community vulnerability to the impact of climate change taking into account the high exposure, high sensitivity, and low adaptive capacity

of the population. The results presented in figure 5.4 indicate a high to a very high level of social vulnerability for the wards located on the outer parts (rural parts) of the city and wards located towards the northern and southern parts. Also, a few wards located near the central part of the city. Therefore, the results indicate that the majority of the most vulnerable community live in areas located in the rural parts of the city, and densely populated areas near the central business district.
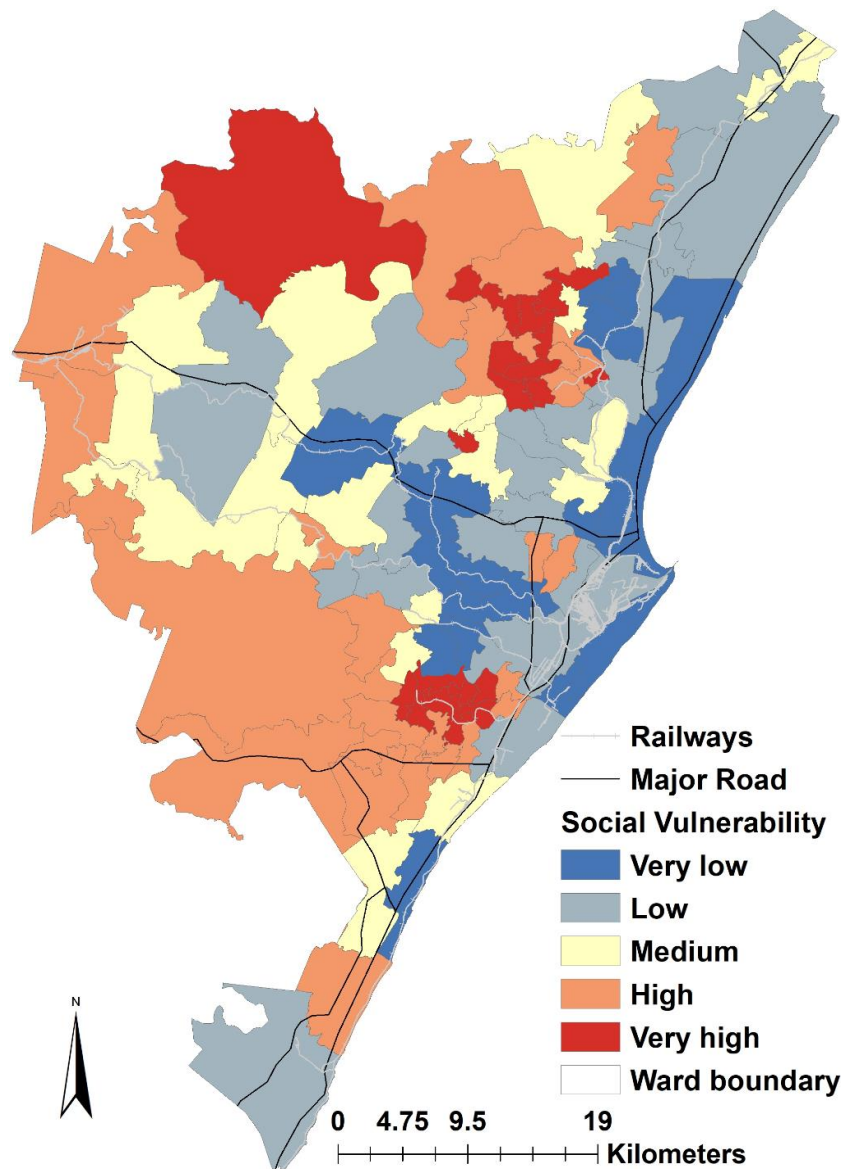
Figure 5. 4: Spatial distribution of social vulnerability in Durban city

5.3. Spatial Distribution Of Climate Change Adaptation Measures Implemented In Durban City

An assessment of the spatial distribution of climate change adaptation measures was done to determine whether they were equitably distributed (targeted locations where the most vulnerable

communities are found). The assessment considered three aspects: target areas where climate adaptation measures were implemented; factors (or reasons) considered when selecting the sites or target areas for the adaptation measures; and the proportion of the vulnerable groups who were target beneficiaries.

5.3.1. Target areas for climate adaptation measures

During the field research, interviewees were asked to identify key adaptation projects or programmes implemented by the municipality in Durban city. Five projects were identified as follows: the Green Corridors project, the Buffelsdraai Reforestation project, the Aller River Pilot project, the Sihlanzimvelo project, and the Palmiet River project. The Buffelsdraai Community Reforestation, the Palmiet River, and the Sihlanzimvelo projects were implemented by the eThekwini Municipality, while Green Corridors and Aller River projects were implemented by the non-governmental organizations (NGOs) in partnership with eThekwini Municipality.
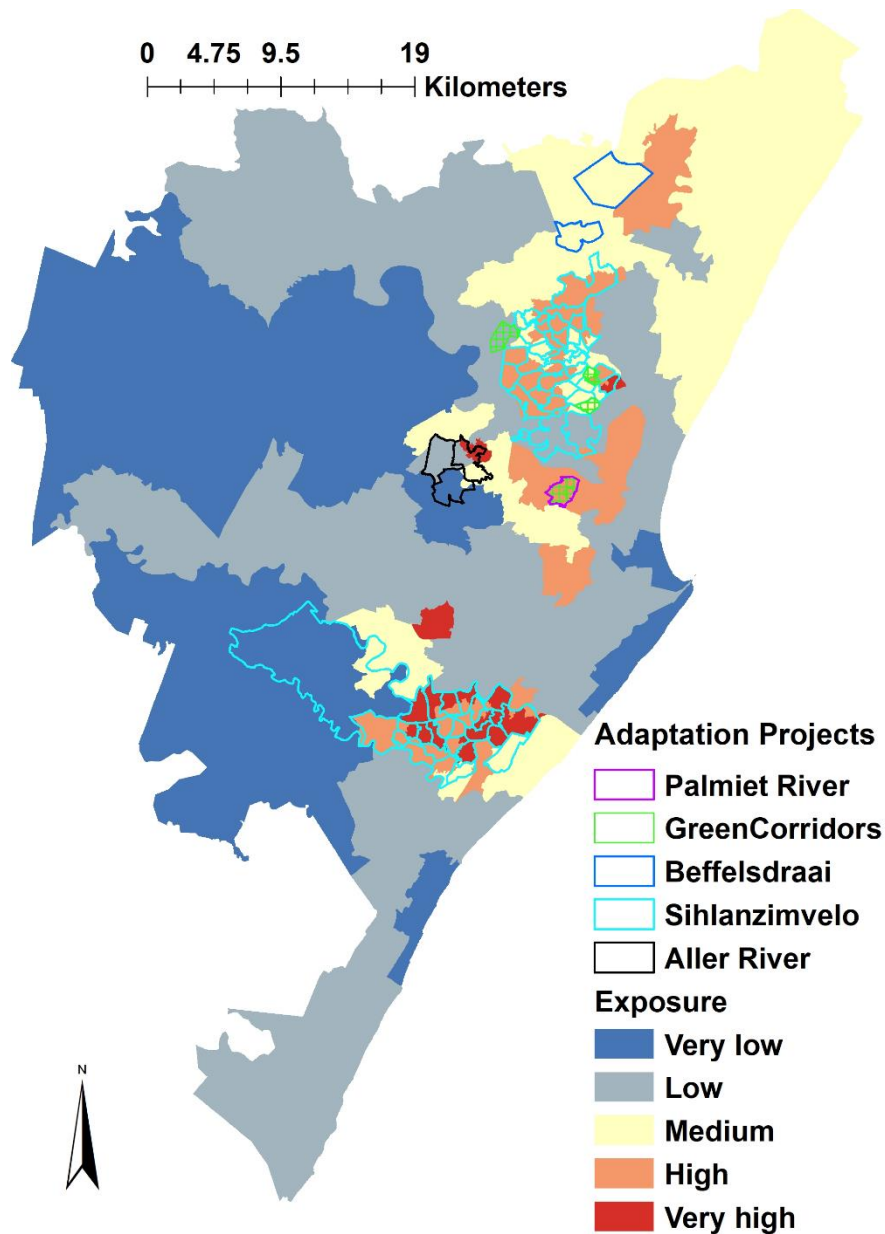
Figure 5. 5: Location of climate adaptation projects in relation to exposure to climate change

The results in figure 5.6 indicate that the Buffelsdraai Reforestation project, and to a larger extend Sihlanzimvelo and Green Corridors projects, were implemented in areas with high levels of sensitivity to climate change impacts. This suggests that the majority of target beneficiaries were the most vulnerable groups (female-headed households, children, older people, and black communities).
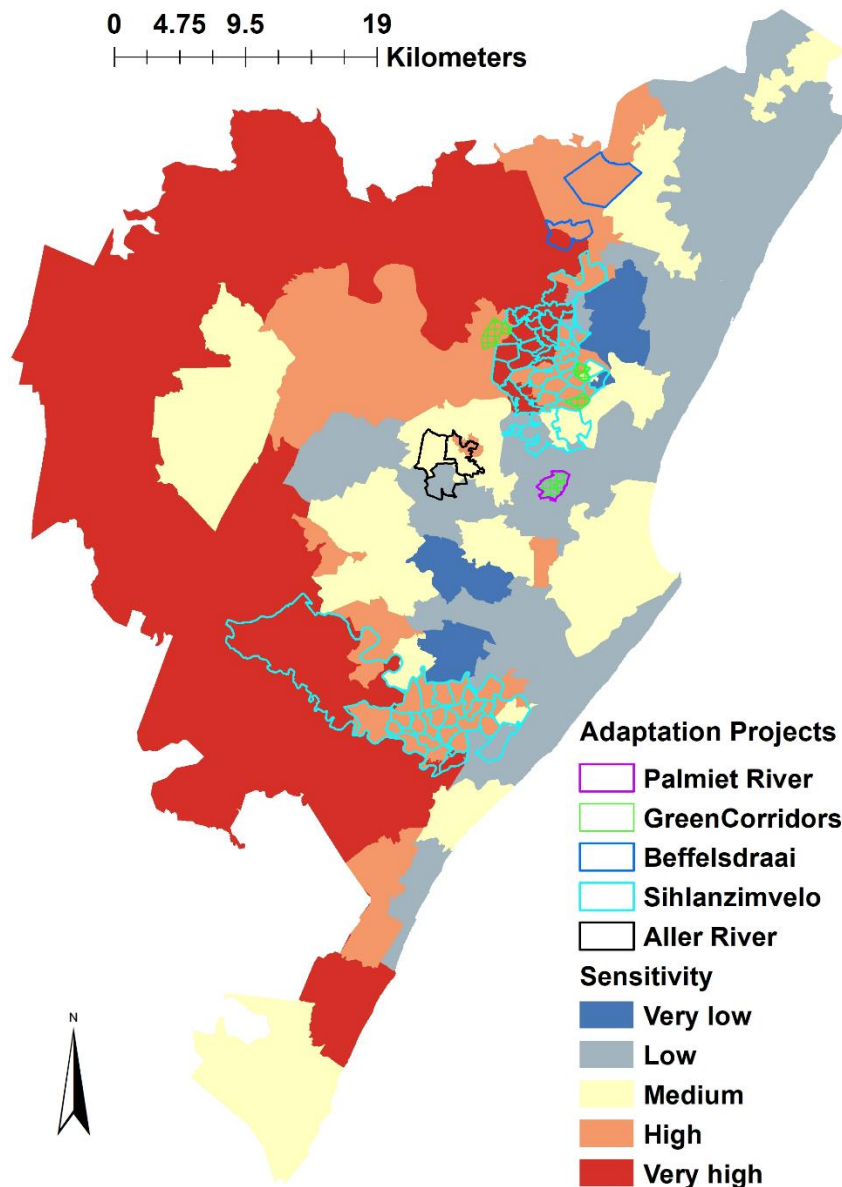
Figure 5. 6: Location of climate adaptation measures in relation to sensitivity to climate change

