CLIMATE CHANGE PROJECTIONS AND PUBLIC BEHAVIOUR TOWARDS ADOPTING INTEGRATED MITIGATION AND ADAPTATION APPROACHES AT A HOUSEHOLD LEVEL IN URBAN AREAS, THE ETHEKWINI MUNICIPALITY, KWAZULU-NATAL.

by

Preshantha Naicker

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Requirements for the degree of

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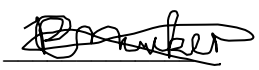
As the candidate's supervisor I have/have not approved this thesis/dissertation for submission.

Signed:  Name: Preshantha Naicker Date: 20/08/2018

ABSTRACT

Globally since the 1970s, the temperature has increased rapidly and remains unpredictable because of its accelerating pace (Thompson, 2010). This has increased the frequency and intensity of daily temperature, together with humidity and extreme heat waves. This has further resulted to increased heat-mortality and decreasing cold-related deaths; extreme flooding; droughts and/or extreme wildfires in some locations. Urban areas around the round are not free from such climate change impacts, and could be compounded with project climate change. Against this backdrop, the aim of this study is to evaluate local climate projections against past, current and future trends and to evaluate public behaviour towards adopting integrated climate change mitigation and adaptation approaches at a household level in urban areas, in the eThekwini Municipality, KwaZulu-Natal Province, South Africa.

To achieve this aim of this study, temperature, precipitation, and humidity anomaly trends in the eThekwini Municipality from were 1957-2014 were evaluated. Representative Concentration Pathways (RCP) 8.5 W/m^{-2} radiative forcing from the Climate Systems Analysis Group (CSAG) was used to evaluate projected mean annual trends in maximum and minimum temperature, and precipitation. RCP 8.5 W/m^{-2} radiative forcing was also used to identify mean monthly anomaly trends for maximum and minimum temperature, precipitation, hot days, dry spells and heat stress for the years 2016-2090. The radiative forcing of 8.5 W/m^{-2} is the projected future condition of extreme warming and predicts that mitigation alone will not change the circumstances of global warming and local climate change. The projections are based on an increasing population growth, the lowest rate in the development of technology, high poverty, and increasing emissions. The projected results reveal that the eThekwini Municipality will continue to undergo fluctuating trends in maximum and minimum temperature, precipitation, and humidity and this will exacerbate future projected heat stress, heat spells, dry spells and hot days.

The synergy between mitigation and adaptation is necessary to avoid the extreme impacts of climate change. The urban household sector is argued to drive climate change action and build adaptive capacity to risks that are unavoidable. To assess public behaviour towards adopting integrated climate change mitigation and adaptation approaches, 100 questionnaires were distributed to urban households in the eThekwini Municipality. Key informants from the Environmental Planning and Climate Protection Department (EPCPD) and South African Weather Service (SAWS) were also interviewed on various aspects of climate change. This was supplemented by focus group interviews with delegates from the Durban Adaptation Charter and Climate Reality Workshop,

The assessment of public behaviour and responses towards adopting integrated mitigation and adaptation approaches at a household level in urban areas show that short-term curtailment measures overarch long-term efficient measures. Urban households have demonstrated some level of awareness

towards climate change and its associated impacts. It was found that local perceptions and behavioural responses to mitigate and adapt to climate change was shaped by governmental institutions and their involvement within urban communities in the eThekwini Municipality. Transformational and integral theories hold significance in changing the old dynamics of incremental, business-as-usual approaches into a proactive integration of mitigation and adaptation. This is a new approach to understanding that the rate of climate change is progressing, and transformational change is required in national and regional policy, which can invoke change at a local level and change urban household perceptions and responses to climate change.

PREFACE

The work described in this dissertation was carried out in the School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal from 2014 to 2018 under the supervision of Dr Ngetar Njoya.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.

DECLARATION- PLAGIARISM

I, Preshantha Naicker, declare that:

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs or other information unless specifically acknowledged as being sourced from other persons.

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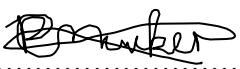
Signed:  ……

LIST OF ABBREVIATIONS

ASR	Absorbed Solar Radiation
BBC	The British Broadcasting Commission
CBA	Community-Based Approaches
CBD	Central Business District
CDM	Clean Development Mechanism
CEBAA	Community Ecosystem-based Adaptation Approach
CERS	Certified Emissions Reductions
CH_4	Methane
CIP	Climate Information Portal
CPC	Climate Protection Campaign
COP	Conference of the Parties
CRGES	The Climate Resilient Green Economy Strategy
CSAG	Climate Systems Analysis Group
DAC	Durban Adaptation Charter
DANIDA	The Danish International Development Agency
DEAT	Department of Environmental Affairs and Tourism
D'MOSS	Durban Metropolitan Open Space System
EMP	Environmental Management Plans
EPCPD	Environment Planning and Climate Protection Department
EPCPP	Environmental Planning and Climate Protection Programme
ET	Emissions Trading
GCF	The Green Climate Fund
GCM	General Circulation Models

GHG	Greenhouse Gases
IMO	International Meteorological Organization
IND	Intended Nationally Determined Contributions
IPCC	International Panel for Climate Change
ISWA	The International Solid Waste Association
LCA	Long-term Corporative Action
LDC	Least Developed Countries
N	Nitrogen
NCCRP	National Climate Change Response Plan
N_2O	Nitrous Oxide
NRC	National Research Council
O_2	Oxygen
PPM	Parts per a Million
RCP	Representative Concentration Pathways
SAR	Second Assessment Report
SE	Socio-Ecological
ST	Socio-Technical
TAR	Third Assessment Report
TERI	The Energy and Resources Institute
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework for Climate Change Convention

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Chapter 1

Introduction

1.1 Background to the study

Climate change can be defined as the long-term trends in the increase of global and regional average mean temperatures, precipitation, and humidity described by its quantitative mean, and changes in the intensity and frequency of climate ranging from months, decades to centuries (Lineman, Do, Kim & Joo, 2015; Thornton, Ericksen, Herrero & Challinor, 2014). According to Joubert (2009) greenhouse gases (GHGs) and trace gases, driven by human activities, found in the earth's atmosphere drive the greenhouse effect, trapping the suns solar energy as heat and warming the earth's surface. These processes drastically alter the natural cycle of the earth's weather patterns by emitting parts per million (ppm) of chemicals into the air and the absorption of gigatons of anthropogenic carbon by the ocean.

Globally since the 1970s, the temperature has increased rapidly and remains unpredictable because of its accelerating pace (Thompson, 2010). This has also caused an imbalance in precipitation trends. Temperature and precipitation are interconnected since an increase in temperature causes an increase in evaporation, leading to cloud formation and heavy precipitation (Karmeshu, 2012). The frequency and intensity of daily temperature, together with humidity and extreme heat waves have doubled, with increasing heat-mortality and decreasing cold-related deaths, extreme flooding, droughts and/or extreme wildfires in some locations (IPCC, 2014). The changes undergone by the earth show the effect of warming at a faster rate than what is being projected. The observed data published by the Intergovernmental Panel on Climate Change (IPCC) is argued to be independent of the 1990 observed data since projected models are physics-based and not functionally accurate to produce recent temperatures (Rahmstorf et al., 2007).This is especially true since sea-level data was not available at that time, which could mean that the climate is warming up at a faster rate than is projected (Rahmstorf et al., 2007).

Due to the uncertainty surrounding the magnitude and frequency of climate change impacts, it is becoming increasingly important to address this phenomenon using climate change projections to inform mitigation and adaptation in urban areas, at a household level (Bhat, Haran, Terando & Keller, 2011). Climate change is institutionalised in a very socio-economic and political context which influences how well a system mitigates and adapts to the adverse impacts of climate change (Thornton et al., 2014). International conventions and instruments have failed to deliver on commitments to mitigating climate change. The weakness of the non-binding nature of the agreement and compliance through market-based measures have failed to produce adequate results (Bausch & Mehling, 2011; Barrett, 2009). Since the inception of the Kyoto Protocol Treaty in 1997, developed nations, and

members of the United Nations Framework on Climate Change Convention (UNFCCC) have not decreed binding emission targets for the year 2020 but have agreed to cut their emissions of 80% by 2050 (Jonathan, 2009). Barrett (2009) states that for an international treaty to be successful, it is imperative that three conditions are fulfilled: Firstly, there must be full corporation of the majority of parties, including the United States, the European Union, India, Japan, China, and Russia. Secondly, there must be compliance and lastly, the incorporation of both participation and compliance conditions within a treaty. The inadequacies can be identified in events that have shaped international climate change negotiations.

Climate science has kept the global mean temperature rise within 2ºC of pre-industrial levels, which narrows the scientific and political objectives of what could be achieved on a much larger scale (Knopf et al., 2012). According to Bausch & Mehling (2011), the meeting of developed and developing countries at Copenhagen in December 2009, did not formalize an agreement by parties on the decision to mitigate GHGs. The meeting failed to reach a decision, exposing the challenge being faced by nations to stabilize long-term GHGs. The Kyoto Protocol treaty produced in December 1997, while recognized as a binding treaty, witnessed the non-compliance of the protocol by the largest emitters being the United States, China, and India (Althor, Watson & Fuller, 2016). The weakness of the non-binding agreement was weakened further by countries asking for the restrictions to be lifted compromising the environmental values and authority of the treaty (Barrett, 2009).

On a local level, McCarney, Blanco, Carmin & Colley (2011) discussed the need for urban governance of climate change to acquire an integrated approach that is recognized by the international community to give autonomous responsibility from national and provincial spheres to local government to create their own climate agendas. This is because much of the exposure of individuals to climate change hazards and its direct and indirect impacts will require an approach that integrates mitigation and adaptation on a large scale that is not limited to the idea of a 2ºC temperature target. Developed countries will be less affected than developing countries since they have financial resources at their disposal, and their mitigation and adaptation measures are currently in place (Chambwera & Stage, 2010).

This study evaluates projected climate change variables of temperature, precipitation, and humidity to explore past, present and projected dynamics of climate variables in relation to urban climate change mitigation and adaptation in the eThekwini Municipality. The extremity of changing weather patterns that can pose a threat to the health of ecosystems and human beings is also evaluated to assess urban vulnerability to climate change impacts and propose interventions that will likely decrease urban household vulnerabilities.

1.2 Concepts and definitions

The IPCC defines climate change as the change of climate over time, whether it is due to natural variability or human activities (Gitay, Suarez, Watson & Dokken, 2002). The UNFCCC expands the IPCC definition, defining climate change "as the change of temperature driven by human activities to the global atmosphere, including natural climate variability observed over comparable periods" (Gitay et al., 2002). Schulze (2011) differentiates climate variability from climate change maintaining that climate variability is reversible and shows trends of a negative or positive deviation from the long-term expected values of temperature, precipitation and dry periods. An example of local variability would be the droughts associated with the El Nino- Southern Oscillation phenomenon. While climate change is irreversible and overlaps the naturally occurring variability, for example, anthropogenic global warming is an effect of the increased temperature from decades to centuries linearly (Schulze, 2011). Climate change and climate variability can produce severe thresholds that can bring about extreme weather conditions resulting in heavy floods and droughts that can become injurious to health.

The increase of GHG emissions by fossil-fuel burning are the catalysts of climate change and are mainly associated with industrialized countries of the north (the United Kingdom, the United States, and Canada). Knopf et al (2012) and Victor & Kennel (2014) refer to a 2ºC temperature benchmark as pretentious and a metaphor that is compressed into a digit to debate a global phenomenon of current weather conditions to suit international political ambitions. There is no way, in which to quantify how much of anthropocentric interference is contributing to climate change and how much of that change is influenced by global warming (Knopf et al., 2012).

Vulnerability is defined in this study as “the degree to which a system is susceptible to or unable to cope with the adverse impacts of a changing climate, including climate variability and its extremes” (Gitay et al., 2002, p 4). Urban vulnerability is defined by Solecki et al. (2015) as a function of three indicators which includes hazards exposure, sensitivity, and adaptive capacity. Solecki et al. (2015) explains each term as (i) Hazards being stresses and changes that affect a system's capacity to cope and interact with their socio-economic and environmental systems; (ii) sensitivity is the degree to which an urban population is impacted on by a climate hazard; and (iii) adaptive capacity is the ability of an urban population to avoid or minimize the negative consequences of climate change. These concepts provide insights into the conditions of an individual’s capacity to cope (Yohe et al., 2006).

Cities and urban households are identified as affluent drivers in the climate debate and will be discussed as the action center where transformational processes can take formation. The socio-technical (ST) behaviour of mitigation explores the social and technical processes through sustainable approaches, while the adaptation of socio-ecological (SE) systems research draws attention to how

systems respond to climate change and the need for increased adaptive capacity of society and ecosystems (Gillard, Gouldson, Paavola & Van Alstine, 2016). The adaptive capacity of individuals can be defined as urban resilience, the ability of a city or urban system to absorb risks, while still composing its identity, structure, and processes (Leichenko, 2011).

Climate-resilient pathways are defined as development trajectories that manage changes through transformation action beyond business-as-usual, incremental response approaches to achieve sustainable development and integrated mitigation and adaptation (Denton et al., 2014).The transformational theory can be defined as a radical change that is large-scale (Bahadur, 2012) and aiming towards long-term sustainability. For example, Kvamsas (2012) presents the scenario of a +4ºC increase in temperature, having severe implications for the socio-ecological systems of countries, especially in Southern Africa, in which systems (social, economic, institutional, ecological) will fail and shift from incremental to transformative approaches (New, Liverman, Schroder & Phil, 2011). The use of such scenarios has enabled scientists and academics to plan towards unpredictable and extreme climate events in the future (Hunt, Maslin, Killeen, Backlund & Schellnhuber, 2007).

General Circulation Models (GCM) are mathematical models that simulate large-scale changes that occur in the atmosphere and oceans, linking the large-scale climate variable properties of temperature and precipitation to local and regional climate variables (IPCC, 2007; Hewitson & Crane, 2006). GCM can be defined as statistical computational advancements of past, present and future forecasting of weather (Thoeun 2015; MacKellar, New & Jack 2014; Teichmann et al., 2013). Based on this method, trends have been projected from the 1950s to 2100. This gives humanity the tool to prepare in advance for immediate or future related impacts through mitigation and adaptation.

Mitigation and adaptation is a contested combination with its pros and cons, but this study argues for an integrated approach of the two, focusing on the need to understand its impacts on people and its propensity to transform local policy, using transformational tools. However, mitigation and adaptation are two separate strategies. Mitigation is a proactive process to minimize GHG emissions by carbon sink interventions, while adaptation is a reactive process that protects people and their resources against risks (Thompson, 2010). The climate change response strategy of South Africa supports transformational change by incorporating climate change and development in local policy toward a low-carbon economy (Beaumont, 2012). Although, mitigation is seen as the main driver for mitigating GHGs, Locatelli, Fedele, Fayolle & Baglee (2016) states that adaptation is still separated within international and national policies, and through allocated financial resource e.g. Locatelli et al. (2016) identified the Green Climate Fund (GCF) designed to increase the efficiency of funding for developing countries towards integrated mitigation and adaptation climate programmes, policies and projects, however, how it will be achieved is yet to be identified.

While adaptation might be used to reduce vulnerability to climate change stresses (e.g. heat waves), mitigation might be compromised e.g. the use of energy-intensive equipment to adapt to increased temperatures (Walsh et al., 2011). However, there are also synergies between mitigation and adaptation, for example, the planting of trees to sequester carbon and counteract the urban heat effect (Walsh et al., 2011). To understand climate change effects, it requires an in-depth study on the projections, thus giving a complete picture of the situation that can drive local action towards mitigation and adaptation.