In figure 5.7 the results indicate that most of the areas were Sihlanzimvelo and Green Corridors projects were implemented have low to very low adaptive capacity. These results suggest that Sihlanzimvelo and Green Corridors projects prioritised areas with poor socioeconomic conditions (e.g. high unemployment, low income) and inadequate social services (roads, hospitals). On the other hand, the results for the Aller River, Buffelsdraai Reforestation, and Palmiet River projects suggest that the focus of the projects were not areas with low adaptive capacity.
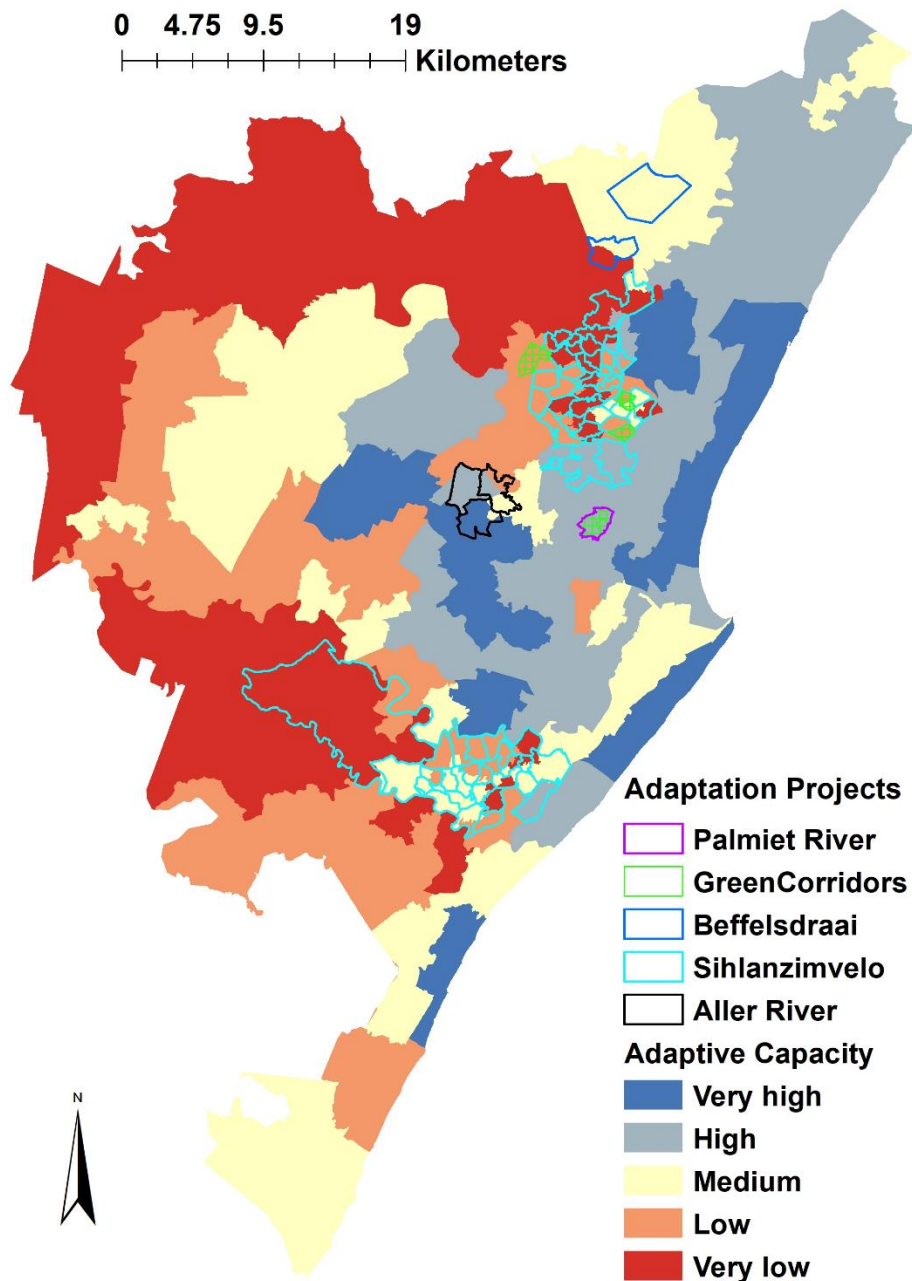
Figure 5. 7: Location of climate adaptation measures in relation to adaptive capacity

Generally, as indicated in figure 5.8 most of the areas where Sihlanzimvelo and Green Corridors projects were located in the wards characterised by high levels of social vulnerability. On the other hand, the areas where the Palmiet River project, and to a larger extent Buffelsdraai and Aller River projects were located in the wards characterised by medium to low social vulnerability. It is important to note that the area where the Palmieri River project was implemented is an informal settlement, which has a very high level of social vulnerability. However, it does not reflect on the map because the informal settlement is located in a ward with high adaptive capacity.
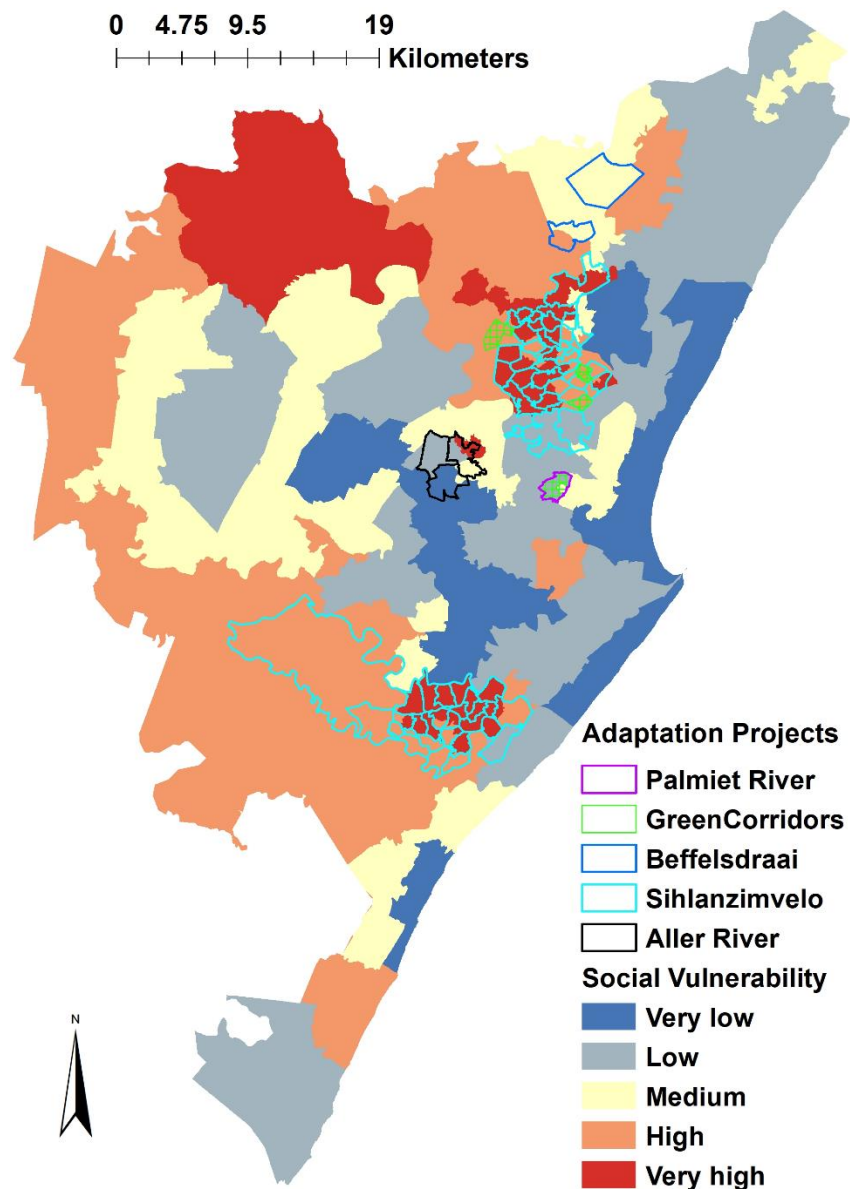
Figure 5. 8: Location of climate adaptation measures in relation to social vulnerability

5.3.2. Reasons for the selection of areas where adaptation measures were implemented

The interviewees were also asked to state the reasons or factors that were considered when selecting sites or areas for the implementation of the adaptation measures. According to the results in Table 5.2, the main reasons identified for the selection of sites or target areas for adaptation measures are as follows: settlements located near the rivers or flood plains; densely populated settlements; and mostly marginalised (with high unemployment levels) settlements. For the Buffelsdraai Reforestation project, the location was selected mainly to create a buffer zone near the landfill through reforestation.

Table 5. 2: Reasons considered when selecting target areas for climate adaptation measures.

The sentences in colour grey indicate reasons related to social vulnerability

Project name	Project location or target areas	Reasons for selection of project location or target areas
Green Corridors Project	Palmiet (Quarry road west settlement), KwaMashu, Inanda	• The settlement (Quarry road west) is not serviced by the municipal solid waste *(Interviewee9)* • The settlement is located in a flood plain, therefore waste goes into the river *(Interviewee9)* • Most marginalised informal settlements *(Interviewee9)*
Aller River Project	Clermont residential area, new Germany residential area, new Germany industrial area	• The river cuts across different areas or settlements *(interviewee7)* • The wards are close to the river *(Interviewee11)* • No river rehabilitation project was done in the Clermont area before *(interviewee9)* • To work on river restoration in a peri-urban setup *(Interviewee7)* • Aller river is highly polluted by industries and communities *(interviewee11)*
Sihlanzimvelo Project	Inanda Namibia, KwaMashu, Ntuzama and some part of Umlazi townships	• Highly degraded rivers in very polluted areas and those areas are mostly within townships *(Interviewee3)* • Townships that are very densely populated *(Interviewee3)* • Areas of high unemployment *(Interviewee13)* • The proximity of streams to the community *(interviewee13)*
Buffelsdraai Reforestation Project	Buffelsdraai, and Osindisweni	• Creation of a buffer zone around the Buffelsdraai landfill site *(Interviewee3)* • Convert the sugarcane plantation to forestry and grassland *(Interviewee3, 6)* • Buffelsdraai is where the municipality was setting up a landfill *site (Interviewee12)* • Reforestation of Buffelsdraai landfill *(Interviewee6)*
Palmiet catchment rehabilitation project	Palmiet settlement (Quarry road west informal settlement)	• Minimize the effect of flooding on the informal settlement (Quarry road west settlement) *(Interviewee 6)* • Palmiet was chosen as a pilot river for a bigger project *(Interviewee3)*

Source: Field interview (2020)

5.3.3. Beneficiaries of climate adaptation measures

An analysis of the target beneficiaries of climate change adaptation measures was done to determine the proportion of vulnerable communities from the target population of climate adaptation measures. The analysis is focused on the number of community members who were directly employed under the adaptation projects and the proportion of vulnerable community from project target areas (indirect beneficiaries of the projects)

The results presented in figure 5.9 show the percentage of jobs created by specific climate change adaptation measures implemented in Durban. The Buffelsdraai Reforestation project created the highest number of jobs (635), followed by the Sihlanzimvelo project (472). Green Corridors and the Aller River project created fewer jobs. There were no records available for the number of jobs created by the Palmiet River project. The major beneficiaries of employment opportunities are vulnerable communities in areas where climate adaptation projects have been implemented.
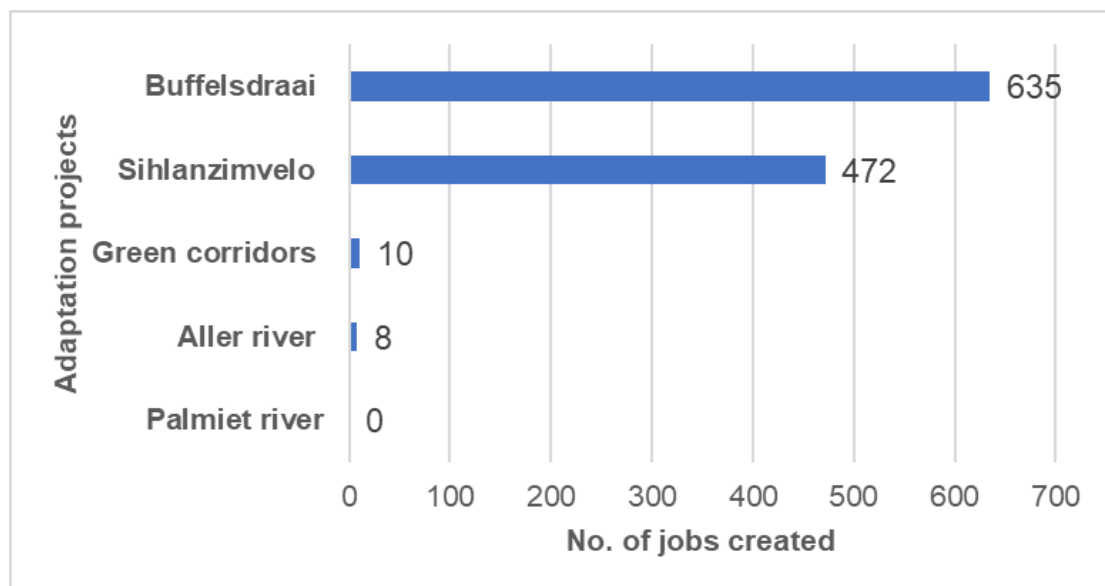
Figure 5. 9: The number of direct beneficiaries of climate adaptation measures

The results in Table 5.3 indicate the proportion of vulnerable communities from areas (settlements) where climate adaptation measures were implemented. In terms of high exposure, the highest percentage is observed for the Palmiet River project, and the lowest is observed for the Buffelsdraai Reforestation project. These results suggest that the Buffelsdraai Reforestation Project may not have targeted areas with high exposure. Regarding high sensitivity, the highest percentage is observed for the Palmiet River project and the lowest for the Aller River project. This suggests that the Aller River project may not have targeted areas with high sensitivity.

Table 5. 3: Proportion of vulnerable community from target areas (settlements).

Climate adaptation measures	Target population (estimate)	Percentage of vulnerable community			
		High exposure	High sensitivity	Low adaptative capacity	High social vulnerability
Sihlanzimvelo	852115	77	86	69	91
Green Corridors	33611	36	64	64	74
Aller River	47258	31	31	31	31
Buffelsdraai Reforestation	10338	0	100	22	22
Palmiet River	7591	100	100	100	100

Source: eThekwini Municipality (2020)

In terms of low adaptive capacity, the results show the highest percentage of vulnerable groups for the target area for the Palmiet River project and the lowest percentage for the Buffelsdraai Reforestation project. This suggests that the Palmiet River project may have targeted areas with low adaptive capacity, while the Buffelsdraai Reforestation Project may not have targeted areas of low adaptive capacity.
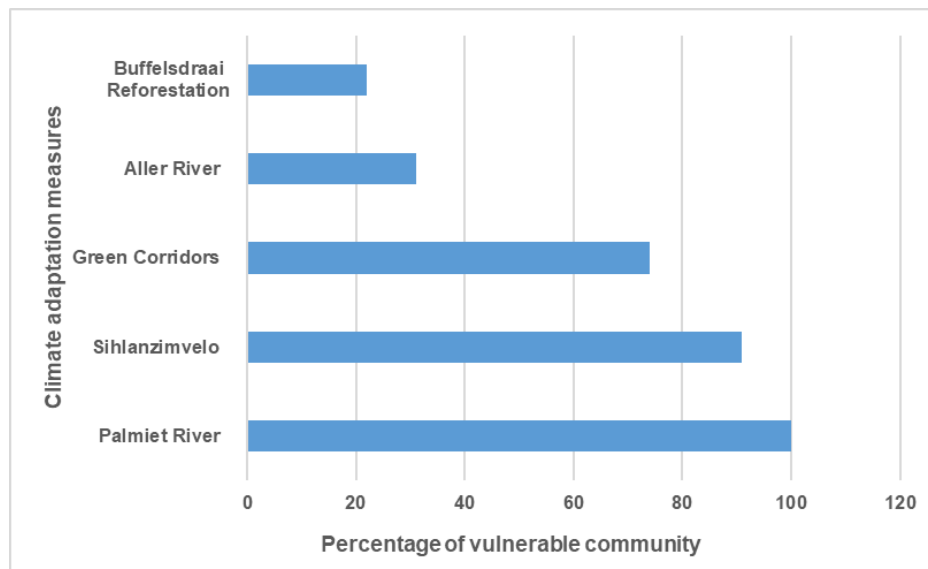
Figure 5. 10: Proportion of target population of climate adaptation measure who are vulnerable

Generally, as illustrated in figure 5.10, the areas where Buffelsdraai Reforestation and Aller River projects were implemented show a low proportion of socially vulnerable communities. This,

therefore, suggests that the Buffelsdraai Reforestation and Aller River projects may not have prioritised areas with high social vulnerability.

5.4. Consequences of climate adaptation measures to the vulnerable and marginalised groups.

An assessment of the consequences was done to determine the achievements and non-achievements , the positive consequences, and the negative consequences of the climate adaptation measures implemented in Durban city. The positive consequences are referred to as co-benefits, and the negative consequences as maladaptation.

5.4.1. Achievements (and reasons for non-achievement) of climate adaptation measures

The assessment of the achievements was conducted to determine the effectiveness of climate adaptation measures in reducing social vulnerability. Interviewees were asked to state whether the objectives of climate adaptation measures were achieved and the reasons where the objectives were not achieved.

The results presented in Table 5.4, indicate that the Green Corridors project achieved its objective in terms of improved waste management in schools and reduced waste going into the rivers. The results for the Aller River project generally show that it achieved its objectives in terms of reduced blockages of sewer lines (contributing to the reduced outbreak of diseases) and reduced amount of nappies going into the river (which contributes to reduced river flooding). However, the project was not successful in terms of changing the behaviour of the community towards the disposal of waste, and preventing the continuous pollution of the rivers by the industries (from New Germany industrial area). The key achievement of the Sihlanzimvelo project was the creation of employment for the local people (472 people employed), reduced damage to infrastructure (culverts), and reduced risk of flooding. For the Buffelsdraai Reforestation project, the key achievements were the promotion of permaculture (e.g. tree planting) and urban agriculture, and transfer of knowledge on climate change to the local people. The Palmiet River project generally did not achieve much. The main achievement of the project was mainly improving the relationship between the municipality and the informal settlers. The non-achievement of objectives is attributed to the refusal by the settlers of Quarry road west settlement to be relocated, and lack of security of tenure by the residents.

Generally, as indicated in figure 5.11 the climate change adaptation measures were more effective in terms of reducing the exposure of the community to river flooding (e.g. WhatsApp flood

warning system, reduced damage to drainages, reduced waste in rivers); and increasing the adaptive capacity of the local community through employment opportunities, reduced crime rate, and improved community participation in projects. The adaptation measures were less effective in terms of reducing the sensitivity of the local community on the impact of climate change.
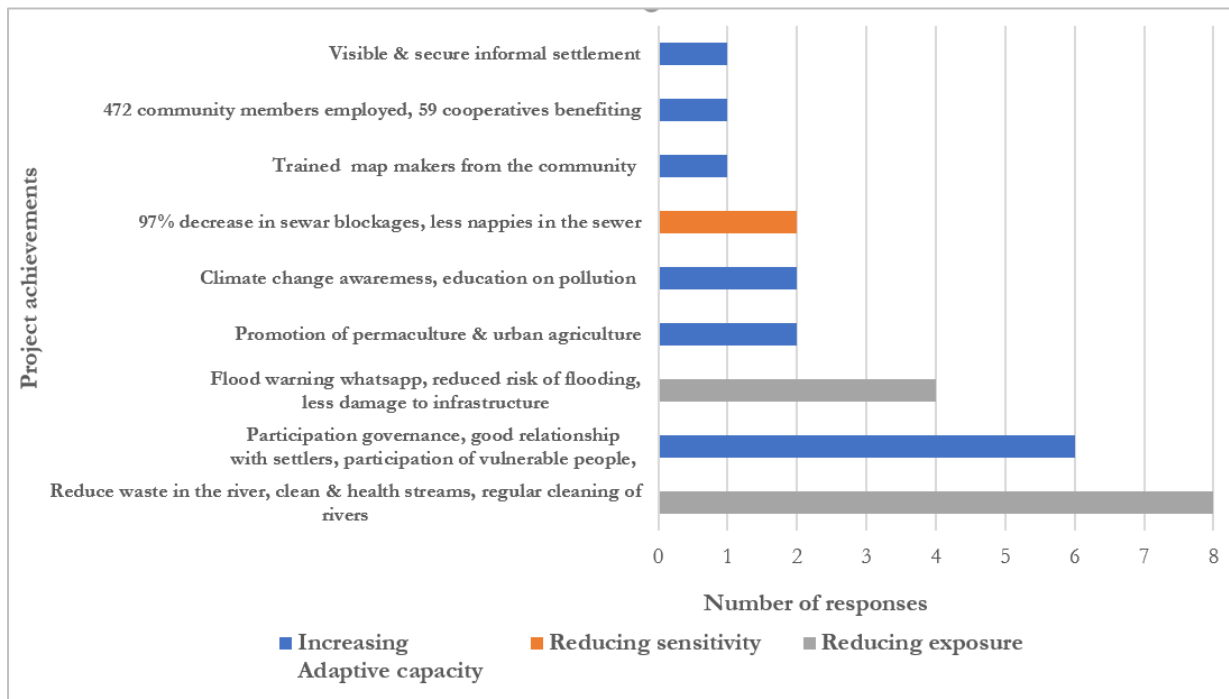
Figure 5. 11: Summary of the achievements of the objectives of the climate adaptation measures

Table 5. 4: The achievements and non-achievements of the objectives of climate change adaptation measures.