This study evaluates the trends in projected climate variables of temperature and precipitation together with humidity, and its impact on urban households and resilience through coping measures, using mitigation and adaptation indicators. The attention to urban climate literature and international policy on climate change has been recognized both locally and internationally through mitigation and adaptation towards projected impacts of climate change (Broto & Bulkeley, 2013). By understanding the behavioural responses of how the political, social, and ecological system integrates mitigation and adaptation towards climate change, we can project how impacts will affect everyday life.

1.3 Motivation

Mitigation and adaptation working independently of each other will lack in its efforts against climate change impacts and developing countries will have to suffer the consequences. Despite the prevailing emphasis on mitigation policies, fossil-fuel combustion and industrial activities had accounted for 78% of GHGs between 1970 and 2010 (IPCC, 2014). On a global scale, economic and population growth are the two main drivers of the increase of Carbon Dioxide (CO_2) fossil-fuel combustion (IPCC, 2014). Campbell-Lendrum & Corvalán (2007) identified the main drivers of GHG emissions in 1990 as buildings accounted for 20% of GHG emissions, agriculture, and waste sector 18% in 1990, and projected to increase to 50% by 2020, while the transport sector 13%, is estimated to double by 2020. Campbell-Lendrum & Corvalán (2007) compare the GHG status of both developing and developed economies. The authors state that despite the historically low per capita of GHG emissions of developing countries to higher per capita GHG emissions of developed countries, developing countries are urbanizing at a faster pace with increasing consumption trends.

South Africa is a water scarce country faced with water shortages due to limited precipitation in the region between the months of January and December of 2015, receiving an annual average rainfall of 403 mm compared to previous years (Alberton Record, 2016). The British Broadcasting Commission (BBC) (2015) identified the 2015 drought as one of the worst events for South Africa in the last 30 years. The focus of this study is the eThekwini Municipality, where long-term drought, identified as the worst drought since 1982, has severely impacted on the local hydrological, socio-economic and ecological systems (British Broadcasting Commission, 2015). For example, the Hazelmere Dam, which supplies water to eThekwini Municipality's Northern areas and towns in the Southern areas was

reported to be as low as 27, 5% in 2015 (eNCA, 2015). The impact of the 2016 drought had left the Hazelmere Dam below 50%, as compared to other dams (Umgeni Water, 2016).

The passive participation of urban authorities and local stakeholders in the debate of urban climate change implies that policymakers are giving minimal attention to urban climate change issues (Joshua, Jalloh & Hachigonta, 2014). Urban activities drive GHGs directly (e.g. fossil-fuel consumption through industrial and transportation emissions) and indirectly (e.g. electricity and production and consumption of industrial and agricultural products) (Walsh et al., 2011).

As the scale of climate change exceeds projected science, a paradigm shift has occurred to use transformational approaches instead of incremental action to impose radical mitigation and adaptation approaches (Bahadur, 2012). Considering the scale of climate change impacts and the urban GHG footprint, the link between transformational approaches and sustainable development bring together goals that promote the integration of mitigation and adaptation on a large-scale. The current incremental approaches are recognized as an extension of risk management approaches to reduce vulnerability (Pelling, 2011), imported into the climate change discourse (Kates, Travis & Wilbrinks, 2012). Climate resilient pathway identifies the need for transformative responses that integrate mitigation and adaptation, rather than incremental "business-as-usual" approaches (Inderberg et al., 2015) e.g. ecosystem and community-based approaches used in one resource resilient area to help communities to cope with climate change can be beneficial in a similar environment elsewhere because of climate change (Wise et al., 2014).

Wilhelmi & Haydon (2009) argue that coping mechanisms is a measure of vulnerability and such information is yet to be collected at a household level. Hence, considering the magnitude of impacts of climate change to urban dwellers, addressing such conditions in urban communities is essential to understanding how sensitive people are to the effects of climate change. This includes how people cope with such changes in their socio-economically active environment.

1.4 Aim of the study

The primary aim of this study is to evaluate local climate projections against past, current and future trends. These include trends from the 1950s to 2014, and RCP 8.5 W/m^{-2} radiative forcing projections from 2016-2100. A secondary aim is to evaluate public behaviour towards adopting integrated climate change mitigation and adaptation approaches at a household level in urban areas, the case of the eThekwini Municipality, KwaZulu-Natal Province.

1.5 Objectives

To achieve the stated aim of this study, the following five objectives will be explored:

1. Determine past and current trends in temperature, humidity and precipitation
2. Determine the RCP 8.5 W/m^{-2} projected changes in temperature, precipitation, and humidity

3. Correlate projected and current trends in climate change
4. Evaluate community perception, mitigation and adaptation strategies towards climate change
5. Evaluate local governmental action and responses to climate change.

1.6 Research questions

The following questions will be addressed in the study:

1. What are the past and current trends in temperature, precipitation, and humidity?
2. What changes in climate variables were projected for the eThekwini Municipality areas?
3. Is there any correlation between past, current and future projected trends?
4. What are community perceptions on climate change, and what progress have they made in their efforts to implement mitigation and adaptation strategies towards climate change?
5. What has been the extent of local government action and responses to climate change?

1.7 Thesis outline

Having introduced the global and local concerns surrounding the phenomenon of climate change in chapter 1, Chapter 2 reviews literature concepts, theories and literature related to climate change and urban response to impacts. Concepts to be reviewed include global warming, climate change projections, impacts and the integration of transformational mitigation and adaptation to the urban household level, and urban household perceptions. Chapter 3 presents the methodology adopted in the study and relates to data collection and analysis. Chapter 4 presents an analysis of the results of historical, current and future trends of selected projected climate variables (temperature, precipitation, together with humidity). RCP 8.5 W/m^{-2} from 2016-2100 is to assess the conditions for temperature and precipitation. Chapter 5 addresses the knowledge and awareness of urban residents on climate change and its effects. It assesses people's behavioural responses in terms of their use of sustainable household mitigation and adaptation approaches. In addition, Chapter 5 evaluates the eThekwini Municipality's EPCCD response to climate change and the impact of those responses to creating climate-resilient pathways in urban communities. Chapter 6 concludes with a summary of the major findings of this study, recommendations and following with limitations.

Chapter 2

Literature Review

2.1 Introduction

According to Joubert (2009), evidence shows that changes to our climate system, referred to as climate change, is triggered by the greenhouse effect which has led to the increase of temperatures, above pre-industrial levels since the 1950s (Figure 2.1). Not only has the greenhouse concentration of gases increased from 280 parts per a million (ppm) in the mid-1700s to over 380 ppm, at a rate of the progression of CO_2. It took approximately 200 years for carbon dioxide to rise by 50 ppm but a shorter span of 30 years for the ppm to rise by the same amount (Joubert, 2009).

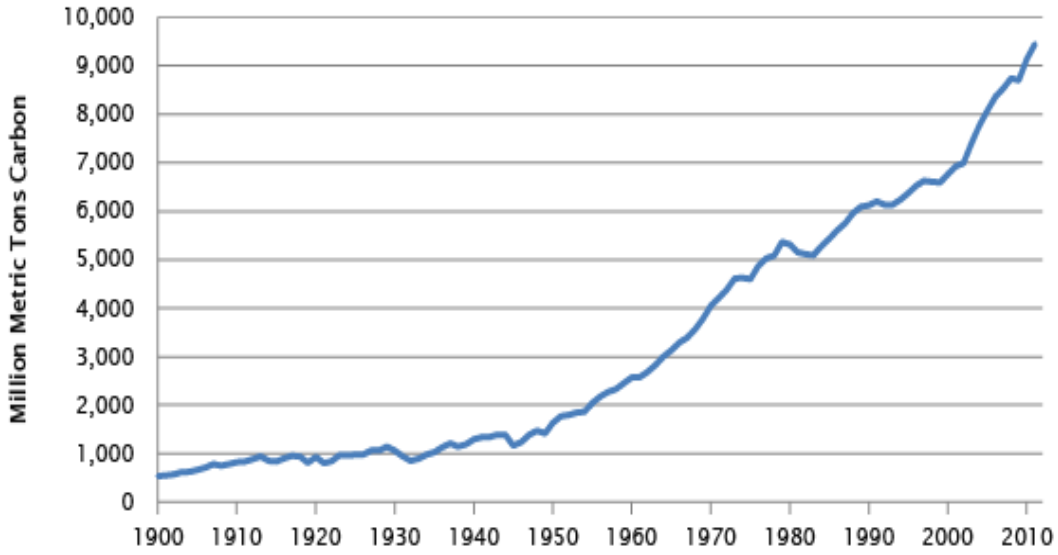

Figure 2.1 The global emission trends from1900 to 2010 **(**Boden, Marland & Andres, 2015) (as cited in United States Environmental Protection Agency, 2016).

It is evident that since the 1950s, an increase in CO_2 emissions fluctuated with evident peaks from the 1980s to 2010 (Figure 2.1). Hao, Ju, Jiang & Zhu (2013) identified that as the change of climate far exceeds the capacity of ecological and social systems to cope, the unpredictable frequency and intensity of impacts encourage scientists to use statistical downscaling models to project long-term climate change. Local attempts at using downscaled approaches have been a great communication tool to project future trends, necessary for political decision-making and to steer sustainability to meet mitigation and adaptation targets, globally and locally (Hao et al., 2013). The use of multi-model projections (the use of more than one model) is considered superior to reducing uncertainty and errors in results, compared to projections of a single model (Tebaldi & Knutti, 2016; Hao et al., 2013). Climate projections, together with the non-conventional use of integrated and transformational

mitigation and adaptation strategies can influence sustainable urban planning of resilient cities that are able to cope with the impacts of urban climate change (Xiao, Xinhu & Wang, 2011).The climate-resilient pathways approach shows decision-makers the needs and effects of a transitioning and transforming society (Wise et al., 2014). Integrating adaptation into development must recognise the uneven power relations, depletion of resources, increased carbon emissions, requiring individuals to live with change, while the local government takes an alternative pathway to development (O'Brien, Eriksen, Inderberg & Sygna, 2015). A climate-resilient pathway manages changes that impact on development and threatens ecosystems while combining flexibility, innovation, participation, and problem-solving through mitigation and adaptation (Denton et al., 2014).

Transformative adaptation addresses the vulnerability, exposure, risks and the failed attempts toward transformational change and sustainable development in the practical, political and personal spheres of change (Revi et al., 2014). O'Brien & Sygna (2013) identify human behaviour has an important area to transform, having been addressed frequently in literature. Dietz, Gardner, Gilligan, Stern & Vandenbergh (2009) proposes that a better understanding of energy efficient equipment and policy tools (e.g. information, persuasive appeals, and incentives) is needed to overcome constraints to behavioural change in households while evaluating energy and water conservation policies on interventions.

Mitigation and adaptation approaches have been mainstreamed to show improved socio-economic and environmental change to livelihoods in developing countries (Ndamani & Watanabe, 2016; Temesgen, Yehualash & Rajan, 2014; McCarthy, Lipper & Branca, 2011). There as also been a different outlook in decision-making to the integration of mitigation and adaptation as a necessary component to coping with climate change since the inception of the IPCC Second Assessment Report (SAR) (Klein, Huq, Denton, Downing, Richels, Robinson & Toth, 2007). The IPCC Third Assessment Report (TAR) provided a balanced critique of the two approaches, addressing the inter-relationship between mitigation and adaptation (Klein et al., 2007). Neither mitigation nor adaptation can work independently since mitigation can take years to produce results. Adaptation does well on an impacted level to produce local level benefits to reducing vulnerability (Klein et al., 2007).

Klein et al. (2007) further point out that the UNFCCC aims to mitigate GHGs in the atmosphere to an acceptable level from anthropogenic interference within a sufficient period, using sustainable development to drive mitigation and adaptation. If climate policy and sustainable development are pursued in an integrated manner it would go beyond the pursuit of sectoral planning and towards evaluating the capacity of how society responds to socio-economic and technological development.

2.2 The theory of global warming and climate change

There are many theories regarding global warming and climate change. Global warming is defined as the increase and long-term trend of earth's global average surface temperature (Lineman et al., 2015; Venkataramanan & Smith, 2011). The theories of global warming and climate change are argued to have resulted from anthropogenic (man-made) GHGs, mainly CO_2 for the past 50 years (Bast, 2010). However, Klein, Schipper & Desai (2005) argue that it is not yet possible to determine if climate change is human-induced or the effect of natural climate variability. Giorgi (2010) maintain that both natural and anthropogenic factors acting together is from the change of land-use; aerosols from extreme volcanic eruptions and the distance of the earth from the sun that can influence climate change on earth. Vardiman (2008) backtracks to the events of past fluctuations of cosmic rays in the suns electromagnetic field, cloud cover, and temperatures that drove the changes since associated with global warming. This can be further explained by the influence of the climate systems internal and external dynamics (Le Treut et al., 2007).

The internal dynamics refer to the mean variability of temperature and precipitation, while the external factors are associated with anthropogenic influence and solar radiation (Le Treut et al., 2007). Joubert (2009) describes the internal and external dynamics of the climate system as being influenced by the atmosphere and ocean dynamics. As global temperature increases, its impact on temperature differences between land and ocean shows a projected increase of precipitation in the higher latitudes and more pronounced and frequent droughts in the subtropics (Thornton et al., 2014). Thus, ocean and atmosphere circulation are also a contributing factor to the heat energy balance (Hardy, 2003).

Joubert (2009) states that the earth's temperature would be 30°C colder than it is today if not for the following gases trapping the suns energy, nitrogen (N) (78%), oxygen (O_2) (21%), water vapour, CO_2, methane (CH_4), nitrous oxide (N_2O), and trace gases (particulate matter) (Trenberth, 2005). The release of an increased amount of GHGs from human sources is what literature and science refer to as anthropogenic interference of the climate system. The CO_2 gas contributes 77% to the warming effect, CH_4 accounting for 14% from agricultural and landfill activities, and N_2O at 8% of warming from agriculture by-products (Joubert, 2009). As earth intercepts the suns short-wave solar radiation, the solar radiation is absorbed by various components on earth and a third is reflected as long-wave radiation back to space (Houghton, Jenkins & Ephiraums, 1997).

This serves as cloud cover being an important indicator of climate change but its uncertainty is the greatest source of weakness in climate models (Peake, 2003). This theory is dependent on the cloud temperature, height and reflectivity properties (ice or water type) with lower level clouds cooling the earth-atmosphere and higher-level clouds absorbing heat, creating a warming effect (Houghton, 2004).

Trenberth & Fasullo (2009) and Joubert (2009) describe the weather and climate on earth depending on the equilibrium of incoming solar radiation (also referred to as the heat in effect of solar radiation) (ASR) and outgoing long-wave radiation (OLR) (heat out effect of solar radiation leaving earth), referred to as the heat energy budget by Anderson, Hawkins & Jones (2016). Joubert (2009) study describes this process leading up to the albedo effect.

Increased warming occurs when the earth's lighter (reflective) surfaces of snow, ice and cloud presence decreases and darker (absorptive) surfaces like the ocean are subjected to absorbing the heat (Donohoe, Armour, Pendergrass & Battisti, 2014). As the lighter (reflective) surfaces of snow and ice decrease and GHG levels increase, darker (absorptive) surfaces like the ocean become a heat retaining system (Donohoe et al., 2014).The build-up of CO_2 in the troposphere (Trenberth & Fasullo, 2009), reduces the reflection of long-wave radiation to space and there is an increase of heat retained in the earth's system (Kramm & Dlugi, 2011; Ramanathan & Feng, 2009). Because of this ongoing process, the earth can see various changes taking place as a result of increased temperatures.