Text in red colour indicates the non-achievements of project objectives

Climate adaptation measures	Objectives	Factors reducing social vulnerability		
		Increasing adaptive capacity	Reducing sensitivity	Reducing exposure
Green Corridors Green Spaces Projects	"objectives is to create dialogues around the waste that is the single-use plastic. The other one is to educate leaners in a participative and learning efficiently" *(Interviewee8)*.	• School education through debates and video shows on waste management *(Interviewee8)*		• A lot of waste directed from the river thereby reducing flooding*(Interview 8)* • Clean and healthy streams *(Interviewee8)*
Aller river pilot project	"The purpose of the project was to educate the people to reduce the disposal of nappies into the river because we end up now having floods of water"*(interviwee1)* "Restoration of the river banks, water quality monitoring, and testing for contaminants, education programmes with communities such as schoolchildren and women"*(interviewee7)*	• Promotes participatory governance, transdisciplinary, co-production *(Interviewee9)* • Community education on pollution **(FGD)** • Not easy to change people's lives and behavior *(interviewee 11)* • Lack of ownership or responsibility by residents (a lot of people are renting) *(Interviewee 9)* • Difficult to change people's behaviour *(Interviewee9***)*** • raised expectations that we can't meet *(interviewee7)*	• Continuous pollution of the river by industries *(Interviewee 9)* • 97% decrease in blockage of the sewer system *(interviewee7)*	• Developed a community WhatsApp flood warning system *(interview7)* • Reduced amount of nappies going into the river *(interviewee7)* • Cleaned up of Aller river *(FGD)* • Fewer nappies in the river *(FGD)* • Cleaned up the stream *(interviewee7)* • Fewer nappies going in the river *(Interviewee9)*
Sihlanzimvelo Project	" to improve the resilience of the natural stream system, to reduce the risk of blockages due to alien	• 472 workers employed *(Interviewee13)* • 59 coops benefiting from the project *(interviewee13)*		• Regular cleaning of the rivers (covering 300 km of the

	vegetation and solid waste, identify erosion risk early, to report sewer breaks and blockages and to reduce unemployment"*(Interviewee13)*	Difficulty to change people's mindset *(Interviewee3)*		7500km of streams & rivers) *(interviewee 13)* • Few incidences of damage to bridges and culverts *(interviewee12)* • There is less damage to the infrastructure *(interviewee 3)* • Reduced risk of flooding *(Interviewee13)* • rivers do get cleaned *(interviewee 3)*
Buffelsdraai community reforestation project	"The Buffelsdraai reforestation project objectives is to restore the whole buffers area with tree species and grass species as well as to create job opportunities" *(Interviewee12)*	• Promotion of permaculture *(Interviewee12)* • Promotion of urban agriculture *(interviewee12)* • Created 635 jobs • Transfer of Knowledge about climate change adaptation *(Interviewee12)*		
Palmiet Catchment Rehabilitation Project	"objectives initially was to minimize the impact of the climate change impact within that settlement. But again part of that was just the settlement needs to be completely relocated because they are just on top of a flood plain"*(interviewee6)*	• Meeting high expectations by the local people *(Interviewee6)* • No sense of ownership by most residents of Quarry road west settlements *(Interviewee6)*	Palmiet river is still polluted by industrial and solid waste *(Interviewee 9)*	Informal settlers refused low-cost housing *(Interviewee 6)* Residents of Quarry road settlement refused to be relocated *(Interviewee6)*

Source: interviews (2020)

5.4.2. Co-benefits of climate adaptation measures

Interviewees were asked to indicate the co-benefits (sometimes referred to as unintended benefits) of the climate adaptation measures. The objective of this assessment was to identify the socioeconomic benefits of adaptation measures to the vulnerable community. The results presented in Table 5.5, show that the co-benefits from Green Corridors project mainly contributed in increasing the adaptive capacity of the local community (e.g. employment creation, skills training) and in reducing sensitivity (a clean environment). Similarly, the co-benefits of the Aller River project also contributed to increasing the adaptive capacity (the creation of employment opportunities, improved security along the river banks, capacity building for the local community, and environmental awareness), and reducing the sensitivity of the community (clean rivers due to reduced nappies in rivers). Regarding Sihlanzimvelo and Buffelsdraai Restoration projects, and to some extent the Palmiet River project, the co-benefits mainly contributed to increasing the adaptive capacity of the community (e.g. employment creation, improved security along the rivers, improved income at household level structures, improved housing structures)
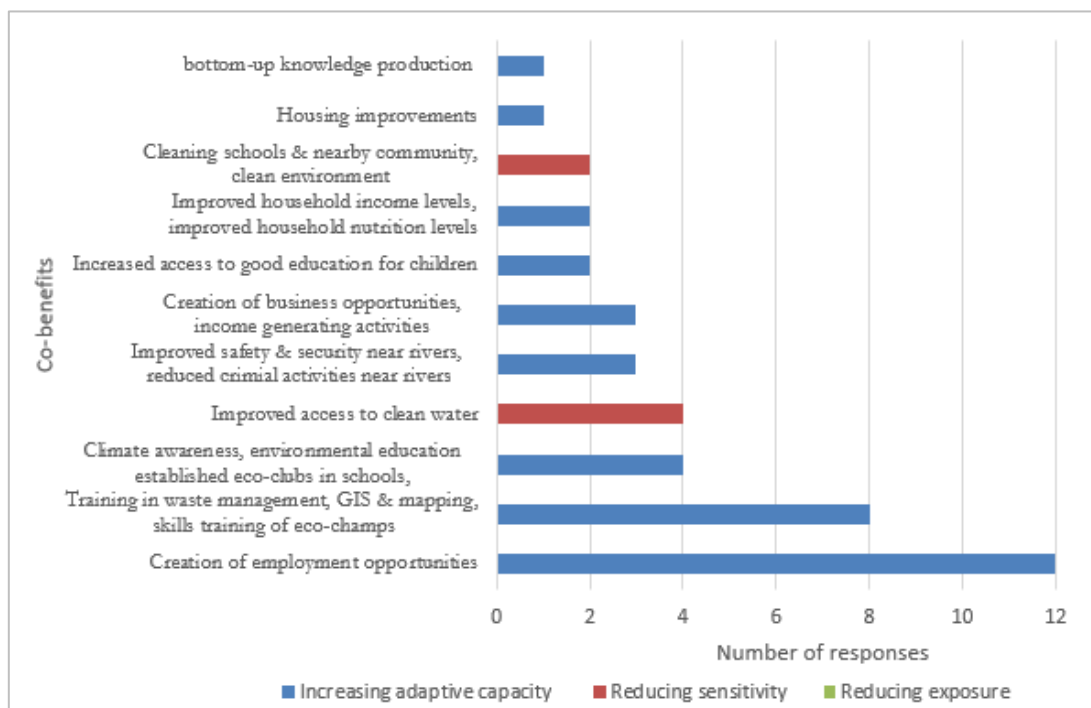
Figure 5. 12: Summary of the co-benefits of the climate adaptation measures

In general, as indicated in figure 5.12, the that climate adaptation measures contributed to increasing the adaptive capacity of the vulnerable community (e.g. through employment, increased security, business opportunities) , and reducing the sensitivity of the community (e.g. through the improved water quality in rivers, which contributes to reducing water-borne diseases).

Table 5. 5: Results for the co-benefits of climate adaptation measures implemented in Durban

Climate adaptation measures	Factors that reduce social vulnerability		
	Increasing adaptive capacity	Reducing sensitivity	Reducing exposure
Green Corridors project	• Creation of employment opportunities *(Interviews3, 9)* • Community training in waste classification and categorisation *(Interview9)* • Community training in the participatory mapping *(interview9)* • Community training in the use of GPS *(Interview9)*	• Cleaning the schools and the surrounding community *(Interview9)*	
Aller river project	• Employment creation *(interviewee9, 7,11)* • Environmental education of school children (interview9) • Improved safety and security near the stream (interview7) • Skills training of the eco-champs (interview7) • Capacity building for co-champions *(interviewee9, 11)* • Vocational skills (Interview3, FGD) • Established eco-clubs in schools *(Interviewee11)* • Environmental education of mothers *(interviewee9)*	• Improved access to clean water (Interview3) • Cleaner environment *(interviewee 11)*	
Sihlanzimvelo project	• Employment of co-ops (Community cooperatives) *(Interviewee12)* • Improved safety and security near the river *(Interviewee12)* • Reduced criminal activities near the river *(Interviewee3)* • Creation of employment opportunities *(Interviewee3)*	• Improved water quality in the stream *(interviewee13)*	

	• Job/business creation *(Interviewee 13)* • Vocational skills *(Interviewee3)*		
Buffelsdraai community reforestation project	• Creation of opportunities for small business development (tree preneurs) *(Interviewee 12)* • Creation of employment opportunities *(Interviewee3, 6, 12)* • Increased access to good education for children *(interviewee6, 12)* • Improved income levels of households • Climate awareness *(Interviewee5)* • Income-generating activities *(Interviewee3, 6)* • House improvements *(Interviewee6, 12)* • Improved nutritional levels at the household *(Interviewee12)*	• Improved access to clean water *(Interviewee3)*	
Palmiet river Project	• Employment opportunity through the waste collection *(Interviewee6)* • bottom-up knowledge production processes, the inclusion of like really vulnerable groups *(Interviewee9)*. • Improved relationship between the municipality and informal settlers *(Interviewee9&6)* • Quarry road west informal settlement is more visible & secure *(Interviewee9)* • Open communication with the informal settlement residents *(Interviewee6)*		

Source: Interviews (2020

5.4.3. Maladaptation to climate adaptation measures

The objective of the assessment of maladaptation was to determine the risk of maladaptation of climate adaptation measures to the vulnerable community.