Trenberth (2011) states that as temperatures increase, evaporation causes moisture on the land surface to be lost. This moisture can continue to circulate in the atmosphere in the presence of wind, which carries moisture to where storm activity, is greater, thus leading to extreme storm activity and precipitation (Trenberth, 2011; Trenberth & Fasullo, 2009). This will affect greatly on how much of rain a region gets and the intensity and frequency of extreme dry spells (Trenberth & Fasullo, 2009). It has been found by Joubert (2009) that water vapour content in the air has increased and suggested by Bast (2010) to be responsible for 36-90% of warming in the atmosphere, followed by CO_2 and CH_4. Idso & Singer (1999) (as cited in Bast, 2010, p.10-11) argues that the IPCC scientific literature on the cumulative forcing of aerosols can completely offset the positive forcing of increased CO_2 in the atmosphere. Idso & Singer (1999) (as cited in Bast, 2010, p.10-11) imply that increasing levels of CO_2 is not an issue since aerosol comprises of dust, sea-spray and sulphate particles that are able to cool the climate. However, if the aerosol matter is dark it will absorb solar radiation and contribute to the warming effect of the climate (North Carolina State University, 2012). To understand and calculate the complexities that follow from atmospheric concentrations of CO_2 and other gases, projected models show how these physical properties function with various components on earth but with uncertainty (Houghton et al., 1997).

2.3 Statistical downscaling of general circulation models and projected climate change impacts

Climate change impacts are experienced more on a regional and local scale, therefore to determine the level of vulnerability of urban communities, analysis of impacts on a local scale requires information on the change of meteorological conditions of a specific area (Feijt, Appenzeller, Siegmund & Von Storch, 2016**).** Climate projection models are probability tools that inform climate science and researchers of trends using historical data to predict future projections **(**Hao et al., 2013**).** Local knowledge systems depend on climate information and science to mitigate and adapt to varying future climate events, whereas science and researchers require it to improve on future predictions of climate impacts (Feijt et al, 2016; Elhakeem, Elshorbagy, AlNaser & Dominguez, 2015). Impact studies show coherence in the statistical downscaling of climate variables, notably temperature and precipitation within their respective localities, showing significant trends, but the use of different applications, predictor variables and periods of observation reduces accuracy and confidence in results (Hewitson & Crane, 2006).

There is a relationship between large-scale properties (e.g. atmospheric circulation, rainfall, temperature) and local features (e.g. water, humans and their landscape) (United States Agency for International Development, 2014; Tadross & Johnson, 2012). Decision-makers require this knowledge of climate impacts in a format that can be measurable on various sectors, for example, water, agriculture, health, safety, and development. However, it is argued by the United Nations Agency for International Development (USAID) (2014) that the spatial scale of GCMs is not conducive to the local scale. Global images are too large to filter down information from a particular region or area to a finer scale for local observation analysis at weather stations (Bhuvandas, Timbadiya, Patel & Porey, 2014; Day, 2013). For global projections to be accessible at a regional and local scale, statistical downscaling is necessary. This is done by applying the locally retrieved data over the large-scale course-gridded GCM data to produce long-term anomaly trends in regions or cities as far as 25 kilometres (Dettinger, 2013; Cooney, 2012). Aflatooni & Aghajanzadeh (2013) study found errors when using GCM without statistically downscaling it, noting that an areas local topography and features do affect results. A recurring pattern in various studies revealed that statistical downscaling is necessary to analyse climate trends and impacts at a regional and local level (Hao et al., 2013).

GCM climate projections drive regional models (Thoeun, 2015) and are important in the design of mitigation and adaptation plans (Bhat et al., 2011). Projected models understand the complexity of the climate system and provide decision-makers with adequate information to inform policy-driven approaches towards integrating mitigation and adaptation (Rana, Foster, Bosshard, Olsson & Bengtsson, 2014). GCM downscaling is appreciated more than any other application because it is inexpensive and less complicated in its computational needs (Hewitson & Crane, 2006). The interaction between global circulation patterns, temperature, and precipitation, among others, is linked to local climate features (water bodies, land surface cover, and mountainous areas) (United States

Agency for International Development, 2014). This type of interaction can provide an image of past and future projections of air temperature and precipitation, which is necessary to understand climate change and its effect on water resources on earth (Elhakeem et al., 2015). The changes in temperature and precipitation will affect local communities in two ways: extreme temperatures, long-term droughts and extreme precipitation resulting in flooding, infrastructural and environmental damage, and in some cases death.

Despite the discourse on the importance of GCM and downscaling, MacKellar, New & Jack (2013) and Tadross & Johnson (2012) question the accuracy of downscaling and projecting trends. Hewitson et al. (2014) raise doubts on the validity of statistically downscaled information applied to adaptation projects at the national, regional and local level while questioning the responsibility of scientists overly exaggerated trends. This therefore, can influence the interpretation of the warming trends of the future climate. Hewitson et al. (2014) further argue that statistical downscaling literature is still foundational research, focused on the best approach to meet the demands of society and global climate networks such as the World Bank and IPCC to develop climate adaptation strategies.

If there is insufficient knowledge on global changes, then there is unreliability in the forecasting of future trends and the unpredictability of human behaviour and its impact on the increase of GHGs (Saraf & Regulwar, 2016). The uncertainty arises from the following themes: (i) the limited use of various models (ii) different scenario-based models with differing outcomes (e.g. Radiative enforcing) (iii) change of GHG emissions in the air (iv) climate variability (Burke, Dykema, Lobell, Miguel & Satyanath, 2012; Greasby & Sain, 2011) (v) incomplete and uncertainty surrounding climate projected information (Bhat et al, 2011).Bhat et al. (2011) found a positive surface temperature anomaly outside the Southern Ocean and Eastern Russia, using more than one model to quantify uncertainty but specifies that models contribute unevenly towards the projected results. This can be due to the sensitivity of varying models under differing future socio-economic scenarios and methods used (Aflatooni & Aghajanzadeh, 2013). The use of a single model approach is not considered applicable by Ziervogel & Zermoglio (2009) since decision-makers and researchers rarely provide a rational understanding for using a single model approach which is frequently applied in projected science literature.

Tebaldi & Knutti (2016) defines multi-model assembles as the use of different models, combined into a “super-ensemble" that shows different conditions of each represented model. The averaged multi-model ensemble integrates better with observations than the use of single models as pointed out in Knutti et al. (2010) & Pierce et al. (2009) (as cited in Bhat et al., 2011). Saraf & Regulwar (2016) argue that using one model to show a single trajectory, amongst many others, is not conducive especially in assessing hydrological trends such as precipitation. Aflatooni & Aghajanzadeh (2013) considers GCMs to provide two results: one that may support a definition of a good result, whilst the

other is prone to errors of uncertainty. Despite motivation, multi-model ensemble projections of observed weather are still in the infancy stage and no parameters will help project real-world accuracy (Knutti, Reinhard, Claudia, Jan & Gerald, 2010). Despite the prevailing of uncertainty, developing countries, like South Africa, are showing initiative in downscaling climate effects based on local conditions but highly rely on projected data produced by developed countries (Cooney, 2012).

Ziervogel et al. *(*2014) argue that a lack of adopting a single approach as "best practice" to solve uncertainties will not bridge the gap in knowledge identified in impact and adaptation assessments. Hewitson & Crane (2006) demonstrate the need for GHGs, humidity and solar radiation to be integrated into downscaling models. It is argued that climate models have the potential to be manipulated by those that build them however; science is continuously improving on the credibility of these models to replicate past changes to project radiative forcing (Manning, 2011).

Multi-model assembles is used in this study to mitigate the challenges associated with the use of a single model, that show different outcomes for historically produced data and RCP 8.5 W/m^{-2} radiative forcings for future projected trends. Also, not identifying a single approach as best practice in research can be detrimental in the proper evaluation of trends. The conditions for projected climate variables of temperature, humidity and precipitation can be evaluated coherently for each model, especially since precipitation trends are difficult to identify using a single model.

2.4 Projected climate change impacts

"Many aspects of climate change and associated impacts will continue for centuries, even if anthropogenic emissions of greenhouse gases are stopped. The risks of abrupt or irreversible changes increase as the magnitude of the warming increases" (IPCC, 2014, p.16).

GHGs cannot be mitigated easily because of its complexities and consequential interaction with the earth's atmospheric properties. The CO_2 in the atmosphere is irreversible, increasing earth's temperature, including future projected carbon emissions for the next 1000 years (Solomon, Plattner, Knutti & Friedlingstein, 2008). Climate models project increased radiative forcing affecting surface heating and the hydrological cycle through evapotranspiration of land surface moisture (Trenberth, 2005). However, climate models find it difficult to project precipitation trends accurately which complicates predictions and makes planning and managing of water resources challenging (Trenberth, 2011). Denton et al. (2014) and Collins & Knutti (2012) identified the following projected impacts globally in the Fifth IPCC Assessment Report:

- Accumulated GHG emissions to date will affect the global mean surface temperature. Between the periods of 2016 and 2035, RCP is time-dependent trajectories showing the long-term concentration of GHGs (Wayne, 2013) project an increase in the range of 0.3-0.7°C.

- Projected changes are expected for global mean temperature continuing into the years from 2081-2100, exceeding the 1.5°C mark for 8.5 W/m^{-2}. RCP 8.5 W/m^{-2} is a non-mitigation scenario of 8.5 W/m^{-2} of radiative forcing with a factor of 3°C, therefore expecting global temperatures to exceed 2ºC warming with respect to present day by the year 2100 (Collins et al., 2013). The Watt per a Square Metre (W/m^{-2}) is defined as measuring the radiative forcing that enters the atmosphere and the energy that escapes to space (Bjørnæs, 2015).
- The increase of global mean temperature by the end of the 21st-century show an increase of 2.6-4.8°C under RCP 8.5 W/m^{-2} from 2081-2100, compared to past projections from 1986–2005;
- There will be hotter temperatures than colder extremes (daily and seasonally), thus increasing the frequency, magnitude, and duration of heat waves; and
- Average precipitation will not be uniform across countries and regions. There will be likely increases and decreases identified with the higher latitudes experiencing more precipitation, while the mid-latitudes and semi-arid regions are more likely to see a decrease in precipitation.

On a global scale, an increase in the global surface temperature will engender sea-level rise through the melting of ice caps, changing patterns in the oceans circulation and temperature (Dasgupta, Laplante, Murray & Wheeler, 2009). This will create intensified storm surges of tropical cyclones observed in past decades, attributable to global climate change (Dasgupta et al., 2009). An average increase in the temperature of the ocean can also affect precipitation trends, globally and locally. Head meteorologists for IPCC suggest that ocean temperature trends in the tropics and subtropics will alter patterns in precipitation, leading to more pronounced and frequent drought episodes (The University of Hawaii at Manoa, 2010). The University of Cambridge (2009) points out that the Mediterranean part of South America and Southern Africa in the subtropics will be prone to fluctuated periods of droughts and intense flooding. Countries located in the higher altitudes will also experience frequent flooding but insufficient storage to contain the excess water will not be available for the drier periods. Kenya relies directly and indirectly on agriculture, and water availability is a necessity to sustain a local community's livelihood, however, due to the long-term drought, many people were left in hunger (Marshall, 2011).

The warming of the ocean's surface temperature will differ between the global average increases of 1-1.5°C (The University of Hawaii at Manoa, 2010). This differentiation will cause frequent and intensified projected impacts of extreme droughts, increased heat waves and floods that have been observed in various studies thus far (Meehl et al., 2007). In particular, droughts and aridity has become a frequent feature in countries that have a much lower precipitation annually. And among the impacts projected, droughts are the least predictable in terms of its frequency and magnitude. Solomon et al. (2009) note that projected models show a 90% increase of drying for sub-tropical countries (Southern Europe, Northern Africa, and Southern Africa) and 80% increase for eastern

South America and Western Australia. China has also experienced severe episodes of droughts in the years 1997, 1999 and 2002 in Zhang (2003) (as cited in Zeng, Zhao, Sun, Ye & Zhai, 2015), accompanied with severe drying, dust storms and water shortages in urban areas. This shows that impacts will fall disproportionately between developed and developing countries.

Myers et al. (2011) state that effects of projected impacts on Africa will not be uniform because of various socio-economic problems encountered. According to Joubert (2009), Southern Africa can expect a temperature increase of 1-3°C by 2050, compared to average temperatures between 1960 and 1990. This will lead to less precipitation and more arid conditions in most parts of Southern Africa, together with heat stress. Joubert (2012) predicts that by 2100, the coastal regions could warm up to 3-4°C and between 6-7°C in the interior regions of South Africa. Based on the output data discussed in Lewis (2011), the eThekwini Municipality expects the following impacts in the eThekwini Municipality (South Africa) with an increase of 1.5-2.5°C in mean annual temperature from 2045-2065:

- Rainfall will likely increase over a short period, making the intensity stronger and increasing pressure on stream flow, the storm water systems, flooding, and soil erosion;
- The sea level rose to 2.7 mm from 1970-2003 along the eThekwini Municipality coastline and is likely to keep rising. The three scenarios being considered by the eThekwini Municipality is: 300, 600 and 1000 mm of sea level rise above the 1980-1999 base by 2100;
- Along with secondary impacts of heat-related stress, decreased food security from the failure of crop yields to prosper under projected conditions;
- And lastly, the inability of biodiversity to adapt to climatic conditions thus impacting on species functioning and the ability for invasive species to survive and benefit from present and future conditions.

Heltberg, steen & Siegel (2008) makes a reference to social scientists limited observation on the impacts of weather on households, communities and institutions, and their response to climate change. As temperatures increase, health impacts will become more pronounced and experienced differently by individuals as they are susceptible to various health risks (Department of Environmental Affairs and Tourism, 2004). Discomfort can arise from frequent episodes of heat waves and stress enhanced by an increase in humidity (Argüeso, Evans, Pitman & Di Luca, 2015).

Humidity can be seen as being a good predictor variable used alongside temperature and precipitation (Hewitson & Crane, 2006).

The city of Surat, in India, showed an increase in temperature and humidity between the years of 1985-2014 and 2011-2014, with heat waves and discomfort requiring policymakers attend to measures to reduce population and health vulnerability in the city (Desai, Patel, Rathi, Wagle & Desai, 2015). If the body temperature rises above 4°C, the body responds by using more energy to cool down, people become vulnerable to dry skin, a fast pulse, cardiovascular diseases, diabetes and asthma (Hardy, 2003).

Based on the aforementioned increase and decrease of temperature and precipitation events, its frequency and intensity vary amongst countries, as is reported in many studies (Mahmood & Babel, 2014). It is stated that it is not the monthly mean conditions that produce the impacts but the daily peaks and lows that add up yearly and on a decadal time- scale to create intensified weather events (Girvetz et al., 2012). Turoğlu (2014) found that thelack of recent studies on temperature and precipitation using daily data to perform a long-term analysis for the City of Istanbul was a challenge, since this is important to identify a regions climate, the rise in temperature, the length of the warm season, and decrease and increase in annual rainfall. Buhairi (2010) found that daily, monthly and annual temperatures for Taiz city, the Republic of Yemen during the period of 1976-2006 had increased over the past 30 years, with warm peaks between summer and winter seasons.

2.5 Climate change, cities and urban resilience

It is currently estimated that globally, cities house about 3.6 billion people (Roberts & O' Donoghue, 2013) and is expected to increase by 70%, reaching an estimated total population of 6.4 billion by 2050 (Da Silva, Kernaghan & Luque, 2012). Cities and urban areas play an important role in growing areas of research because of urbanization, their built environments, and role in economic growth (Lankao, 2008).Urban areas are responsible for 71% of global energy-related carbon emissions and this figure is expected to grow as the rate of urbanization exceeds present trends (Rosenzweig, Solecki, Hammer & Mehrotra, 2010).Urban areas are identified as high-risk zones for severe climate change impacts and associated risks (Lankao, 2008).

There are two identified impacts of climate change: (i) direct impacts that become more pronounced over time by changes in temperature, precipitation, heat waves and flooding, and (ii) indirect impacts from direct impacts cause stress on cities infrastructure and people's ability to mitigate and adapt to climate change (Da Silva et al., 2012). It was found by Yao-Dong et al. (2013) that if the temperature is above or below 26.4°C, people especially the elderly in South China will face direct health complications (stroke, cardiovascular disease), and indirect impacts from malaria and dengue fever reaching higher altitudes because of climate change. Flooding is common in urban areas depending on its duration, intensity, timing, temperature and the debris it carries along, indirectly impacting on infrastructure, livelihoods and health (Kundzewicz et al., 2016). These impacts will continue to disturb the functioning of urban communities, causing infrastructural damage to public and private

property (e.g. roads, bridges, urban drainage) (Neumann et al., 2015). In Arizona, California, and Mexico, 7 million people faced 12 hours of a power failure because of the reported high temperatures and heat stress to infrastructures having reached 46°C (Wilbanks & Fernandez, 2013).

Lankao (2008) states that the link between urban areas, specifically at the local level, and climate change have been less explored in the literature compared to other areas of research. In the last few years, there has been a growing consensus on cities and urban areas as first responders and adapters to climate change (Rosenzweig et al., 2010). Broto & Bulkeley (2013) argue that our understanding of responding to urban climate change has been recognized through developed economies and their perceptions of mitigation-driven action. Developing countries are prone to varying risks of climate change, especially since their socio-economic environment is dependent on the climate and financial incentives to mitigate and adapt effectively to climate change (Mendelsohn, 2008). Lankao (2008) states that along with the study of exposure, there is a need to assess the vulnerability of the urban population to adapt with the resources they have and basic infrastructural services they are entitled to.

The resilience of urban communities is now recognized vividly in the climate literature**.** Urban resilience principals recognize that urban areas require soft and hard approaches that engage with various stakeholders and governance; addressing current issues while considering the long-term implications, building strong leadership and action and focusing on vulnerable communities (Asian Development Bank, 2014). India, among other countries, faces rapid urbanization of the urban poor, therefore requiring the city to focus on strategies in the provision of proper services to strengthen adaptive resilience (Asian Development Bank, 2014). Leichenko (2011) points out that the promotion of urban resilience is required for enabling mitigation and adaptation. Urban resilience through mitigation and adaptation at a community level is possible if the capacity of urban systems to cope with climate change is thoroughly researched (Saavedra, Budd & Lovrich, 2012). Pu & Qiu (2016) found that of the 1296 urban resilient globally circulated research articles published, many were from the developed countries, especially the United States. Southern scientists have argued that most studies feeding into global assessments of urban resilience and climate change focus directly or indirectly on issues more relevant to the North and are often based on assumptions not transferable to the South (Chemnick,2017). Broto & Bulkeley (2013) noted that this is true since studies evaluated focused on developed economies and responses to the emergence of urban features of cities to policy responses.

Hebbert & Jankovic (2014) state that the slow mainstreaming of cities to climate change is due to scientists, urban studies, and international authorities not recognizing cities as a priority on the climate change agenda.

Further strengthening the debate in favour of integrated climate change management, Lankao (2008) adds that although mitigation is a priority to curb emissions, adaptation is equally important to minimizing vulnerability. A case study in Malawi by Joshua, et al. (2014) revealed that 1 out of the 20 adaptation projects or programmes that were implemented focused on urban areas.Academic research and sustainable projects have focused predominately on the impacts of climate change on rural well-being, neglecting urban household vulnerability (Joshua et al., 2014). When urban local communities become more aware of their environment and included in the climate change planning and implementation process, they will be able to challenge the governing system and effectively institute transformative social and political changes (Archer et al., 2014).

2.6 The integration of mitigation and adaptation

Increased greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems, therefore sustained reductions in greenhouse gas emissions together with adaptation, can limit climate change risk (IPCC, 2014).

Development cannot persist on a deteriorating environmental resource base and development within the sustainable development discourse should meet the needs of the present without compromising the needs of future generations (The World Commission on Environment and Development (as cited in Papa, 2015). Climate change can affect development, and technological and institutional change is critical to minimizing GHGs (Denton et al., 2014). Therefore, a climate-resilient pathway is politically and economically favoured and defined as, "a process for managing changes in the climate and factors affecting development, with the integrating of mitigation and adaptation into sustainability, avoiding anthropocentric interference to the climate system (Revi et al., 2014). However, Wise et al. (2014) contest the use of pathways by Revi et al. (2014), arguing that pathways refer to metaphors that are preferably used only in the process of decision-making rather than reaching a final outcome. Howell et al. (2016) emphasizes that support for adaptation should not hinder mitigation since the magnitude of local climate change is likely to reduce the adaptation of natural and human systems toward the impact of climate change.

Adaptation and mitigation are policy driven by various actors (international, national, regional and local institutions). Mitigation serves as an important sustainable indicator to help developed and developing countries meet their commitments through emissions trading (ET) and Clean Development Mechanism (CDM). ET allows for industrialized countries to buy and sell GHG permits, while the CDM balances the emissions of a country with emission reduction projects undertaken overseas (Peake, 2003). This is because mitigation was an early measure to manage the warnings of climate change and adaptation a “taboo" that hindered mitigation efforts in addressing climate change (Howell et al., 2016). Wise et al. (2014) re-conceptualizes the idea of adaptation as a pathway of

change and response to address drivers of vulnerability and not just as a process to avoid risks. Climate science has evolved, and adaptation is now addressed as a necessity rather than a trade-off to mitigation. Mendelson, Morison, Schlesinger & Andronova (1997) (as cited in Dolsak, 2001) states that developing countries will have to contend with the effects of climate change, while economically stable nations being North America and Europe will benefit from climate change, therefore this makes adaptation critical to the resiliency of developing and least developed countries so urgent.

The current progress in climate change international policy and the progress of countries to reduce GHG emissions is lacking in progression. Dolsak (2001) argues that measuring the concentrations of global emissions is not enough to determine progress made by countries because mitigation cannot proceed autonomously. The exclusion of mitigation in adaptation projects will be detrimental to the decrease of GHGs leading to maladaptation practices, likewise if adaptation is not addressed within mitigation projects (Locatelli et al., 2016).

Until now, climate change initiatives have been place- and context-specific driven, pointing out that no single approach can be instituted in every location (IPCC, 2014). Developing countries have a low tolerance to pursue a low-carbon and climate-resilient pathway, whereas developed countries have the capacity to manage a high-risk environment with both mitigation and adaptation (IPCC, 2014). The inequity in emissions generation between the global powers and developing economies is so apparent that to decrease GHGs, the major emitters will need to curb emissions in the main categories that drive climate change as argued by Banerjee in 2012 (as cited in Denton et al., 2014). Wilbrinks & Kate (2010) (as cited in Denton et al., 2014) point out that in order to achieve cohesion amongst the varying sectors, integrating mitigation and adaptation with other interventions within the broader context of sustainability and resilience is instrumental.

Wilson & McDaniels (n.d.) (as cited in Denton et al., 2014) suggest three reasons why integrating mitigation, adaptation, and sustainable development is important. Firstly, the values embedded in decision-making are common to all three approaches. Secondly, impacts identified in one sphere can have significant repercussions for the others. Thirdly, alternatives for one process might be a means for achieving an underlying value for the other categories. Inadequacy in existing mitigation measures in the depletion of GHGs in the atmosphere has presented adaptation as a beneficial, long-term solution. This probably explains why 85% of articles on adaptation appeared in Global Environmental Change Journals since 2005, this also could be attributed to IPCC findings on mitigation and adaptation climate science (Bassett & Fogelman, 2013).

Adaptation is not a planned response to only projected risks in the future but to current risks from local climate variability, although it is difficult to compare adaptation to climate change and adaptation to climate variability (Klein et al., 2005). It is necessary to determine the level of

vulnerability faced by communities, in accordance with their circumstances that constrain adaptation efforts (The Energy and Resources Institute, n.d). Archer et al. (2014) notes that despite the potential of adaptation, barriers toward adaptation is measuring its capacity and impact as a response instituted in institutions and in political contexts that govern the functioning of communities of developing countries (Butler et al., 2015; Lemos et al., 2007). In the urban context, although both approaches align objectively and subjectively to the goals of sustainability, integrating them into the sustainability of cities proves difficult (Walsh et al., 2011). To integrate mitigation and adaptation in urban areas, it would require an equal contribution of effort from differing parties such as governmental, non-governmental organizations, public and private companies (Walsh et al., 2011).

Reckien, Flacke, Olazabal & Heidrich (2015) refer to cities as agents that have a less complicated political system with enough power to initiate local climate change action. Reckien et al. (2015) claim that information that is unclear on climate change impacts is one of the drivers toward poor implementation of climate change action. Furthermore, Reckien et al. (2015) conducted a study on European response to climate change. The study showed that 35% of large and medium cities have no mitigation plan, 72% do not have adaptation plans, and 25% have an integrated plan of mitigation and adaptation. For African developing countries, (Mbow, Smith, Skole, Duguma & Bustamante, 2013) dual contribution of mitigation and adaptation benefits can be achieved through forest ecosystems to offset the carbon released from deforestation and providing resilience to communities towards current and future projected climate change.

Adaptation goals in mitigation projects can enhance a sustainable outcome from a socio-economic perspective by strengthening local stakeholder engagement and national policy-makers believe that adaptation can benefit the political economy (Locatelli, Pavageau, Pramova & Di Gregorio, 2015). Holling (2001) defines sustainability as the capacity to create, test and maintain adaptive capacity while creating opportunities. Thus, sustainable development is seen as the driver to integrating mitigation and adaptation strategies together through international and local planning (Nolon & Salkin, 2011; Bizikova, Robinson & Cohen, 2007). Ecosystem-based mitigation and adaptation have become populated in international literature among agricultural, resource management and forestry sectors (Locatelli et al., 2015). However, there exist anecdotal assessments without the quantitative scope on the effectiveness of the approach in use that is less integrated into the decision-making process (Munroe et al., 2012).

The measurement of success of mitigation and adaptation at an urban community level is yet to be evaluated. The link between adaptation and practitioners remain fragmented, as adaptation practitioners rarely know how to go about understanding climate data, relying on information generated by institutions like the IPCC (Ziervogel & Zermoglio, 2009).

2.7 The transformational theory

Moser and Ekstrom (2010, p. 22026) (as cited in Taylor, Cartwright & Sunderland, 2014, p.17) states, *"Adaptation involves changes in socio-ecological systems in response to actual and expected impacts of climate change in the context of interacting non-climatic changes. Adaptation strategies and actions can range from short-term coping to longer-term, deeper transformations, aimed to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities".*

This definition goes beyond the much-cited definition of adaptation in the IPCC generated reports. This definition also extends beyond climate change. It acknowledges non-climatic changes (urbanization, household sustainability, the role of governance) as having a defining role in the influence of climatic change. Transformative change is demonstrated as both mitigation and adaptation by the University of Cambridge (2009) investing in low-carbon technologies and the sharing of adaptation costs between developed and developing countries. The role of transformative adaptation in a wider sense is a developing theme that is gaining momentum in redefining a new approach to climate change in the form of mitigation and adaptation. Sustainability and maintaining a climate-resilient pathway is indicative of a transition from the old approach to centralizing mitigation of GHGs. Denton et al. (2014) states that transformational change is a climate-resilient pathways approach, going beyond incremental adaptation to transformational adaptation of a new location and human, technological and biological systems, to reduce vulnerability and risks associated with climate change.

Transformational and incremental adaptations are two different approaches towards the climate change phenomenon. Incremental is the extension of actions and behaviours currently in place to reduce vulnerability or enhance benefits maintained at a level sufficient enough. Transformational change is a response to events that are disruptive and constructed upon the foundation of the incremental approach (Denton et al., 2014). Although transformational change has not conceptualized, integrative thinking sees the world as interconnected and interdependent entities. It sees and appreciates complexities, can withstand uncertainty and refutes simple cause and effect reductionism models that separate a system and its issues, with an onus on long-term sustainability (University of Cambridge, 2009).

As the scale of climate change and economic development increases across the globe so does the need for transformative action on a much larger scale. For example, the GCF by the UNFCCC was developed to help finance countries towards mitigation and adaptation initiatives which have not sought a process towards the integration of both strategies (Locatelli, 2016; Mersmann & Wehnert, 2014). The process of the GCF is as complicated as reaching an agreement on emission targets. Many actors, identified by Locatelli (2016) including the governments of donor countries, secretariats,

agencies with authority, can influence the integration of mitigation and adaptation of funded projects. The need for integrated transformational approaches is a guiding principle to dealing with a changing climate.

The transformational theory transforms and challenges the current systems structure, relations and behaviours that contribute to climate change and social vulnerability (Denton et al., 2014; Marshall, Park, Adger, Brown & Howden, 2012).People socially and economically build an identity to their environment and a change occurring within a person's sense of place can result in an individual searching for solutions that are likely to be sustainable, or through governmental influence (Marshall et al., 2012). Of the 535 papers reviewed in a study by Basette & Vogelman (2013) (as cited in Wise et al., 2014, p.329), only 3% of journal articles viewed adaptation as a transformational process and the other 70% as adjustment adaptation.

The move to adopt transformational change is a fairly new concept. Although its literature is gaining appeal in the academic and science field, its implementation on the international agenda is still unknown (Locatelli et al., 2016). Gillard et al. (2016) & O'Brien & Sygna (2013) identify transformation in three spheres: the practical, political, and personal. The practical sphere measures the outcome of technical responses that affect climate policy with strategies for mitigation and adaptation. The political sphere is responsible for addressing the practical sphere, understanding transformation, issues and solutions and trade-offs. The personal sphere is the transformation of an individual's beliefs, values, and worldviews.

Climate change action starts with planning, designing and implementing projects and programmes on a scale that can benefit the climate, environment, and people. Both transformational theory and theory of change support the idea of planning and implementing projects and programmes on a large scale. One that can incorporate mitigation and adaptation; benefit the political, social, economic, natural environment and sustainable development.

In response to a paradigm shift to transformational change, the Green Climate Fund's (Mersmann & Wehnert, 2014, p.8) stated objectively is:

In the context of sustainable development, the Fund will promote the paradigm shift towards low-emission and climate-resilient development pathways by providing support to limit or reduce their greenhouse gas emissions and to adapt to the impacts of climate change.

As is the inextricable link between climate change and sustainable development, so is the link between transformational change and sustainable development. Barriers and challenges to the concept are inevitable, likewise with any other process (Mersmann & Wehnert, 2014). The barriers that hinder proper integration are interventions that were designed to work independently. For example, Wilbanks

et al. (2007) states that mitigation is globally instituted, and adaptation is locally embedded; research and policy directives are identified as often being unaligned, and the constituencies and decision-making are situated on different authoritative levels (as cited in Denton et al., 2014).