The assessment of the risk of maladaptation in climate adaptation measures was based on the framework by Barnett & O'Neill (2013) as indicated in Table 5.6. The results show a high risk of maladaptation for the Palmiet River project because it focused on reducing exposure through the reconstruction of the river banks and relocation of the community. The project activities are expensive, and the relocation can have a disproportionate effect on the community. The results also show a medium risk of maladaptation for the Aller River and Sihlanzimvelo projects because it focused on reducing sensitivity through river restoration and regular cleaning. These activities are fairly expensive they are continuous and require sustainable funding. The results for Green Corridors and Buffelsdraai projects show a low risk of maladaptation because the projects focused on increasing the adaptive capacity of the vulnerable groups, which is less expensive and socially equitable.

Table 5. 6: Analysis of the risk of maladaptation for climate adaptation measures

Climate adaptation measures	Increasing adaptive capacity	Reducing sensitivity	Reducing exposure
Green Corridors projects	• To create dialogues around the waste that is the single-use plastic *(interviwee8)* • School education through debates and video shows on waste management *(interviwee8)*		
Aller River project	• Educating the people to reduce the disposal of nappies into the river *(interviwee1)*	Restoration of the river banks, water quality monitoring, and testing for contaminants *(interviewee7)*	
Sihlanzimvelo project		Regular cleaning of the rivers (covering 300 km	

		of the 7500km of streams & rivers) (*interviewee 13*)	
Buffelsdraai Reforestation project	• Promotion of permaculture (*Interviewee12*) • Promotion of urban agriculture (*interviewee12*)		
Palmiet River project			Minimize the impact of the climate change on or within Quarry Road West settlement through the reconstruction of the river banks and the wetlands, and community relocation (*interviewee6*).
Risk of maladaptation	**Low risk**	**Medium risk**	**High risk**
Reasons for the risk of maladaptation	• Measures/activities are socially equitable as they target the vulnerable community • Cost-effective activities or projects • No-regret adaptation measures – benefit the community even without the impact of climate change (e.g. employment creation) • They emit less GHGs	Fairly expensive as removal and disposal of solid waste and alien vegetation is a continuous process and may be costly	• Reconstruction of the river banks can change the environmental/ecological aspects of the areas • Re-location can have negative social and economic effects on the vulnerable community, and very costly on the part of the Municipality

Source: framework adapted from Barnett & O'Neill (2013).

The assessment of maladaptation was also based on maladaptation outcome criterion by Barnett & O'Neill (2010) as indicated in Table 5.7. Interviewees were asked to state the negative consequences (maladaptation outcomes) of the climate change adaptation measures on the vulnerable community. The results show maladaptation outcomes for the Buffelsdraai Reforestation related to the increase of the cost of land attributed to the project, which may affect

the vulnerable community in terms of the cost of housing. The results also show maladaptation outcome for the Green Corridors projects related to pollution due to effluent from solid waste, which may increase the risk of the community in terms of diseases

Table 5. 7: Assessment of maladaptation in climate adaptation measures

Maladaptation criterion	Maladaptation outcomes	
	Buffelsdraai Reforestation project	Green Corridors project
Disproportionately burdening the most vulnerable: If in meeting the needs of one sector, system or group, adaptation actions increase the vulnerability of those at risk, they may be maladaptive	High competition for people to have access to land close to the Buffelsdraai Reforestation project. Therefore buying a site there is quite expensive *(Interviewee6)*.	Green Corridors project: Smell and maggots from solid waste storage facilities which were located close to houses, affected the households and the people were not happy *(Interviewee 8)*.

Source: Maladaptation criterion adopted from Barnett & O'Neill (2010).

5.4.4. Summary results based on the outcome evaluation criteria of climate adaptation measures

Table 5.8 gives a summary results of the outcome evaluation of the climate change adaptation based on effectiveness, equity, co-benefits, and maladaptation criteria. Generally, the results show that all the projects were effective except for the Palmiet River project. Further the projects created co-benefits which mainly contributed to increasing adaptive capacity and reducing the sensitivity of the community. The results also show that the Aller River was not equitably distributed as the target proportion of the vulnerable community was low. The results also indicated a high risk of maladaptation for the Palmiet River, and moderate risk for the Aller River and the Sihlanzimvelo projects.

Table 5. 8: Summary of the results of climate adaptation measures based on the outcome evaluation criteria

Evaluation criteria	Outcomes of climate adaptation measures				
	Green Corridors	**Aller River**	**Sihlanzimvelo**	**Buffelsdraai Reforestation**	**Palmiet River**
Effectiveness	• Increasing adaptive capacity • Reducing exposure	• Reducing exposure • Reducing sensitivity	• Increasing adaptive capacity • Reducing exposure	Increasing adaptive capacity	

Co-benefits	• Increasing adaptive capacity • Reducing sensitivity	• Increasing adaptive capacity • Reducing sensitivity	• Increasing adaptive capacity • Reducing sensitivity	• Increasing adaptive capacity • Reducing sensitivity	Increasing adaptive capacity
Equity	A high proportion of socially vulnerable communities	A low proportion of socially vulnerable communities	A high proportion of the socially vulnerable community	A medium proportion of socially vulnerable communities	A high proportion of socially vulnerable communities
Risk of maladaptation	The low-risk project as it focused more on increase the adaptive capacity of the vulnerable community	Moderate risk project as it focused more on reducing the sensitivity of the Aller River system	Moderate risk as it focused more on reducing the sensitivity of infrastructure	A low-risk project as it focused more on increasing the adaptive capacity of the community	A high-risk project as it focused more on reducing exposure to flooding of the settlement
Reasons for the risk of maladaptation	No-regret measures as the project benefited the community even without climate change	River restoration is fairly expensive as it requires continuous funding & cleaning	Fairly expensive projects in terms of sustainable funding and continuous	socially equitable measures as it benefits the community in terms of employment creation	Rehabilitation of river banks & planned relocation has negative consequences both environmentally & socially

Source of evaluation criteria: Barnett & O'Neill (2013); Sherman & Ford (2014); Weiland et al. (2015)

6. DISCUSSION

6.1.   Introduction

The results of the research are discussed in terms of the current spatial distribution of social vulnerability in Durban city, and the spatial distribution and consequences of climate adaptation measures. In the first section, the results of the current spatial distribution of social vulnerability in Durban city and the factors influencing the distribution are discussed; in the second section, the spatial distribution of the adaptation measures is discussed in terms of equity. In the third section, the consequences of the adaptation measures are discussed concerning effectiveness, co-benefits, and maladaptation (negative consequences of adaptation measures).

6.2.   Current spatial distribution of social vulnerability in Durban

The social vulnerability analysis was used to identify wards that were vulnerable to the impact of climate change, and to identify the factors that influenced different dimensions of vulnerability (exposure, sensitivity, and adaptive capacity). The assessment of social vulnerability was based on the social vulnerability framework used in a study by Kazmierczak, (2015) in Helsinki. The framework combines adaptive capacity, sensitivity, and exposure dimensions. The factors used in the analysis include the demographic, socioeconomic, built environment, and physical environment. This is different from the method used in the previous study by Apotsos (2019) in Durban, which only utilized the demographic and socioeconomic factors. The use of built environmental factors was also applied by Holand et al. (2011) in the study of social vulnerability in Norway. The key advantage for calculating social vulnerability based on adaptive capacity, sensitivity, and exposure, is that it helps to identify different dimensions of vulnerability for the wards, which can be useful for targeted implementation of adaptation measures by the municipality.

The results revealed a very high level of social vulnerability for the wards located closer to the city center, and mainly characterised by informal settlements or the former township areas. These results confirm the results of the previous study on social vulnerability by Apotsos (2019). Further, most of the wards were located close to flood-plain or rivers, and therefore the residents were more exposed to seasonal flooding. The study also revealed a high level of social vulnerability for

the wards located in the rural parts of the City. Most of these wards have less access to social facilities such as railway stations, clinics, and public transport. The wards also have a high population of the most vulnerable groups such as female-headed households, children, elderly people, and black communities. Most of the wards in the rural parts are located in areas under the jurisdiction of the Traditional Authority (eThekwini Municipality, 2018). This could be a challenge for the local municipality to implement adaptation projects in the area.

6.3. Spatial distribution of climate adaptation measures in Durban city

Equity outcome criteria were used to evaluate whether the adaptation measures targeted and benefited the vulnerable and marginalised groups (Sherman & Ford, 2014). The analysis was done spatially based on the distribution of climate adaptation measures in relation to social vulnerability. Most of the climate adaptation measures focused on areas closer to the rivers, streams, and landfills (Buffelsdraai Reforestation project). This was based on the objectives of the projects, which were related to river restoration, riverbank rehabilitation, and reforestation of the landfill. Therefore, most of the target areas were located closer to the streams or rivers. Besides the Buffelsdraai Reforestation and Aller River projects, the target areas were informal settlements or former township areas with a high level of social vulnerability. The target area for the Buffelsdraai Reforestation project was the landfill, which was mainly located in the ward with medium social vulnerability. However, the project created employment opportunities for female-headed households and the youths (Mancebo, 2011) from the surrounding communities (Osinisweni settlement), which were socially vulnerable. The target areas (New Germany residential and industrial areas) for Aller River projects were mainly located in the wards with low levels of social vulnerability. Therefore, a high proportion of the target population was not vulnerable, which suggests that the project was not equitably distributed.

The study also revealed that climate adaptation measures were not widely distributed as they did not cover areas located in the periphery of the city, mostly rural areas, with high social vulnerability. As indicated in the results, the rural parts of Durban city have a large population of marginalised groups (e.g. female-headed households and black population), with low-income levels and unemployment. The people in rural areas have less access to public services such as railway transport, public bus transport, and hospitals. Therefore, these areas may not be easily accessible during severe storms, floods, or other climate-related impacts (Kazmierczak, 2015). Further, most of the projects were implemented on a pilot basis and this could be one of the reasons they were not widely distributed.

6.4.   Consequences of climate adaptation measures on the vulnerable communities

Sherman & Ford (2014) used effectiveness criteria in a study to evaluate the engagement of stakeholders in climate adaptation projects in developing countries. Projects considered effective were those that achieved the stated objectives or outcomes within a given period. In this research, the effectiveness criterion was used to evaluate the climate adaptation measures implemented in Durban. The results indicate that, besides the Palmiet River project, all the climate adaptation measures were generally effective in achieving the objectives and reducing social vulnerability. The adaptation measures were more effective in terms of reducing the exposure of the community to flooding and increasing the adaptive capacity. The climate adaptation measures also created several co-benefits, which contributed to increasing adaptive capacity and to a lesser extend reducing sensitivity. Co-benefits such as employment creation, skills training for the youths, and reduction of crime rate contribute to the wellbeing of the vulnerable community and consequently improving the adaptive capacity (Ford et al., 2015). Further, a reduction in crime rate makes it easy for the community to engage in business and social activities and for children to freely play outside (which is also associated with improved health).