Jones & Carabine (2013) present an example of Ethiopia's Climate Resilient Green Economy Strategy (CRGES). This strategy aims to mobilize Ethiopia's low-carbon economy by increasing sustainable agricultural production and food security, protecting forests, increasing electric power generation from renewable energy, and fostering modern energy efficient technology in transport, industry and construction sectors. The second component aims at integrating disaster risk reduction and management into the CRGES's wider objectives and helps foster mainstreaming and integration of resilience and adaptation objectives into sectoral and regional plans (Jones & Carabin, 2013). However, the strategies were developed by high-level government officials with limited or no interaction with national or local stakeholders. Secondly, despite adaptation being a necessity to downscale vulnerability, mitigation is still widely recognized for international funding. Thirdly, there is no mention of the involvement of local urban communities or households, despite the economy being reliant on agriculture and driven towards a low-carbon economy to decrease emissions (Jones & Carabin, 2013). Wise et al. (2014) supports the idea of proactive adaptation that manoeuvres between incremental actions of proximate causes with transformative societal change, although limited scope and planning were shown towards transformational change in local governments in Australia and the United States.

Transformative actions outlined in the IPCC (2014) include (i) improved energy efficiency and cleaner energy sources; (ii) reduced energy and water consumption in urban areas through greening cities and recycling water; (iii) sustainable agriculture and forestry; and (iv) protection of ecosystems for carbon storage and other ecosystem services. The transformative theory is considered to have a positive value in provoking the idea of radical change in addressing climate change and most importantly aligning governmental goals that were previously fragmented (IPCC, 2014).O'Brien & Hochachka (2010) challenges the notion of the transformational theory into integral adaptation stating that the evolution of mitigation and adaptation is for people to adjust to the physical changes around them but to conform themselves to new understandings of the human-environment relationship.

2.8 Integral adaptation

Fall (2005) (as cited in O'Brian & Hochachka, 2010, p.5) explains integral theory as:

> *"An approach that includes and transcends any single method of inquiry to create a comprehensive map of human capacities. This map includes both individual and collective realms, different ideas about evolution or change over time".*

The application of integral theory is not a new approach to address environmental issues. Riedy (2009) analysed the question of how to facilitate a more effective response to climate change at the household scale from an integral theory perspective. Riedy (2009) argues our lifestyle drives climate change, while an individual's behaviour is the contributing factor to responding to climate change. The integral theory contains four quadrants of behavioural change (Upper Right), cultural change (Lower Left), systemic change (Lower Right) and personal change (Upper Left), (Esbjörn- Hargens, 2012; Hochachka, 2009) (Figure 2). The upper right quadrant is described by Riedy (2009) as the area to target for behavioural change. The lower right uses the category of behavioural responses to transform and communicate the desired mitigation method within a technological space.

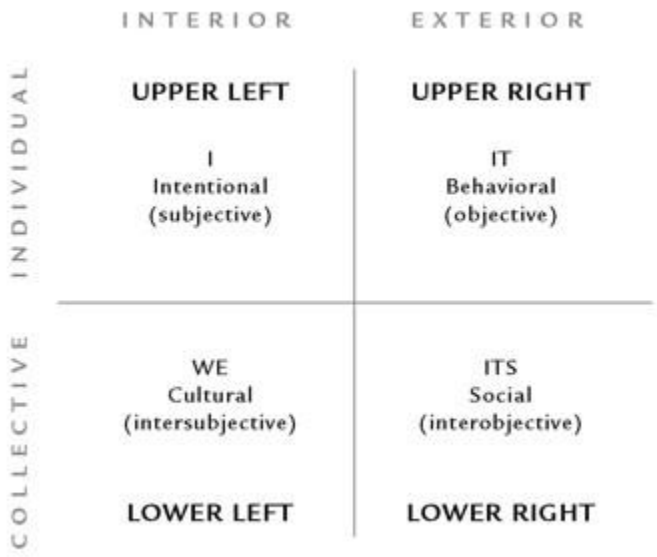

Figure 2.2 The four quadrants of integral theory (Esbjörn-Hargens, 2012).

O'Brien & Hochachka (2010) claim that climate change research largely focuses on the external aspects of the problem, while neglecting the internal values and beliefs of a person. Both authors give an example of the thinking behind the motivation for researchers studying climate change. Researchers are seen as both the problem and the solution. Some researchers are driven by the motivation of funding for research (externally), whereas some have a passion for the subject of climate change (internally), although the consensus is all scientists want humanity to adapt towards climate change, while uncertainty and international governance is a barrier to understanding both the internal and external paradigms (O'Brien & Hochachka, 2010). Internal (how one feels) and external validity (measuring what one does) should not be used separately to understand a problem but concurrently (O'Brien & Hochachka, 2010).

Riedy (2009) identifies the lower-left quadrant as the cultural part of sustenance of knowledge between individuals by means of small or large groups sharing pro-environmental commitments from

household experiences. This enables individuals driven by a change agent to continue their motivation by means of appreciation and acceptance among group members to exact change toward a shared initiative. Local communities require first hand and practical knowledge that can benefit them in the long-term, for example, methods that can improve financial circumstances through the better use of energy in a household or use of long-term smart energy saving equipment.Riedy (2009) explains the upper-left quadrant as what internally brings about a change within an individual, shaped by their beliefs, values, attitude, and experiences. Therefore, change agents are required to promote urgency on the subject of climate change by knowledge sharing

Allen & Crowley (2015) argue that the knowledge about climate change and its effects on people's lives do not provide the impetus needed to address the issue. Kahan et al. (2012) argue that societal-risks is dominated by emotion or how less of an impact their opinion will make on their peers. Moreover, people with high science literacy seek out shared worldviews, whereas, for a common citizen, the technical aspects would be difficult to comprehend (Kahan et al., 2012).

Understanding an individual's behavioural response to climate change is one of the objectives as a necessity to identifying the human and environment relationship as ever changing, especially because humans have contributed immensely to the increasing GHG emissions found in the atmosphere. There are not many examples of integral adaptation in climate change literature but none the less, integral adaptation is considered necessary because it can offer adequate changes to responses and strategies needed to confront climate change from a household position. O'Brien (2008) identified institutional changes as being minimal without considering behavioural changes. People need to experience the externality and objective side of climate change while recognizing that human values are important aspects of understanding the impacts. Considering the impacts of climate change, adaptation is integral in sustaining human well-being as is mitigation for the sustainable and economic development of a country (Lagos & Wirth, 2009). Despite the urgency to move to a low-emissions economy, governments and organizations are still regarded as being in the study phase of uncertainty regarding the effects of climate change (Chinowsky et al., 2011).

Woiwode (2013) argues that the objective quantitative thought never controls the subjective qualitative process. This is true because when a person understands the subjective part of them, only then can they work together with people and address climate change with solutions.

2.9 Public perception of climate change

JoAnn, Nadkarni & Rhie (2012) add that 79% of cities worldwide perceived changes in temperature, precipitation, and natural hazards, with half of the respondents reporting impacts they believe is related to the changing of climate. A study conducted on the American community revealed that public opinion is influenced by science, media and personal observations (Rabe & Borick, 2012). The

role of science in projecting reliable and accurate climate information on impacts and risks had linearly awakened awareness and concern of the general public. However, the knowledge emanated from climate change science, which drives climate agreements and policy globally, is argued by opponents to be scientifically uncertain to justify inaction (Lewandowsky, Oreskes, Rishey, Newll & Smithson, 2015).

Conflicting perceptions between scientists and politics is argued to be based on what is causing global warming and climate change. This led Lewandowsky et al. (2015) to use the term seepage defined as the unnecessary scientific claims in scientific literature rather than judgments based on scientist's personal and professional reasoning. Merton (1942) (as cited in Lewandowsky et al., 2015) argued that science should remain within the scientific community, transcending social and political boundaries, that knowledge should be for scientific knowledge, and be exposed to criticism before considered accurate to the public. On the contrary, scientific knowledge is said to be jeopardized by the scientific stereotype that threatens the views of scientists.

The IPCC consensus on global warming survey on authors of peer-reviewed journals shows that between 1995-2004, 87% of authors agree to the earth warming and believe climate change is human-induced (Rosenburg, 2010) (as cited in Anderegg, 2010, p.332). Oreskes (2004) says that of the 928 peer-reviewed articles, 75% explicitly to implicitly agree that global warming and climate change is human-induced, and 25% of authors say it is a natural phenomenon. Cook et al. (2013) found that 97.7% of authors agreed on anthropogenic-induced climate change but that this consensus is not in the domain of public knowledge. However, the 97.7% expert consensus on human-induced global climate change was denied by Nuccitelli (2014) as reflecting the views of a small minority of experts and distorting public opinion on climate change published in the Wall Street Journal editorial page. It can be said that the framing of climate change and its risks in the public domain is generalized (Esbjörn-Hargens, 2012). This is in the symbols, languages, and personalized by one's knowledge, values, experiences, and conditions, consistent with Esbjörn- Hargens (2012) diagram (Figure 2).

2.10 Public response to climate change

An individual who has experienced an impact of climate change would have a greater perception towards adopting a more sustainable lifestyle compared to individuals that has not experienced the same risk to their well-being. Spence, Poortinga, Butler & Pidgeon (2011) found that people are less likely respond to taking mitigation action unless they have experienced the impacts associated with climate change.

In response to climate change, mitigation and adaptation are being extensively studied together with climate change. Rai & Rai (2013) maintain that a change in public attitude is dependent on the role of government and changes brought upon by technology and lifestyle changes. Mitigation and adaptation

responses are enabled by factors of effective institutions and governance, innovation and investments in low-carbon technology, sustainable livelihoods, behavioural and lifestyle choices (IPCC, 2014). Leiserowitz (2005) argue that people's response can also be shaped by interpretive communities that either perceive the risks of climate change as alarming or a non-existent risk. For example, the American community either strongly believes in the danger of climate change or that the impacts will be experienced demographically and temporally by people located further away or by nature (Leiserowitz, 2005). The power on how to respond to climate change and its risks will reside amongst the most influential groups being the scientists, the persuasive political international figures in climate change governance and various interest groups (Leiserowitz, 2005).

The lack of concern for climate change is said to be much less than what is communicated in research (Spence et al., 2011). This is due to people not grasping the theory because of how it is projected in climate science or individuals not having experienced its effects (Spence et al., 2011). Hulme (2009) states that no amount of certainty or sufficient amount of clarity from scientists about future projected change will lead to better public engagement with the issue of climate change. People are also driven by other factors other than lack of knowledge and these include psychological, emotional, and behavioural barriers. People relate to weather in different ways, daily projections of weather are given less importance in the framing of climate change than the long-term average climate conditions (Spence et al., 2011). Kamara (2006) identified a growing consensus that peoples' attitude towards their environment is shaped by their level of education, their knowledge, values and the importance of protecting those values, which ultimately determines their behaviour on the immediate environment and how environmental issues are viewed.

Sustainability and the engagement of people to learn and apply that knowledge in the form of action often fail. In terms of waste management, Jayasubramanian, Saratha & Divya (2015) study of Indian perceptions toward the segregation of waste and recycling showed that respondents are aware of how to segregate waste and recycle but do not practice it. A similar study was done by Ahmed (2012) who studied household perception on wastes found that respondents did not know how, where and when to dispose of waste but relied on government’s provision of bins to dispose of waste and alternative energy to use fans and conditioners.

In addition, exploring the dimensions of what transforms behaviour can be significant in transitioning to global sustainability. Attari (2014) identifies two types of behaviour: intent and impact orientated behaviour. Intent orientated behaviour is the motivation that leads to understanding environmental issues, while impact-orientated behaviour is the impact of behaviour on the environment (Whitmarsh, 2008). Frederiks, Stenner & Hobman (2015) points out that this stems from various gaps in knowledge, values, attitude, and intention towards action. It is important to fill in those gaps and

understand the factors that result in people's inability to fulfil their obligations to a more sustainable and economically viable path for themselves.

2.10.1 Household energy and water responses

Frederiks et al. (2015) point out that despite people saving on energy and water, weighing out the costs and benefits of sustainable living does not translate to pro-environmental initiatives in the long-term.

Pro-environmental behaviour consists of two types of behaviours: efficient behaviours that invest in environmentally-friendly technology and curtailment behaviours are repetitive short-term approaches, reducing consumption patterns (Lin, 2015). Public responses to saving energy and water or the recycling of waste can, in fact, be very bias and many are of the belief that efficiency lies in curtailing efforts. A study conducted by Attari (2014) found that participants opted for curtailment measures as opposed to investing in long-term water efficient equipment because of upfront costs of not being able to afford to retrofit. Therefore, the short-term gain is preferred over the long-term investment of water and energy saving efficiency. Attari (2014) also found that American households believed in adopting curtailment action or efficiency action, but underestimated water used by standard equipment, for example, water released during the flushing of a toilet. This shows lack of knowledge and how to effectively use such measures in a household. House-Peters & Chang (2011) found that socio-economic and climatic variations were factors responsible for variable water use, for example, people were identified to increase water use during the hot, dry months, reacting to changes in their actual and perceived environment. Socio-demographic characteristics (gender, age, race) of is argued to influence people's responses to climate change, along with other climatic impacts that enhances their ability to respond to local changes surrounding them (Howe, Thaker & Leiserowitz, 2014).

Population and economic growth will increase energy demand, and this will place a strain on socio-economic structures of developing countries. In an energy saving survey conducted by Attari et al. (2010) it was discovered that curtailing activities do not have much of an impact when compared to energy efficient saving equipment (e.g. efficient light bulbs and eco technology). For example, switching a light on and off is not as effective in saving energy as when compared to solar powered energy saving light bulbs. The knowledge emanating from energy efficiency research remains uncertain whether there will be a positive response to information campaigns to change household responses (Simcock et al., 2013). This can be attributed to what Abrahamse, Steg, Vlek & Rothengatter (2005) point out as very little attention given to the actual environmental impact of energy saving, the reason behind an individual's motivation to save energy or use more energy in a household and the extent thereof of such behaviour.

2.10.2 Household waste management responses

Waste is defined by United Nations Environmental Programme (UNEP) (2010, p.8-9) as "organic matter of food, paper, wood, garden trimmings, and domestic grey water, wastewater, and sewage. Waste management of solid and liquid matter is the process by which waste is collected, processed and disposed of or reused as recyclable and non-recyclable wastes (Jayasubramanian et al., 2015). Urban areas produce more solid and liquid waste than rural areas and contribute 5% towards global warming, however, the waste sectors capacity to minimize and mitigate greenhouse gas emissions is underestimated (Bogner et al., 2007).

One of many challenges identified by Ahmed (2012) is the management of urban waste and how that waste is collected, recycled, treated and disposed of in an environment that is undergoing temperature changes. In Italy, people indicated a concern for health risks generated through poor waste management in households that could lead to infectious diseases and cancers due to changing temperatures (Sessa, Giuseppe, Marinelli & Angelillo, 2009). Landfill sites are known for their contribution to climate change by their production of GHGs by microbes containing methane-producing bacteria that release 50% methane, 50% carbon dioxide and < 1% of trace gases when they die and decompose (Bogner et al., 2007). Methane emission is a major source of GHGs, 25 times more potent than CO_2 (UNEP, 2010). It is described as a possible cause of the warming trends in atmospheric temperature (Saunois, Jackson, Bousquet, Poulter & Canadell, 2016).

Waste management is referred to as a silent contributor to climate change because the burning of fossil fuels adds to the accumulation of GHGs in the atmosphere (Nnaji, 2011). The integrated solid waste management initiative is a plan that guides actions through eco-design, reduce, recycling, recovery and disposal of solid wastes, but weakly implemented to address climate change (Zeng et al., 2010). An example of this is profiled in Jacobi & Basen (2011) study looks at the project in Sao Paulo developed after the Johannesburg Summit in 2002, to reuse household solid waste from 51 material sorting centres, while waste pickers contracted to the local municipality manage 20 of the waste sorting centres.

Several studies have been conducted on household solid waste management. Banga (2011) study on Uganda (Kampala) management of solid waste identified the following indicators of waste management (i) household income (ii) gender (iii) the level of awareness (iv) Education. Banga (2011) study revealed that households neglected to separate waste because household income did not afford them the opportunity to have separate bins to segregate waste. Secondly, people lacked awareness on how to separate waste: the biodegradable from the non-biodegradable. Thirdly, people with less education are likely to separate their waste to earn an income. In contrast, Yoada, Chirawurah & Adongo (2014) study revealed that people disposed of their food debris as waste, while some used plastic bags to recycle their materials appropriately or the roadside and gutters. This study

further noted that in Ghana, there is an emerging perception that deprivation of education is the reason underlying poor management of waste, including proper sanitation and knowledge of environmental issues (Yoada et al., 2014).

Singhirunnusorn, Donlakorn & Kaewhanin (2012) identified other external factors that pose a challenge to waste management: (i) lack of responsibility/laziness, (ii) dependence on institutions to take responsibility for concerns of the environment, (iii) lack of time/shortage of space, (iv) demographic factors and females being the majority to recycle than males, (iv) higher income houses with higher recycling rates, (v) convenience and access. Otitoju & Seng (2014) study on Malaysian households revealed that the inability of government authorities, weak coordination between government officials and various stakeholders were the real issue.

The waste management hierarchy of the waste management act avoids unnecessary waste through various measures of the lifecycle of a product (Muzenda, 2014). Diamond (2009) defines it as avoiding or reducing the amount of waste used that is hazardous; reuse is reusing the item that would have been discarded, and recycling items that can be useful for example, reusing plastic and glass bottles that would have been discarded. The International Solid Waste Association (ISWA) (2009) (as cited in UNEP, 2010) describes the terms as '…a valuable conceptual and political prioritization tool developing waste management strategies to limit resource consumption and protecting the environment'.

International pressure has driven South Africa to adopt and integrate the reuse, reduce and recycle worldwide initiative to campaign and promote proper disposal of waste. As South Africa continues to grow economically, so will its generation of waste. "Waste is not waste: recycling creates an opportunity for resource sustainability" (Muzenda, 2014, p. 111). Resource sustainability has the ability to transform communities, especially urban communities. If, and when urban communities are made aware of the importance of waste disposal in the waste stream, gradual changes and behavioural changes will emerge. Jayasubramanian et al. (2015) study identifies encouragement through incentives to help promote sustainable behaviour and specifically help urban households to mitigate their waste more efficiently.

2.11 Global international agreements and local governmental action

An international agreement on climate change is what drives global climate action. Despite successful collaboration toward a low-emissions carbon economy, failure to reach a binding agreement of an emissions reduction target for climate change policy and conventional agreements has remained unfulfilled. The development towards strong global environmental and climate change governance has been a slow process but gradually countries are recognizing the damage and fatalities of global warming and climate change on their economies and social well-being. The International

Meteorological Organization (IMO) in 1873, for the study of the earth's climate and the 1987 Montreal Protocol proved to be a historical success in the depletion of ozone substances that contribute to radiative forcing of climate change (Velders, Anderson, Daniel, Fahey & Mcfarland, 2007).It was successful since countries collaborated to the depletion of stratospheric ozone of harmful chlorofluorocarbon that prevented tens of millions of cases of human cancer caused by ultraviolet radiation (Hardy, 2003). But to date, International Corporation and action have failed to deliver a level of that stature (Barret, 2009).

In 1992, the global environmental governance for climate change, the UNFCCC, which was agreed upon at the Rio Earth Summit, was created to mitigate and curb GHG emissions that contribute to the greenhouse effect and climate change (United Nations and Climate Change, 2016). The Conference of the Parties (COP), the main authority of UNFCCC, engaged with delegates annually to discuss progress in their commitments to meet the convention's objectives, but proved to be ineffective in digressing climate change effects (UN-HABITAT, 2011). Since 1995, there have been annual COP meetings but no binding agreement being formulated (Riedy & McGregor, 2011).

At COP3, the Kyoto Protocol was adopted in 1997 and created to reduce emissions by strengthening commitments of developed countries to reduce their emissions (Roberts, 2016). Given the largest and fastest increase of CO_2 from pre-industrial levels of 278 ppm to 385 ppm in 2008, temperature anomaly rose by 0.74°C (Lagos & Wirth, 2009). The Kyoto Protocol failed in its attempts to obtain corporation especially from the US and how a country should meet its target (Barret, 2009; Hardy, 2003).The United States considered the Kyoto Protocol as comprising of a list of unrealistic goals, and small island states affected by rising sea-level considered the protocol as lacking the strength to deal with dangerous climate change (Hardy, 2003). Leal-Arcas (2011) argues that the largest of GHG emitters (be it developed or developing countries) should be liable to act. The lack of willingness of the major emitters especially the United States lack of support and a domestic legislation for an international treaty has influenced China's diversion from commitment (Falkner, Stephan & Vogler, 2011).

The first commitment for COP 11 was declared for the period of 2008-2012 in 2005, and negotiations for the second commitment in COP11, Montreal (Riedy & McGregor, 2011). The Bali Action Plan (BAP) agreed to at COP 13, to fulfil negotiations before COP15 in Copenhagen was weakened by the uncooperative action between developed and developing countries (Riedy & Mcgregor, 2011; Christoff, 2008).The United Nations Climate Change Conference held in Copenhagen, Denmark, in 2009, did not reach a commitment of the parties due to the global financial crisis and the recession has affected economies between 2008 -2009 (Chinowsky et al., 2011; Riedy & Mcgregor, 2011). The COP 16 Cancun Agreements formalized the Copenhagen Accord, to stay below the 2°C mark, and

COP 17 proving that the Copenhagen Accord and pledge to stay below the 2°C mark may not fulfil the aim of the Cancun Agreement (Riedy & Mcgregor, 2011).

The Cancun Adaptation Framework, adopted in 2010 under the UNFCCC decided on a low-emissions future by financially assisting developing countries with $30 billion until 2012, and to raise an amount of $100 billion for long-term funding until 2020, and technology to mitigate and adapt (United Nations and Climate Change, 2016). Despite promising initiatives from developed countries at the Cancun Conference, lack of trust from developing and less developed countries surfaced because activities and emission targets were non-binding (Latin, 2012). This would be carried out at the discretion of parties (World Resources Institute, 2010).

The 12th December 2015, COP 21 Paris agreement, considered an international milestone for countries who committed to define and increase their Nationally Determined Contributions (NDC) to climate change while contributing to the objectives of the international convention (Streck, Keenlyside & Von Unger, 2016).The Paris agreement clearly states that every party should make a concerted effort to reduce GHG emissions and report on their Intended NDCs every five years from 2030 (Savaresi, 2016). The treaty also requires the efforts of developed countries because of their historical GHG footprint within the affected countries to assist them with mitigation and adaptation (Bultheel et al., 2015). Bultheel et al. (2015) point out that the international agreement further enforces regulations for countries to effectively mitigate climate change.

Long-term funding is defined through the global partnership approach to sustainable development through shifts in policies, for example, Global Environmental Fund (GEF) aiding developing and least developed nations with infrastructural and financial resources (Mackenzie, 2003). The National Climate Change Response Plan White Paper (NCCRP) of 2011 sees the South African government's vision to create a climate-resilient, low carbon society but remains largely sectoral with less emphasis on moving beyond current climate variability (Garland, 2014). South Africa's plan to create a climate resilient pathway to mainstream climate change into policies and interventions requires the three spheres of government to align policy, legislation, regulations and plans to the National Response Climate Change Strategy.

Local municipal tasks are not just complying and implementing legislation, policies, and programmes but providing effective governance according to local and global trends. Since the enactment of the South African National Climate Change Response (NCCR) 2011, White Paper identified local government, cities and municipal adaptation and mitigation as drivers towards climate change (Taylor et al., 2014).

Additionally, local government is knowledgeable of local conditions and has the potential to motivate for the prioritised funding from private, public, international and national bodies to channel resources

and finance hence determining what a city has the incentive to do (International Federation of Red Cross and Red Crescent Societies, Red Cross and ProVention Consortium, 2009). Local government requires climate resilient infrastructural and financial resources from national government to create a favourable environment that will attract foreign investments (OECD & Bloomberg Philanthropies, 2014).

International conventions and conferences that drive climate change action are instrumental in uniting countries to minimize the effects of climate change occurring globally through climate agreements to reduce emissions. This type of interaction is important to the well-being of countries globally. The impact of climate change is not uniform. Countries experience weather and impacts differently, from mild to extreme. Internationally-driven climate change lays the foundation to build national and local policies that are tailored to local conditions. By understanding the political environment on which local governments, local municipalities and cities function (Taylor et al., 2014), the politics and underlying constraints can be identified to explain the root challenges in climate policy. Although there is progress in terms of awareness and the knowledge needed to identify the severity of current and future climate change impacts, implementation of mitigation and adaptation efforts are still being mainstreamed.

2.12 Conclusion

Climate change is a common and reoccurring theme in scientific literature. The projected impacts outlined in this chapter significantly demonstrate the severity of a change in temperature and precipitation, together with humidity on a global and local scale. Theoretically, the environment is continually being shaped by human actions. To bypass conventional and incremental approaches that have had no bearing on a positive outcome towards climate change, a transformational approach is required. Transformational approaches can assist with large-scale, radical changes that conjoin with sustainable development.

The household sector is critical in integrating both mitigation and adaptation. Energy, water, and waste can be sustainably mitigated and societies with the right information can adapt to climate change. International climate change frameworks are key to shaping national and local policy but the gap between mitigation and adaptation is still being argued. The question is whether two contested principals can be integrated to work efficiently with minimal trade-offs. Moreover, climate change is instituted within a political framework that is dependent on financial, ecological, social, institutional and geographical variables to build adaptive capacity towards potential climate change impacts as identified in Burton & Dredge (2007). A fragmented governance system proves ill-fated to local governmental processes and this reflects onto local communities, especially urban communities. Climate change is still a developing subject and work in progress but is still being championed by relevant organizations and cities.

Chapter 3

Research Methodology

3.1 Introduction

This chapter presents and outlines the methods used in this study. The relationship between data and methodology is inextricably linked (Leedy & Ormrod, 2010).

A mixed-methods approach using quantitative and qualitative data is suggested for proper monitoring of impacts and household behavioural responses (Heltberg et al., 2008). This enabled a proper evaluation of the impact of selected climate variables and how local government and the local municipality are bridging the gap between projected science and household behaviour and perceptions.

3.2 The Study Area of the eThekwini Municipality

The eThekwini Municipality has established its name as the economic hub of development with the largest port located on the East Coast of South Africa and rapidly urbanizing (eThekwini Municipality, 2012). The eThekwini Municipality is located in one of the 35 global biodiversity hotspots in the world- containing grasslands, savannah and forest areas (Roberts, Morgan, O'Donoghue, Guastella, Hlongwa, & Price, 2015). The Durban Metropolitan Open Space System (D'MOSS), covers a third of the municipality (Figure 3.1) with 7-10% of the D'MOSS area being managed and protected by the eThekwini Municipality for its threatened ecosystem services (Roberts et al, 2015). In Roberts (2008), it is stated that the metropolitan area is managed by the eThekwini Municipality and is supported by 2300 square kilometres of the municipal area (Figure 3.1). It comprises of an estimated 3.5 million people of various races with 74% Indigenous Africans, followed by Indian, Coloured and Whites (17.7 and 2% respectively) and with two-thirds of the municipality considered rural and said to be urbanizing rapidly (Roberts, 2008).

The eThekwini Municipality faces many challenges of unemployment, poverty, service backlogs to the people living in the city, climate variability and its effects has impacted immensely and redefined the socio-economic environment after apartheid regime. The eThekwini Municipality has the highest percentage of poverty, with high levels of inequality of people living below the food poverty line (Roberts et al., 2015). There is the issue of the environment and development agenda that requires attention (Roberts, 2008). South Africa, being a sub-tropical country, is prone to long-term droughts that can severely enhance weather events such as heat waves, humidity, and extreme precipitation. The weather patterns see temperature changes from 1.5-2.5°C and rainfall in shorter duration, increasing the intensity of storms, flooding and damaging of infrastructure (Lewis, 2011).

Satterthwaite (2007) identifies urban areas as being susceptible to flooding. Concrete, paved and impenetrable surfaces reduce water infiltration, thereby increasing surface runoff of water. The same author also found that flooding occurrences were due to the poor management of drainage channels, clogged by solid-waste or no drainage channels constructed for surface runoff water in residential areas. The 2015 flooding episodes in the eThekwini Municipality resulted in infrastructural damage, flooding, death, and contamination of residential properties by poorly maintained manholes with over spilling with faeces onto private property (Appendix 6). Aside from flooding, the frequent dry spells are expanding the water crisis and are the longest and severest drought South Africa (including the eThekwini Municipality) has faced in years (British Broadcasting commission ,2016).