On the other hand, the Palmiet River project did not achieve its intended objective of reducing the exposure of the residents of Quarry Road West Informal Settlement to flooding. The objective of the project was to construct the river banks to prevent flooding of the settlement and to relocate some residents to the new low-cost housing (Interview, 2020). The majority of the community members refused to relocate citing long distances to jobs and lack of business opportunities (Interviews, 2020). It was further noted that most of the residents were not permanent residents of the settlement (they came to work in Durban from other provinces) (Interview, 2020). However, the Palmiet River project created some co-benefits such as the improved relationship between the informal settlers, the Municipality officials, and the researchers from the Unversity of KwaZulu Natal (UKZN) (Martel & Sutherland, 2019).

While most of the climate adaptation measures were effective in terms of achieving the objectives, a moderate to high risk of maladaptation (Barnett & O'Neill, 2013) were observed in some projects. A high risk of maladaptation was observed for the Palmiet River project, which focused on reducing exposure of the Quarry Road West Informal settlement to flooding. The project carried a high risk because the river bank rehabilitation project is expensive and may result in environmental degradation. Also, the relocation of the settlement may have a disproportionate effect on the vulnerable groups as most of them work or involved in informal trading in the city

center or surrounding areas (Interview, 2020). Modest risk of maladaptation was observed for the Aller River and Sihlanzimvelo projects, which focused on reducing the sensitivity of infrastructure and river banks or catchment areas. The projects carried a modest risk of maladaptation because river restoration projects are fairly expensive as it requires continuous cleaning of the rivers and removal of alien vegetation as well as sustainable funding. Maladaptation was also assessed based on the maladaptation criterion by Barnett & O'Neill (2010), which measures whether the outcomes of climate adaptation measures have a disproportionate effect on the vulnerable communities. The results of this study revealed that the implementation of the Buffelsdraai Reforestation project contributed to the increase in the cost of land closer to the project area (Interview, 2020). This may have negative consequences to the vulnerable communities in terms of access to affordable land and increase housing rentals. Further, the effluent from the solid waste storage facilities under Green Corridors project was also a source of concern in terms of the health of a vulnerable community. The results revealed that the residents living in houses closer to areas where storage facilities were located, were affected by bad smell and maggots coming from solid waste (Interview, 2020).

7.   CONCLUSIONS AND RECOMMENDATIONS

The main objective of this research was to establish whether the outcomes of the climate of climate adaptation measures implemented in Durban city, South Africa helped to reduce or exacerbate social vulnerability. To achieve this objective, the following specific objectives were considered: to assess the spatial distribution of social vulnerability to climate change; to map the spatial distribution of climate adaptation measures implemented in Durban city; and to assess the consequences of climate adaptation measures implemented in Durban city. In conclusion, the key findings of the research are summarised based on the specific research objectives. Recommendations to the local Municipality and for further research are given based on the conclusions.

7.1.   To assess the spatial distribution of social vulnerability to climate change

An assessment of the spatial distribution of social vulnerability in Durban city was conducted to identify the vulnerable and marginalised groups and the factors that contribute to vulnerability. The findings of the research revealed that wards with very high social vulnerability are those located closer to the city but away from the public transport routes or railway stations. The wards are characterised by high population density, low-income levels, high unemployment levels, and most of the housing structures are informal. These wards also have a high population of the most vulnerable groups such as female-headed households, children (below the 5 years), old people (65 years and above), and a high population of black people. Most of these wards are also located closer to flood plains of rivers and therefore are susceptible to flooding. Further, the wards located on the outskirts of Durban city, mostly in the rural parts have a high level of social vulnerability. The wards also have a high population of the most vulnerable groups, and low income and low education levels. The wards also have a problem with accessibility to railway stations, public bus routes, and health facilities.

7.2.   To map the spatial distribution of climate adaptation measures implemented in Durban city

Mapping of the spatial distribution of climate adaptation measures was also undertaken to establish where the adaptation measures were implemented, and whether they considered the vulnerable and marginalised communities. Generally, the results revealed that the adaptation measures

implemented in Durban are equitably distributed as the majority of the target population were vulnerable communities. Further, the results indicate that projects such as Buffelsdraai Reforestation created employment and business opportunities that mostly benefited women (female-headed households). However, the results suggest that the Aller River project was not equitably distributed as a high proportion of the target population was not vulnerable. The main focus of the project was the restoration of the Aller River, where a high proportion of the communities living closest to the river were not socially vulnerable. The study also reveals that the adaptation measures were not widely distributed across the city. The projects did not cover areas in the periphery of the city, mostly the rural areas where social vulnerability was high. The results show that these areas have a high population of people with low income and education levels, high population of female-headed households, very young children, and inadequate public infrastructures such as clinics, public bus routes roads and railway stations

7.3. To assess the consequences of climate adaptation measures implemented in Durban city

An assessment of the consequences of the climate adaptation measures was done to establish the effectiveness, the co-benefits, and the risk of maladaptation of the adaptation measures. The findings revealed that besides the Palmiet River project, climate adaptation measures were generally effective in terms of achieving the stated objectives and reducing exposure and increasing the adaptive capacity of the community. The adaptation projects such as Buffelsdraai Reforestation and Sihlanzimvelo contributed to the increase in the adaptive capacity of the vulnerable community through employment creation. The Sihlanzimvelo project also contributed in terms of reducing the exposure of the community to flooding through reduced damage to public infrastructure and improving the flow of the stream/rivers through regular cleaning, and removal of alien vegetation. Further, the projects created several co-benefits (such as skills training, business opportunities, and improved security near the rivers) that helped in terms of increasing the adaptive capacity and reducing the sensitivity of the most vulnerable communities. On the other hand, the Palmiet River project was not effective as it did achieve its objective of reducing exposure of the community from Quarry Road West settlement, through river bank reconstruction and relocation of the community. Additionally, all adaptation measures were not effective in terms of reducing river pollution and changing the mindset of the community concerning indiscriminate dumping of solid waste in the rivers and sewer system. This was contributing to high sensitivity as the river pollution and blocked sewer exposed the community to water-borne diseases.

In terms of maladaptation, the results revealed a high risk of maladaptation for the Palmiet River project, which focused on reducing exposure of the community to flooding. Further, the results revealed a moderate risk of adaptation for the Aller River project and Sihlanzimvelo. The projects mainly focused on reducing the sensitivity of the rivers (river restoration) and infrastructure, which are fairly expensive as they require continuous funding. Maladaptation outcome was also observed for the Buffelsdraai Reforestation project regarding the increase in the cost of land near the project area. This was attributed to the increase in the number of people deciding to settle closer to the project. This was likely to have negative consequences on the vulnerable community in terms of the cost of building houses and renting. However, it was not very clear based on the results of this research whether the high cost of land would be directly attributed to the Buffelsdraai Reforestation project. Maladaptation was also suspected for the Green Corridors project in terms of air pollution and soil contamination resulting from the effluent from the solid waste storage facilities. Due to lack of space in informal settlements, the storage facilities were located closer to the houses and communal ablution blocks, which was negatively affecting the households.

7.4.   Recommendations

The following are the recommendations arising from the research carried out in Durban city, South Africa.

- The implementation of climate adaptation measures should be extended to cover the rural parts of Durban with high social vulnerability resulting from low-income levels, low education levels, and a high number of vulnerable groups.
- The Municipality should consider implementing more climate adaptation measures focusing on increasing the adaptive capacity of the vulnerable community. These projects carry a low risk of maladaptation and create more benefits to the vulnerable community even in the absence of climate change impact
- More attention should be taken when designing projects (such as cost-benefit analysis) that focus on reducing sensitivity and exposure to climate change to reduce the risk of maladaptation
- Further research is required to establish the extent to which the Buffelsdraai Reforestation project influences the increase in the cost of land near the project, and how it was affecting the vulnerable community.

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Appendix 4.1: Introductory letter

UNIVERSITY OF TWENTE.

eThekwini Municipality
Environmental Planning and Climate Protection Department
166 KE Masinga Road
Durban, South Africa

FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

FROM	DATE	PAGE
Dr. A.M. Madureira	8 January 2020	1 of 1
E: m.madureira@utwente.nl	OUR REFERENCE	
T: +31534898014	002 MM/pw	

SUBJECT
Introductory Letter for Mulimba Yasini

Dear Sir/Madam

I am writing to you to introduce Mr. Mulimba Yasini, who is currently a Master of science (MSc) student in the Department of Urban and Regional Planning and Geo-information Management (ITC-PGM), of the University of Twente, in the Netherlands.

Mr Mulimba Yasini will be conducting a field research, as part of his MSc thesis, on "social vulnerability and climate adaptation action" in Durban City (eThekwini municipality), South Africa. His research will involve interviews with Municipality officials, climate change experts from the local university, and NGOs representatives and community members involved in climate change activities.

Any assistance rendered to him from your side will be greatly appreciated. I am available for further inquires regarding this student and his field research.

Yours sincerely,

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The Netherlands

Appendix 4.2

INFORMED-CONSENT FORM FOR MSC RESEARCH PROJECT

_____

INTRODUCTION

I am a Master of Science (MSc) student at the Faculty of Geo-information science and earth observation (ITC) at the University of Twente in the Netherlands. I am carrying out research to establish "how adaptation actions and measures in Durban are related to social vulnerability". The information that will be collected from this research will be used for academic purposes only and the identities of the respondents will not be disclosed. You may refuse to answer any particular question and leave the interview at any moment. The interview will take approximately sixty minutes. In the first half, I will ask several questions about the planning process through which adaptation plans were created by the eThekwini Municipality. In the second half, I will ask some questions about the outcomes of adaptation measures implemented by the Municipality. In this interview, adaptation measures refer to programmes or projects implemented in Durban city by the Municipality aimed at mitigating climate change and reducing social vulnerability. Socially vulnerable groups refer to the most vulnerable and marginalized groups in Durban, such as low-income households, children, women, elderly, disabled, and ethnic minorities.

Before we start the interview, I would like to request you to sign this informed consent form. Please take your time to read through it, and let me know if you have any questions.

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [*DD/MM/YYYY*], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
I understand that taking part in the study involves an audio-recorded interview and written notes. The recording will later be transcribed as text and the recordings will be deleted.	☐	☐
Use of the information in the study		
I understand that information I provide will be used for academic purposes only and my identity will not be disclosed.	☐	☐
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	☐	☐
Future use and reuse of the information by others		
I permit the transcribed text data that I provide to be archived in the university database (where personal information is not identifiable) so it can be used for future research and learning.	☐	☐

Signatures

_____   _____ _____
Name of participant (s) [printed]   Signature   Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability ensured that the participant understands what they are freely consenting.