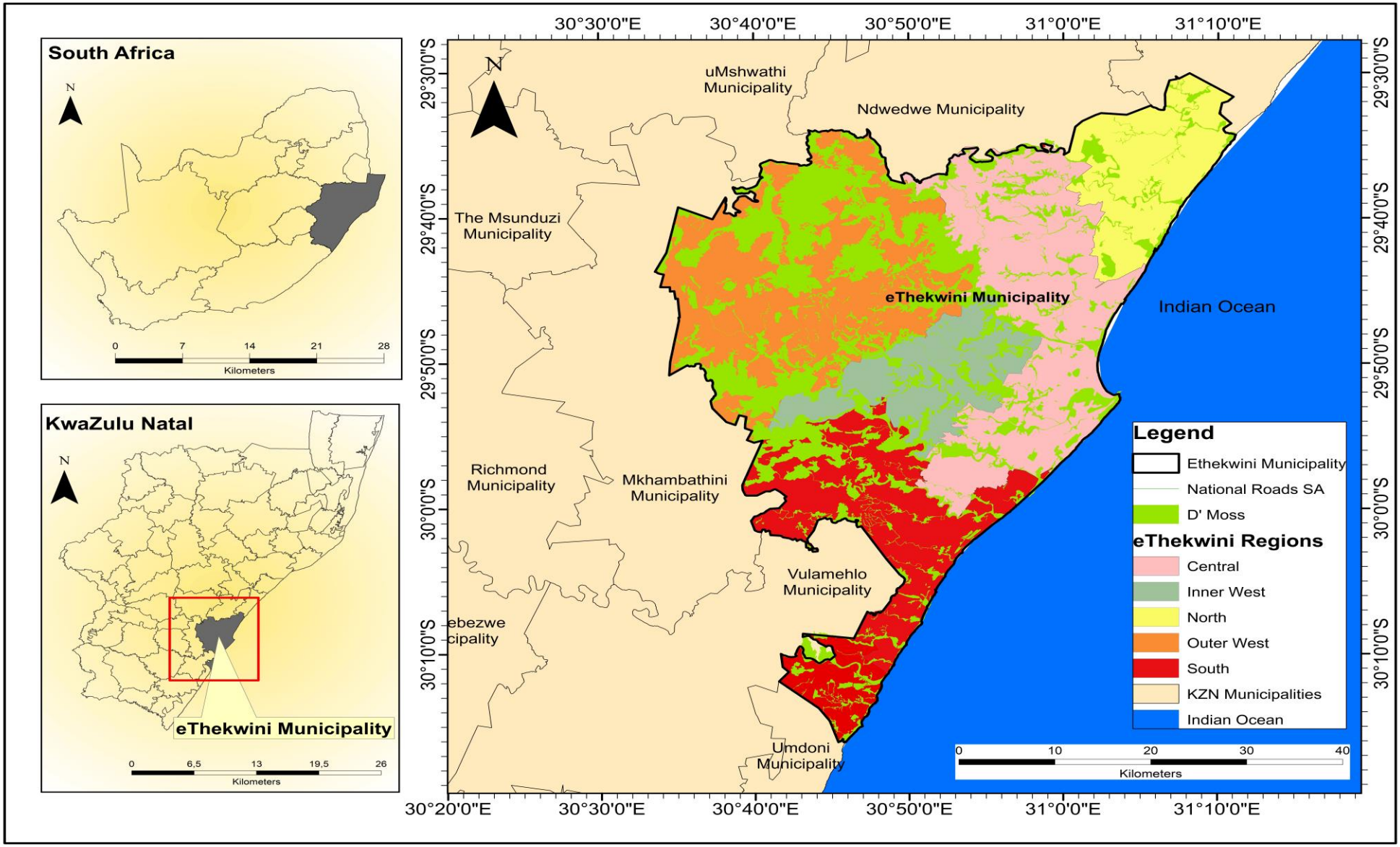

Figure 3.1 The study area, the eThekwini Municipality, KwaZulu-Natal Province (Data source: School of Agricultural, Earth and Environmental Sciences; University of KwaZulu-Natal).

3.3 Research design

A research design is constructed around the research problem. It is a plan of how the research was conducted, and according to Mouton (2001), a research design looks at what the study intends to investigate; how the research problem of the study can prove the researcher's aims and objectives to the research questions being investigated validly. The study uses Mouton (2001, p.137), "Three Worlds Framework "by conceptualizing a research problem from a real-life problem and linking it to the world of scientific research and everyday life to show the choice of methods and how it impacts on the way we investigate real-life phenomena.

Mouton (2001) explains the framework of the three worlds as worldview 1 consisting of the social and physical world that we live in, where knowledge is produced and used, which enables us as human-beings to function effectively in our everyday lives. Worldview 2 uses theories, concepts, instrumentation in the form of questionnaires to develop the research problem-design-methodology-conclusion, specific to this study is urban households and their perceptions and behavioural responses to climate change. Worldview 3 is concerned with the critical reflection of our understanding of a problem, usually reflecting on what method or theory to explain the phenomena that would lead to valid results. The research methodology selected was a mixed-approach, consisting of quantitative and qualitative methods.

3.4 Data types and approaches

Quantitative data use closed-ended questions whereas qualitative data uses open-ended questions without pre-determined responses (Creswell, 2014). Taylor & Turnbull (2005) put forth a compelling argument between quantitative and qualitative, although they may have differences and similarities, both may interlock based on the aim and objectives of a study.

3.4.1 Qualitative

Lauer & Asher (as cited in Leedy & Ormrod 2010) maintain that the qualitative method is subjective and any form of investigation begins in a qualitative form that drives a person to think or act in a certain manner, and allows for flexibility in attaining data in any way possible, within a given time-frame. Pidgeon (2012) (as cited in Capstick, et al., 2015) points out that those qualitative approaches provide more value than what is acquired from quantitative approaches, thus providing insight into people's perceptions of climate change, linking their emotions and engagement with the issue.

3.4.2 Quantitative

Leedy & Ormrod (2010) discusses the qualitative approach as being objective of a large population and reduces its data to a numerical value, in this case identifying trends and correlations between climate anomalies. Unlike qualitative, quantitative explores problems by statistically analysing a

problem. The researcher attempts to prove or correlate findings that validate or can add to existing knowledge.

Taylor & Turnbull (2005) maintain that each approach is selected as the domineering one and the other as a sub-component, however, both methodological designs can be mixed. Leedy & Ormrod (2010) agrees with the mixed method approach, emphasizing that using such an approach helps to understand the problem holistically and with complete clarity, which cannot be done if pursued individually. In harmony with Taylor & Turnbull (2005) and Leedy & Ormrod (2010), this study adopts the mixed approach involving the use of qualitative and quantitative data.

3.4.3 The mixed method

A mixed method design is considered when a quantitative or qualitative study is insufficient by itself to understanding the research problem adequately. The design entails for the researcher to determine what variables to include in the study. Then the researcher studies those selected variables with a large sample of individuals. Creswell (2014) proposes that the researcher understands the characteristics of both quantitative and qualitative independently, therefore, giving the researcher an added advantage to combining different methodologies. The use of multiple methods allows for the inclusion of various issues and strategies surrounding the methods of data collection. For example, the adoption of various methods emphasized using questionnaires, interviews and statistical instrumentation (Johnson, Onwuegbuzie & Turner 2007). The authors say that a researcher should collect multiple types of data and use various methods that when combined can either complement or work against each other. This gives a researcher the advantage of mixing methods in a single study to obtain sufficient amount of information and findings for a reliable research study (Johnson & Turner, 2003).

The research topic pursued in this study is both very objective and subjective; the design of the study required an integrated approach of both paradigms (qualitative and quantitative). This study sought to find correlations between locally projected climate trends of the eThekwini Municipality, with projected trends reviewed in the literature. Moreover, it seeks to identify what engenders the public to use climate change mitigation and adaptation approaches in an urban area. The objective of this study is to integrate qualitative and quantitative data in order to bridge the gaps introduced by a single approach as expressed in Taylor and Turnbull (2005). Furthermore, science is what drives society and their thinking. Climate change affects people and the environment in many ways. There is an inextricable relationship between people and the environment. Locally, projected trends are imperative to communicating what is driving changes on earth and exacerbating local conditions. Planning and decision-making at local level require such data and information to shape local policy and help people mitigate and adapt to a changing climate. This reasoning explains the adoption of a mix study approach in this study.

3.5 Primary and secondary data sources

Primary data is data that is collected by the researcher in real-time. Primary data for this study was collected from 100 questionnaires on urban household perceptions and behavioural responses to adopting approaches that link mitigation and adaptation as suitable drivers of climate change urban resilience. Interviews were conducted with the Environmental Planning and Climate Protection Department (EPCPD), in the eThekwini Municipality. Representatives from SAWS was also interviewed. This was appropriate for understanding how the science of climate change has impacted physically on the historical climate and its impact on present-day climate. Pictures of the event were taken and used to further illustrate the intensity of extreme weather conditions.

Secondary data is conceptualized from primary data sometime after the actual event (Sapsford & Jupp, 2006). It is impersonal and available data or information that is excluded from the researchers own findings. Secondary data for this study was obtained from newspaper clippings, books and journals, while temperature, precipitation, humidity, hot days, dry spells, and heat stress data was obtained from the SAWS and CSAG Climate Information Portal (CIP).

3.6 Data collection and analysis

3.6.1 Sampling method

The sampling design used in this study was a non-probability sampling approach that does not guarantee that every individual will be sampled or has a chance of being included in the sample (Leedy & Ormrod, 2010). This approach was selected because it allowed the researcher to select a representative sample, a smaller group representing the views and opinions of the majority of people in the eThekwini Municipality.

Two sampling methods were used, namely, purposive sampling by randomly selecting predetermined areas, namely from the North (Tongaat, Verulam, Mount Edgecombe), North Central (Durban North, Morningside, Phoenix), South (Isipingo, Amanzimtoti), South Central (Chatsworth, Merebank, Umhlatuzana) and Inner West (Malvern, Pinetown, Queensburgh, Westville). The heads of households between the ages of 18 and over were identified and interviewed. The sampled households were identified by randomly selecting areas using a map to identify the main urban areas within and around the Urban Core of the eThekwini Municipality (Leedy & Ormrod, 2010). Secondly, the snowball technique was used together with purposive sampling. Considering that snowball sampling is a non-probability approach used to select people that previously had a higher probability of being excluded from the sample, in particular households that are geographically dispersed within the eThekwini Municipality (Heckathorn, 2011).The snowballing technique is used by selecting acquaintances to introduce participants for the study, as this chain of participants builds up; this creates the snowballing reaction (Steven, 2013). In this study, some participants were able to refer to

others who were willing to participate in the study. This referral system was instrumental in reaching hidden household populations through emails that could not be included in the purposive sample during an active investigation, considering that not every area in the eThekwini Municipality could be sampled.

In this respect, snowball sampling is similar to purposive sampling used to select participants with convenience and within a dispersed demographic. The snowballing approach is considered a chain reaction that can reach any corner and in this case any household. This allowed the researcher to cover a broader area of the eThekwini Municipality regions and to capture a diverse range of opinions from all races, across both genders and academic appraisals.

The interviews in this study were conducted were based on a semi structured interview schedule, consisting 100 sampled households. Out of the 100 households, 85 were interviewed in-situ, while the remaining 15 were contacted using the snowball technique, whereby some participants were able to refer to others who were willing to participate in the study. The 15 households selected through this technique were either given copies of the questionnaire or sent to them via email to be returned once self-completed. These methods resulted in a more representative sample, which identified households that had a probability of not being included in the sample.

3.6.2 Key Informant Interviews

The key informants for this study included Hlongwa from the EPCPD and DeJager, from the South African Weather Service (SAWS). The information from the informants was obtained through structured interviews using a set of predetermined questions for the purpose of shaping an opinion on how a specific topic is perceived, to delve deep into a phenomenon, where detailed insight is required (Gill, Stewart, Treasure & Chadwick, 2008). An interview with E. DeJager (personal communication, August 11, 2016) and N. Hlongwa (personal communication, March 16, 2016) informed the study on currently projected climate variables of temperature, precipitation, and relative humidity; and in what way urban communities are being implemented in the category of urban household mitigation and adaptation. The research questions also investigated the role of ecosystem-based approaches in the integration of mitigation and adaptation in establishing programmes and skills based approaches in creating resilient urban communities in the eThekwini Municipality (Appendix 2).

3.6.3 Local climate projected data

The term anomalies refer to changes in climate variables relative to a baseline (Real Climate, 2014). The mean annual anomalies for temperature, precipitation and humidity were calculated from climate data obtained from the SAWS. These were calculated by averaging their 12-month values.

The mean annual value of the latest baseline period of 30 years from 1981-2010 was calculated from the temperature, precipitation, humidity values. A baseline period can be described as the observed

climate and average conditions with which climate change data is associated and aids in constructing future scenarios (Smith et al., 1996). The most recent baseline period is selected because scientists require knowledge about climate change and how it is impacting on the present and future conditions of the climate. The aim is to determine how much the climate has changed in the eThekwini Municipality relative to the average baseline for the period of 1981-2010.

The daily mean for temperature, precipitation, and humidity was calculated to obtain the mean monthly values from 1957–2014. To calculate the mean annual values for maximum and minimum temperature, the 12 months maximum and minimum of the year were totalled and then divided by the total of 12 months. The mean annual for precipitation and humidity was calculated using the same method (totalling the values for 12 months and dividing by 12).

According to the World Meteorological Organisation (2017) and P. Kloppers (personal communication, May 9, 2018) baselines and their anomalies are calculated by:

- The baseline period must preferably be at least 30 years. Currently, the latest 30-year baseline period is 1981– 2010, that serves as the 30-year mean reference period to calculate the mean annual normal per station.
- The mean annual anomalies for each year from 1957 to 2014 are calculated for temperature, precipitation and humidity.
- The mean annual for each year is subtracted from the mean baseline period that defines the change of climate as either a positive or negative anomaly trend.
- The mean annual anomalies identified in the graphs for each year were used to determine if above-normal or below-normal conditions were occurring for a specific year.

To calculate the projected trends for RCP 8.5 W/m^{-2} minimum and maximum temperature and precipitation, the same steps described above were applied to obtain the mean annual anomalies for projected models MIROC-ESM, CanESM2, and MIROC5 from the year 2016-2100. The mean annual was calculated for years ranging from 2016-2035, 2046-2065 and 2081-2100.

The SAWS and projected CSAG data were analysed using Microsoft Excel. The aim was to do a trend estimation to determine if there was a relationship between the climate variables identified in this study. In the case study of the eThekwini Municipality, the relationship between the historical climate and projected climate for temperature, precipitation and humidity were analysed. Projected RCP 8.5 W/m^{-2} graphs for the years 2016-2090 (Appendix 4) for the eThekwini Municipality was also extracted from the CSAG Climate Information Portal (CIP) website. The study found it necessary to analyse the mean monthly anomaly trends for temperature, precipitation, hot days, dry spells and heat stress. This was instrumental to understand how projected models influenced the mean annual trends for the current, intermediate and distant future outlined in this study.

The need to assess the consistency of projected models in its projection of trends was necessary to determine the accuracy of those trends. A data analysis was performed. A data analysis is used to determine if a relationship exists between two datasets. The National Research Council (NRC) in 2004 (as cited in National Centers for Environmental Information, n.d.) defines climate data records as time-series of sufficient length and consistency to determine climate variability and change that can be used for the socio-ecological environment. This data was presented in a line graph with an X- and Y-axis. The X-axis consisted of the years and the Y-axis consisted of temperature and precipitation using the metrics Degrees Celsius (°C) and Millimetres (mm) for precipitation. Humidity is not identified by a metric unit but expressed as a percentage.

3.6.4 Urban household questionnaires

The distribution of questionnaires enabled the researcher to draw different opinions and conclusions about the larger population from open and close-ended questions (Appendix 1). Moreover, it is not possible to sample an entire population, namely households when studying the urban locality. Researchers work on a probability that their chosen sample will provide the answers that are needed to obtain high confidence in their findings (McHugh, 2008). In this study, a semi structured interview schedule was used, consisting of 100 urban households that were selected randomly (Section 3.6.1). In this case, a mixed approach questionnaire was administered to participants and in each questionnaire, the nature of the study, its aim, and objectives were described to the participants.

The purpose of the questionnaire was to evaluate the knowledge, perception and their integrated mitigation and adaptation approaches towards climate change... Specifically, some questions among others related to whether they have heard about climate change and from where, how they viewed climate change, whether they have been affected by various aspects of climate change (temperature, rainfall, drought, floods) and how, and whether were aware of or benefited from any local government climate change projects (Appendix 1). Other aspects of the questionnaires related to mitigation and adaptation at household level. The use of open-and close-ended questions made the interview process smooth and less complicated.

3.6.5 Workshop discussions

Data from the Durban Adaptation Charter (DAC) workshop was obtained through an interactive assessment. The stakeholder engagement process during this study included various delegates, both locally and internationally, within the environmental and climate change field. The questions and statements made at the DAC workshop provided useful information on their perception of climate change and the role of local government in creating awareness. The various delegates asked questions to the panel of judges consisting of the Climate Reality Project, the local governmental and non-governmental organizations in the category of science, impact, policy, and solutions (Appendix 3). This interactive approach was not conducted by the researcher but a panel of judges, to assess how

officials, from various sectors and organizations in and around Africa and the world felt, and what they had observed regarding climate change and locally based action in cities.