_____   _____   _____
Researcher name [printed]   Signature   Date

Study contact details for further information: Mulimba Yasini,
 m.yasini@student.utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant or wish to obtain information, ask questions or discuss any concerns about this study with someone other then the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-bms@utwente.nl

Appendix 4.3:

INTERVIEW GUIDE FOR MUNICIPALITY OFFICIALS
_____

Introduction

I am an MSc student at the Faculty of Geo-information science and earth observation (ITC) at the University of Twente in the Netherlands. I am carrying out research to establish "how adaptation actions and measures in Durban are related to social vulnerability". The information that will be collected from this research will be used for academic purposes only and the identities of the respondents will not be disclosed. You may refuse to answer any particular question and leave the interview at any moment. The interview will take approximately thirty-five minutes. I will ask some questions about the outcomes of adaptation measures implemented by the Municipality. In this interview, adaptation measures refer to programmes or projects implemented in Durban city by the Municipality aimed at mitigating climate change and reducing social vulnerability. Social vulnerability is defined as *"a measure of sensitivity and lack of adaptive capacity to a number of natural hazards"* (Reckien, 2018, p.1439). Socially vulnerable groups refer to the most vulnerable and marginalized groups in Durban, such as low-income households, children, women, elderly, disabled, and ethnic minorities. Before we start the interview, I would like to request you to sign the informed consent form. Please take your time to read through it, and let me know if you have any questions. Is it okay with you if this interview is recorded?

Do you have any questions or comments before we continue with the interview? I will now start the recording.

Personal Information

I will start with a few general questions on your role in climate adaptation planning and implementation.

1. Date and time of interview (interviewer to indicate)_____
2. Gender (interviewer to Indicate)_____

3. Full name (interviewer to Indicated)_____
4. What is your current position in the Municipality?
5. How long have you worked for eThekwini Municipality?
6. How long have you been involved in climate change adaptation planning?

Adaptation Outcomes

The next set of questions will focus on the outcomes of the adaptation measures implementation in Durban city by the Municipality.

Climate change adaptation measures

Durban city has been identified as one of the cities in the Global South (developing countries) that has successfully implemented climate adaptation measures (programmes or projects).

7. Which climate adaptation programmes or projects have been implemented in Durban city by the Municipality in the last 10 years?
8. Where are these projects/programmes located (*to indicate on the table/map provided)?*
9. What are the main reasons/factors that were considered in the selection of the location of each project/programme?
10. What is the target population (target beneficiaries) for the specific programmes/projects?

Achievements of the Adaptation measures

These next few questions will consider the achievements of adaptation measures implemented by the Municipality regarding the planned objectives or targets.

11. What are the main objectives of the specific programmes/projects implemented by the Municipality in the Durban city?
12. Have the objectives or targets for the specific climate adaptation measures been achieved?
    a. if yes: what are the main achievements?
13. If some of the objectives were not achieved, what are the main reasons?

Secondary benefits (Co-benefits)

Besides the targeted objectives, adaptation measures can create co-benefits to the local people such as employment opportunities, income-generating activities, acquisition of new skills, or enhancing local knowledge on climate change.

14. What co-benefits did the adaptation measures implemented by the Municipality create for the socially vulnerable groups?
15. Have there been improvements in terms of access to social services or basic infrastructure improved as a result of the implementation of adaptation measures?

    a. If yes, specify (e.g. improved health services, clean water, waste management)

Negative consequences (maladaptation)

Adaptation measures can sometimes adversely affect (maladaptation) the vulnerable groups such as displacement, increase in house rentals, or increase in the cost of public transport.

16. Has there been the displacement of the local people or increase in the cost of accommodation (e.g. due to gentrification) as a result of the implementation of adaptation measures?
17. What other adverse effects on the vulnerable community are attributed to the implementation of climate adaptation measures?

Concluding Remarks

18. Do you have any other information that you would like to add?

19. Do you know any people or organizations that could provide valuable input for our research?
20. Do you have the resources containing information about the adaptation plans or projects you can share (e.g. policy documents, NGO or research publications, promotion videos)
21. **I will now end the recording,**
22. **Thank you for your time.**

Appendix 4.4

INTERVIEW GUIDE FOR CLIMATE EXPERTS & NGOs
_____

Introduction

I am an MSc student at the Faculty of Geo-information science and earth observation (ITC) at the University of Twente in the Netherlands. I am carrying out research to establish "how adaptation actions and measures in Durban are related to social vulnerability". The information that will be collected from this research will be used for academic purposes only and the identities of the respondents will not be disclosed. You may refuse to answer any particular question and leave the interview at any moment. The interview will take approximately thirty-five minutes. I will ask some questions about the outcomes of adaptation measures implemented by the Municipality. In this interview, adaptation measures refer to programmes or projects implemented in Durban city by the Municipality aimed at mitigating climate change and reducing social vulnerability. Social vulnerability is defined as _"a measure of sensitivity and lack of adaptive capacity to several natural hazards"_ (Reckien, 2018, p.1439). Socially vulnerable groups refer to the most vulnerable and marginalized groups in Durban, such as low-income households, children, women, elderly, disabled, and ethnic minorities. Before we start the interview, I would like to request you to sign the informed consent form. Please take your time to read through it, and let me know if you have any questions. Is it okay with you if this interview is recorded?

Do you have any questions or comments before we continue with the interview? I will now start the recording.

Personal information

The first few questions under this section are about the general information and your role in climate adaptation activities in Durban city.

1. Date and Time (indicate)_____
2. Gender of the interviewee (indicate)_____
3. Name of the interviewee? (Indicate)_____
4. How long have you worked for your organization/institution?_____
5. What is your role in your organisation?_____

Climate Adaptation Measures

The next set of questions will focus on the outcomes of the adaptation measures implementation in Durban city. Climate change adaptation measures Durban city has been identified as one of the cities in the Global South (developing countries) that has successfully implemented climate adaptation measures. Which climate adaptation measures (programmes or projects) have been implemented in Durban city by the Municipality (or in partnership with the municipality) in the last 10 years?

Could you specify the areas/wards where the projects you have identified have been implemented?

6. What would you say are the main reasons/factors that were considered in the selection of the location of each project/programme you have mentioned?

Achievements of the climate adaptation measures

This next set of questions will consider the achievements of the objectives and possible reasons for not achieving the objectives of the adaptation programmes or projects implemented by the Municipality.

7. What would you say are the main objectives or targets of the specific climate adaptation projects or programmes implemented by the Municipality in the Durban city?
8. What do you see as the main achievements of adaptation projects or programmes regarding the planned objectives?
9. Are there certain objectives that have not been achieved?
10. If yes: What would you say are the major reasons the intended objectives were nor achieved?

Co-benefits of the adaptation measures

Besides meeting the intended objectives or targets, adaptation projects or programmes can create co-benefits to local people such as employment opportunities, income-generating activities, development of vocational skills, access to social facilities, or improvement of the local environment.

11. What do you see as the co-benefits of climate adaptation projects or programmes to the socially vulnerable groups in Durban city?

Negative consequences (maladaptation) of the adaptation measures

Implementation of adaptation measures can also adversely affect (maladaptation) the vulnerable groups such as displacement, increase in house rentals, or increase in the cost of public transport.

12. Are there community members that have been relocated or displaced as a result of the implementation of climate adaptation projects or programmes by the Municipality in Durban city?
13. If yes: How has this impacted the lives of the vulnerable groups?

Concluding remarks
14. Do you have any other information that you would like to add?
15. Do you have booklets or pictures that I can use to support my research?
16. Do you know any people or organizations that could provide valuable input for our research?
17. **End of interview. Thank you for your time.**

Appendix 4.4

FOCUS GROUP DISCUSSION GUIDE
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Introduction

I am an MSc student at the Faculty of Geo-information science and earth observation (ITC) at the University of Twente in the Netherlands. I am carrying out research to establish "how adaptation actions and measures in Durban are related to social vulnerability". The information that will be collected from this research will be used for academic purposes only and the identities of the respondents will not be disclosed. You may refuse to answer any particular question and leave the interview at any moment. The interview will take approximately thirty-five minutes. I will ask some questions about the outcomes of adaptation measures implemented by the Municipality. In this interview, adaptation measures refer to programmes or projects implemented in Durban city by the Municipality aimed at mitigating climate change and reducing social vulnerability. Before we start the interview, I would like to request you to sign the informed consent form. Please take your time to read through it, and let me know if you have any questions. Is it okay with you if this interview is recorded? Do you have any questions or comments before we continue with the interview? I will now start the recording.

General questions
1. Indicate date and time of meeting:_____
2. Indicate the names of participants:_____

3. Indicate Gender_____

Introductory questions

Durban city has been identified as one of the cities adversely affected by climate change-related impacts due to its location and socio-economic factors.

1. Have you ever heard the term Climate change?

   a. If yes, what do you understand by climate change?

   b. if not (the interviewer briefly explains the meaning of climate change and its impacts).

2. Which of these climate change-related impacts has been experienced in your areas for the past 10 years? *(participants to place stickers to identify the most occurring event) :*

   a. flooding,

   b. heatwave (very high temperature)

   c. drought

3. How did flooding, heatwave, or drought affect your daily activities or life in general?

4. What measures have your community taken to prepare for the impacts of flooding, drought, or heat waves?

Achievement of adaptation measures

The eThekwini Municipality has implemented different climate adaptation projects or programmes in Durban city for the past 10 years aimed at preventing flooding, reducing the impact of drought or heat waves on the local people.

5. Which climate adaptation programmes or projects have been implemented by the Municipality in your area for the past 10 years?

6. What are the main objectives (purposes) of these adaptation projects or programmes?

7. Would you say the adaptation projects or programmes implemented by the Municipality in your area have achieved the intended objectives or not?

   a. If yes: What do you see as the key achievements?

   b. If not: Could you indicate possible reasons for these results?

Co-benefits of adaptation measures

Besides achieving the intended objectives, climate adaptation projects or programmes can create other benefits (co-benefits) to local people such as employment opportunities, income generation activities, vocational skills, access to social facilities, or improvement of the local environment (green space).

8. What has improved or changed in your area, your life, or your family as a result of the implementation of the climate adaptation projects or programmes by the Municipality?

9. Did you or members of your household benefit (e.g. employment opportunities, vocational training, or income-generating activities) from the climate adaptation projects or programmes implemented by the Municipality?

Negative consequences (maladaptation) of climate adaptation measures

Climate adaptation projects or programmes can also adversely affect local people. (e.g. relocation/displacement, increased cost of public transport or increased cost of housing rentals).

10. Have you, family members, or the community been adversely affected in any way by the implementation of climate adaptation measures in your area? If yes, how have you been affected:

Concluding remarks

4. Do you have anything that you wish to add to our discussion?

5. If you would like to have feedback on what we have discussed, you can contact me later through WhatsApp number or email address which I will provide *(indicate WhatsApp number or email address)*

6. **End of discussion: Thank you for your contribution (***Interviewees to be given small presents, e.g. ITC keyholders***)**

Appendix 4.6.

SELF ADMINISTERED QUESTIONNAIRE- MUNICIPALITY OFFICIALS

Introduction

I am an MSc student at the Faculty of Geo-information science and earth observation (ITC) at the University of Twente in the Netherlands. I am carrying out research to establish "how adaptation actions and measures in Durban are related to social vulnerability". The information that will be collected from this research will be used for academic purposes only and the identities of the respondents will not be disclosed. You may refuse to answer any particular question and leave the interview at any moment. The interview will take approximately thirty-five minutes. I will ask some questions about the outcomes of adaptation measures implemented by the Municipality. In this interview, adaptation measures refer to programmes or projects implemented in Durban city by the Municipality aimed at mitigating climate change and reducing social vulnerability. Social vulnerability is defined as *"a measure of sensitivity and lack of adaptive capacity to several natural hazards"* (Reckien, 2018, p.1439). Socially vulnerable groups refer to the most vulnerable and marginalized groups in Durban, such as low-income households, children, women, elderly, disabled, and ethnic minorities.

Before we start the interview, I would like to request you to sign the informed consent form. Please take your time to read through it, and let me know if you have any questions. Is it okay with you if this interview is recorded?

Do you have any questions or comments before we continue with the interview? I will now start the recording.

Personal Information

I will start with a few general questions on your role in climate adaptation planning and implementation.

1. Date and time of interview (interviewer to indicate)_____

2. Gender (interviewer to Indicate)_____

3. Full name (interviewer to Indicated)_____

4. What is your current position in the Municipality?

5. How long have you worked for eThekwini Municipality?

6. How long have you been involved in climate change adaptation planning?

Adaptation Outcomes

The next set of questions will focus on the outcomes of the adaptation measures implementation in Durban city by the Municipality.

Climate change adaptation measures

Durban city has been identified as one of the cities in the Global South (developing countries) that has successfully implemented climate adaptation measures (programmes or projects).

7. Which climate adaptation programmes or projects have been implemented in Durban city by the Municipality in the last 10 years?

Climate adaptation projects/programmes	Tick (where appropriate)
Buffelsdraai community reforestation project	
Green Corridors Green Spaces project	
Palmiet pilot projects	
Sihlanzimvelo Project	
Aller river pilot project	
Ighaza Lethu (our initiative) slum upgrading project	

8. Where are these projects/programmes located (*to indicate on the table/map provided)?*

Climate adaptation projects/programmes	Location	
	Settlement name	Ward number
Buffelsdraai community reforestation project		
Green Corridors Green Spaces project		
Palmiet pilot projects		
Sihlanzimvelo Project		
Aller river pilot project		
Ighaza Lethu (our initiative) slum upgrading project		

9. What are the main reasons/factors that were considered in the selection of the location of each project/programme?

Climate adaptation projects/programmes	Reasons/factors considered for choosing project location
Buffelsdraai community reforestation project	
Green Corridors Green Spaces project	
Palmiet pilot projects	
Sihlanzimvelo Project	
Aller river pilot project	
Ighaza Lethu (our initiative) slum upgrading project	

10. What is the target population (target beneficiaries) for the specific programmes/projects?

Project name	Target Beneficiaries	Number of Beneficiaries		
		Male	Female	Total
Green Corridors Green Spaces project				
Aller river project				
Sihlanzimvelo Project				
Buffelsdraai reforestation project				
Palmiet Catchment Rehabilitation Project,				
Ighaza Lethu (our initiative) slum upgrading project				

Achievements of the Adaptation measures

These next few questions will consider the achievements of adaptation measures implemented by the Municipality regarding the planned objectives or targets.

11. What are the main objectives of the specific programmes/projects implemented by the Municipality in the Durban city?
12. Have the objectives or targets for the specific climate adaptation measures been achieved?
    a. if yes: what are the main achievements?
13. If some of the objectives were not achieved, what are the main reasons?

Climate adaptation measures	Objectives or targets	Achievements	Reasons for no-achievements
Green Corridors Green Spaces project			

Aller river project			
Sihlanzimvelo Project			
Buffelsdraai reforestation project			
Palmiet Catchment Rehabilitation Project,			
Ighaza Lethu slum upgrading project			

Secondary benefits (Co-benefits)

Besides the targeted objectives, adaptation measures can create co-benefits to the local people such as employment opportunities, income-generating activities, acquisition of new skills, or enhancing local knowledge on climate change.

14. What co-benefits did the adaptation measures implemented by the Municipality create for the socially vulnerable groups?

15. Have there been improvements in terms of access to social services or basic infrastructure improved as a result of the implementation of adaptation measures?

    a. If yes, specify (e.g. improved health services, clean water, waste management)

Negative consequences (maladaptation)

Adaptation measures can sometimes adversely affect (maladaptation) the vulnerable groups such as displacement, increase in house rentals, or increase in the cost of public transport.

16. Has there been the displacement of the local people or increase in the cost of accommodation (e.g. due to gentrification) as a result of the implementation of adaptation measures?

17. What other adverse effects on the vulnerable community are attributed to the implementation of climate adaptation measures?

Concluding Remarks

18. Do you have any other information that you would like to add?
19. Do you know any people or organizations that could provide valuable input for our research?
20. Do you have the resources containing information about the adaptation plans or projects you can share (e.g. policy documents, NGO or research publications, promotion videos)
21. **I will now end the recording,**
22. **Thank you for your time.**

Appendix 4.7: Factors contributing to social vulnerability to climate change in Durban city

Dimension	Indicators	Description and justification	Contribution to social vulnerability
Sensitivity			
Demographic factors	Children under 5 years old	Percentage of children under the age of five years (Apotsos, 2019). Children are adversely affected by climate change impacts such as flooding and heatwave. For example, flooding is often associated with outbreaks of diseases that easily affect children. similarly, the heatwave has a health effect on the lives of children(Breil et al., 2018). Therefore the factor is assigned a positive contribution.	Positive (+)
	65 years old and above	Percentage of residents who are 65 years and above (Apotsos, 2019). Just like children, old people are adversely affected by climate change-related impacts such as floods and heatwaves. Therefore, this factor is to assign a positive contribution to social vulnerability	Positive (+)
	Female-headed households	Percentage of households where the head of the household is female (Apotsos, 2019). Women, in particular, female-headed households face difficulties to recover from climate change impacts (e.g. flooding, drought) due to inadequate financial resources, multiple responsibilities, and physiological characteristics (Shirley et al., 2003).	Positive (+)
	Black population	Percentage of persons who are black (Apotsos, 2019). Due to the history of apartheid, the black population in South Africa is mainly settled in areas that are susceptible to flooding and other climate change hazards, and with less access to social facilities (Shirley et al., 2003; Apotsos, 2019).	Positive (+)
	Non-Citizens	Percentage of residents who are not citizens of South Africa (Apotsos, 2019). Residents who are not South African citizens may have challenges accessing aid or information related to climate change impacts due to the language barrier (Shirley et al., 2003). Therefore, they are more vulnerable to climate change-related impacts.	Positive (+)

Adaptive capacity			
Socio-economic factors	IsiZulu language	Percentage of residents who speak IsiZulu (Apotsos, 2019). This factor contributes to vulnerability in those people that do not speak the official language (English in the case of South Africa) may have problems understanding climate change messages written in English (Breil et al., 2018). This affects their ability to prepare and recover from climate change impacts.	Positive (+)
	IsiXhosa language	Percentage of the residents who speak IsiXhosa language (Apotsos, 2019). People that do not speak the official language (English in the case of South Africa) may have problems understanding climate change messages written in English (Breil et al., 2018). This affects their ability to prepare and recover from climate change impacts.	Positive (+)
	Other African languages	Percentage of residents who speak other African languages (Apotsos, 2019). People who cannot speak the local language may have difficulties accessing health facilities or support in case of flooding or other climate-related impacts (Breil et al., 2018). This, therefore, affects their ability to prepare and recover from climate change impacts.	Positive (+)
	Sign language	Percentage of residents who use sign language due to difficulties in talking (Apotsos, 2019). This contributes to the vulnerability of persons using sign language to read climate change messages and thus affecting their ability to prepare and recover.	Positive (+)
	Low income	Percentage of persons between the ages of 25 and 65 years old earning less than eight hundred Rands (R800) per month. This indicator is assigned a positive contribution because a lack of income means a person cannot prepare or recover from climate-related impacts (Breil et al., 2018).	Positive (+)
	Unemployment	Percentage of persons aged between 25 and 65 years who are not employed (Apotsos, 2019). Unemployed people have no financial capacity to prepare or recover from climate change impacts such as floods (Breil et al., 2018).	Positive (+)
	Low education	Percentage of residents who are 20 years old and above who have not completed primary education (Apotsos, 2019). Low education is considered as	Positive (+)

		contributing to social vulnerability. Residents with low education may not have adequate knowledge to prepare or recover from climate change-related impacts (Shirley et al., 2003). Further, residents with low education are also unlikely to find good employment that can guarantee them sustainable income (Shirley et al., 2003; Holand et al., 2011)	
	Informal employment	Percentage of people employed in low-skilled jobs (e.g. informal business) (Holand et al., 2011). People who are employed in the informal sector (low skilled jobs) are more likely to lose their jobs/business in an event of flooding and thereby taking longer to recover (Holand et al., 2011).	Positive (+)
Built environment factors	Proximity to clinics	Measures the nearest distance to the clinics. " The lack of proximate medical services may delay immediate relief and prolong recovery. (Holand et al., 2011).	Negative (-)
	Proximity to health posts	A measure of the nearest distance to the health posts. " The lack of proximate medical services may delay immediate relief and prolong recovery. We, therefore, include distance to the nearest hospital as a further measure of lifelines" (Holand et al., 2011, p.6).	Negative (-)
	Proximity to rail stations	A measure of the nearest distance to the rail station. Proximity to railway facilities such as a station can serve as an exit point in case of evacuation due to flooding (Holand et al., 2011).	Negative (-)
	Proximity to public transport routes	A measure of the nearest distance to the public transport routes. Proximity to transport routes/roads can serve as an escape in case of evacuation or relief distribution routes in case of a disaster (flooding)	Negative (-)
Exposure			
Built environment factors	Population density	The ratio of population to the total area (square km) of the spatial unit (ward). Population density contributes positively to social vulnerability in that, in case of flooding, a high number of people will be adversely affected. Furthermore, the higher the number of people in a given area, the more difficult it is to evacuate in case of floods or other climate-related impacts (Holand et al., 2011; de Loyola Hummell, Cutter, & Emrich, 2016)	Positive (+)

	Type of dwelling	Percentage of housing that is informal (Apotsos, 2015). Informal housing is poor quality temporary structures made of plastic/metal sheets, wood, or mud bricks. These types of houses are easily destroyed during heavy floods and can be extremely hot during high temperatures (heatwaves) (Shirley et al., 2003). Therefore, people living in these type of houses are vulnerable to climate change impacts such as flooding and heatwaves	Positive (+)
Physical environment factor	Proximity to flood hazards	A measure of the nearest distance to the flood zone. Settlements located on or near the flood zones are more vulnerable to floods as compared to those located far away.	Positive (+)