During the workshop, data from 50 local and international officials were collected to address the state of climate change mitigation and adaptation action in this study. This assessment was to assess (i) the success of the workshop contributing to the plight against climate change (ii) the behavioural responses based on various delegates questions and opinion of what is being done and needs to be done in cities and the areas in which local government/local municipality's need to address through mitigation and adaptation..

3.7 Ethics in research

Any research that includes interaction with human beings, animals or any creature that has the ability to express emotions, experiencing any sort of discomfort or fear, to think and to be deceived, requires ethical practice by the researcher until the end of the research process (Leedy & Ormrod, 2010). Kvamsas (2012, p, 50), "points out that it is important to remember the power relationship in research and how it affects research". According to Bryman & Bell in 2007 (as cited in Research Methodology, 2016) the following 10 ethical guidelines should be acknowledged during the research process:

1. No harm should come to the research participant
2. The dignity of the research participant should be a priority
3. The consent of all research participants should be acquired before beginning undertaking research.
4. Privacy should be ensured throughout the research process
5. A preferred level of confidentiality between the researcher and the participants
6. There should be anonymity of individuals and their personal details
7. A lack of truth or ambiguity pertaining to the aims and objectives should be avoided
8. Affiliations and funding from any source should be acknowledged
9. There should be honesty and transparency until the research is completed
10. Any type of information, including primary data findings that are biased, should be avoided.

Any research would not be possible without the authorization of an individual included as a subject of a research. The individual, animal or any form of creature should be treated with the utmost of care, honesty, appreciate, with integrity and shielded from any harm that can come about in the sharing of information. Stringent efforts and diligence were taken to comply with these research ethics. A formal request seeking permission to interview the participant was taken before administering the questionnaire. Participants were assured that information provided would remain anonymous. No details or personal references were instituted about the participants in this dissertation.

Firstly, ethical clearance was obtained from the ethics committee of the University of KwaZulu-Natal based on compliance with the research ethics. Letter of approval from gatekeepers was obtained to use data in this study (Appendix 5). Secondly, a brief overview was provided on the research questionnaire to each and every participant on the aim, objectives and including what was expected of them during the research process. Anonymity and privacy of personal information were maintained throughout the research process (particularly their names, tertiary qualification, income, and location). During data analysis, particular care was taken in analysing both the quantitative and qualitative data. The calculation of climate variables was repeatedly checked to ensure that each mean and anomaly were correctly tabulated in excel without succumbing to errors. Qualitative data, especially data obtained from the open-and close-ended questionnaire were carefully categorized according to each response themes and special care was taken to acknowledge every participant's responded to the questionnaire.

3.8 Conclusion

This chapter has covered the research methodology and given insight into the research design of the study. This is a mixed approach study, comprising of a qualitative and quantitative component that employs a case study approach. This section also explained in detail the primary and secondary data used in the study, as well as the data collection process, the methods used to analyse the data and ethics when undertaking the research for the study.

Chapter 4

Local Projected Climate Trends

4.1 Introduction

Since the 1950s (Chapter 2 and Figure 2.1), an increase in carbon dioxide emissions had peaked from the 1980s to 2010. Evidence of on-going climate warming is expected as science begins to prepare for an increase of 3-4°C (IPCC, 2016). According to Joubert (2009), Southern African temperature is expected to increase from 1-3°C by 2050, compared to average temperatures from 1960-1990. Ziervogel (2014) states that mean annual temperature in South Africa have increased by at least 1.5 times more than the observed global average of 0.65°C over the past 5 decades, along with extreme precipitation. With regards to the eThekwini Municipality, the IPCC (2016), describes RCP as bands of colour used to show future projected changes of radiative forcing while using socio-economic scenarios to identify trends for GHGs from 2000-2100.IPCC (2016) further asserts that the warming of the earth is longer than the existence of GHGs in the atmosphere. Manabe & Stouffer (2007) discussed the intake capacity of the ocean and its deeper layers in the absorption of surface temperature that can take from decades to centuries to lose this excess heat (Manabe & Stouffer, 2007). As a result, temperature and precipitation anomalies can fluctuate to an extent that is not consistent enough to project accurately.

This chapter begins by analysing and discussing historically projected anomalies of temperature, precipitation, and humidity for the period 1957-2014 obtained from the SAWS. This is followed by a discussion on projected data from 2016-2100 using RCP 8.5 W/m^{-2}. This includes a discussion related to temperature, precipitation, and number of hot days, dry spells and heat stress obtained from the CSAG CIP. These discussions aid in further evaluating how much of an influence these climate variables can have on the aggravation of other climate-induced events and if there is a correlation between the selected climate variables and their anomaly trends identified in this study. This identification of trends will help determine if the urban areas of the eThekwini Municipality are undergoing a positive or negative anomaly trend, and how this trend will proceed into the future should mitigation not be sufficient on its own.

4.2 Historically projected climate variables

In Schulze & Kunz (2011), the temperature is discussed as the climatological parameter used to measure the energy status of the earth with a measure of certainty. The mean annual temperature is an indicator used to measure the environmental status of a location, as well as a good indicator of year-to-year temperature variability (Hanson, Sato & Ruedy, 2012). In South Africa, the mean annual precipitation decreases uniformly westwards from the escarpment across to the interior plateau, but

this could also be impacted on by the terrain that induces precipitation between the escarpment and the ocean in the southern and eastern coastal margins (Schulz, 2011).

4.3 Temperature, humidity and precipitation anomalies

Trends of past temperature, precipitation, and humidity anomalies show fluctuating changes indicative of a changing climate. The overall SAWS anomaly trends for maximum and minimum temperature reveal that temperature, precipitation, and humidity have been fluctuating since 1957 (Figures 4.1 and 4.2).

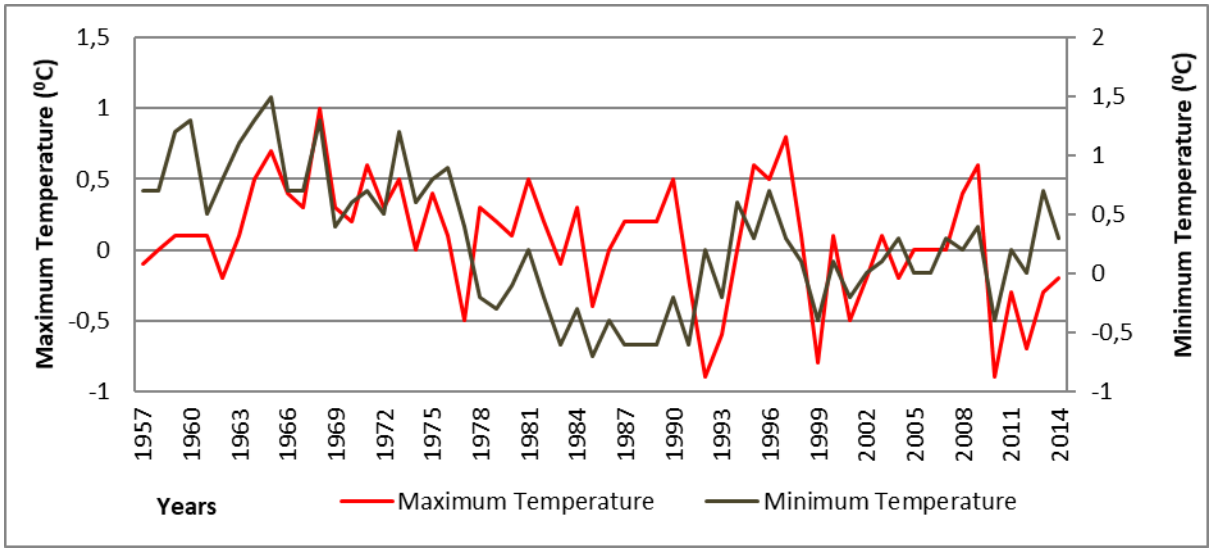

Figure 4.1 Mean annual maximum and minimum anomalies for the eThekwini Municipality, KwaZulu-Natal (Data Source: SAWS, 2016).

Maximum and minimum temperature anomalies generally rose and fell simultaneously from 1957-2014. However, there were years when the minimum temperature anomalies rose higher than the maximum and other years when it was lower than the maximum. For example, in 1965, the minimum temperature was higher than maximum temperature with an anomaly of 1.5°C. Again, in 1973, 2013 and 2014, minimum temperature anomalies were higher than the maximum. This is indicative of the extreme variability of temperature related to global warming. High peaks of maximum temperature anomalies occurred in 1968, 1997 and 2009.The results have proven that it is not possible to project a consistent linear trend of either a positive or negative anomaly progression in the graphs. However, the results correlate with Department of Environmental Affairs and Tourism (2013), which maintain that some of the highest rates of maximum temperature increase for South Africa were among others in the 1990s and 2000s.

The results presented for precipitation anomalies were compared to trends in humidity (Figure 4.2).Relative humidity in climate literature is defined as the amount of water vapour that air can hold until it reaches saturation point and then condenses (Umoh, Akpan & Bassey , 2013).

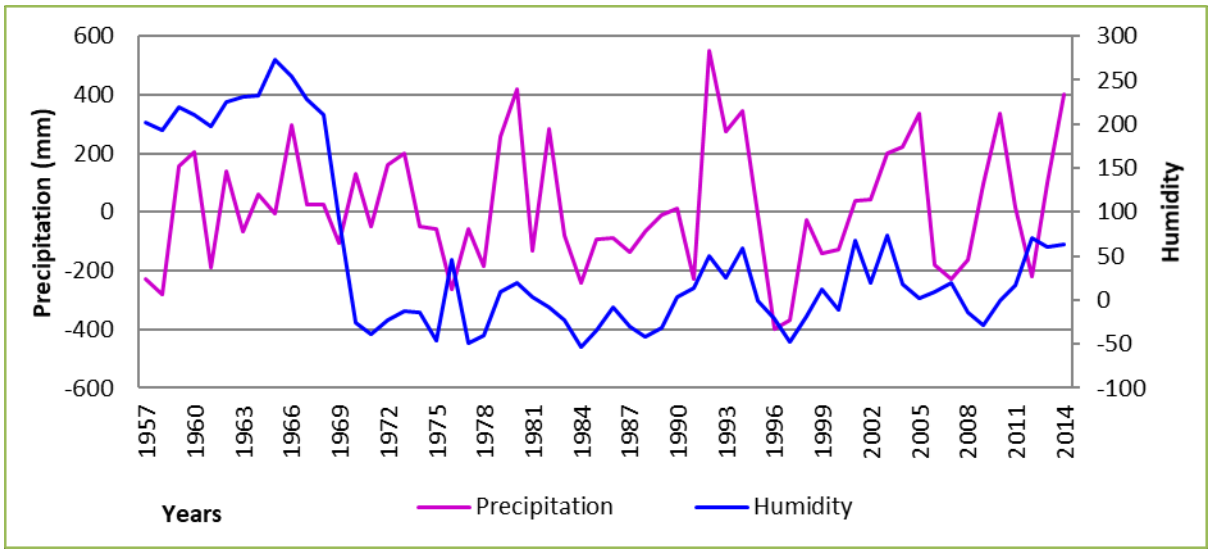

Figure 4.2 Mean annual precipitation and humidity anomalies for the eThekwini Municipality, KwaZulu-Natal (Data Source: SAWS, 2016).

The process can be identified as when relative humidity is low, temperature is high, and the air is considered dry. The higher relative humidity is, the more humid the air is, and therefore showing a high probability of precipitation occurring. There are both contrasting patterns and similarities (Figure 4.2). When there is a high humidity anomaly potential, this is accompanied by the probability of precipitation. Generally, from 1957-1966 (Figure 4.2) when humidity anomalies were increasing, precipitation anomalies increased. This trend shows humidity as a contributing factor in the development of precipitation. However, there are periods when humidity was high, and precipitation was low or when precipitation was high, and humidity was low (Figure 4.2). This is a similar pattern identified for maximum and minimum temperature anomaly trends in Figure 4.1. For example, in 1984 and 1996, a decrease in humidity was accompanied by a decrease in precipitation. However, in 1996 and 2011, there was an inverse relation between humidity and precipitation. These trends show the unpredictability of climate variables to climate change.

Precipitation in South Africa is said to be highly variable from year to year, showing wet and dry periods with occasional extremes (MacKellar et al., 2014). It was identified by Dube & Jury (2003) that periodic droughts occurred in South Africa in 1982, 1983 and 1984. It was also found in the same study that KwaZulu-Natal had experienced fluctuations of decreases and increases in precipitation from 1987-1996, and periodic droughts in the years 1992 and 1993 in the eThekwini Municipality.

While in general, the precipitation fluctuations in Dube & Jury (2003) is consistent with Figure 4.2, their mention of the 1992 and 1993 droughts do not harmonise with Figure 4.2, which instead show extreme rainfall peaks for those years. Increased temperature can lead to evaporation and the circulation of that moisture in the atmosphere being driven to where storm activity is progressing (Trenberth, 2011; Trenberth & Fasullo, 2009). However, the trends show that when the temperature peaked in the year 1997, precipitation and humidity were low (Figure 4.1 and 4.2) and when precipitation peaked in the year 1992, the maximum and minimum temperature dropped. This pattern illustrates the general inverse relationship that exists between temperatures on the one hand, and humidity and precipitation on the other hand. On the contrary, when maximum temperature increased in the year 2009, precipitation was steadily increasing in the year 2009. Again, exemplifies the unpredictability related to climate change that disrupts established weather and climatic patterns.

4.4 Correlating trends of temperature, precipitation and humidity

Babatola (2013) observed a similar trend in a mean annual graph of relative humidity and precipitation, concluding that the relative humidity in the air most likely influences the amount of precipitation. It was found that in comparison to each other, when maximum temperature anomalies peaked, precipitation and humidity showed decreasing anomaly trends. For example, this correlates with trends observed in 1997 (Figures 4.1 and 4.2), signifying a period of drought and dry conditions, therefore consistent with the observed trends in Babatola (2013) and Trenberth (2005). There were also trends of increasing temperature anomalies, with an increase in precipitation and a decrease in humidity anomalies. The trends also show that a climate variable can evolve without the influence of the other variables. For example, decreasing mean annual anomaly trends were observed in the year 1969 for maximum and minimum temperature, precipitation, and humidity, indicating the complexity of climatic variability. This mean annual trend shows that temperatures for both maximum and minimum temperatures were lower than normal, as is the same trend for precipitation and humidity that depicts the air as being drier than what is usually expected during normal conditions (E. DeJager, personal communication, May 3, 2018). This would compensate for the negative trend that was encountered

4.5 Projected climate variables for the period 2016-2100

This sub-section evaluates projected temperature and precipitation anomaly trends, to determine how they affect national, regional and local climate. RCP 8.5 W/m^{-2} is illustrated and discussed for the years 2016-2100, using the 1981-2010 baseline to identify if anomaly trends fluctuate similarly to SAWS trends (Figures 4.1 and 4.2). In this sub-section, hot days, dry spells and heat stress are also evaluated (see also Appendix 4).

The ensemble mean annual projections from the earth system models MIROC-ESM[1],CanESM2[2] and MIROC5[3] is shown for 2016-2100 in different colours (Figures 4.3 to 4.5) (Yang & Saenko, 2012; Watanabe et al., 2011; Watanabe et al., 2010), displaying the maximum and minimum temperatures, and mean annual precipitation projections. These help to identify if trends show fluctuations as was illustrated in Figures 4.1 and 4.2.

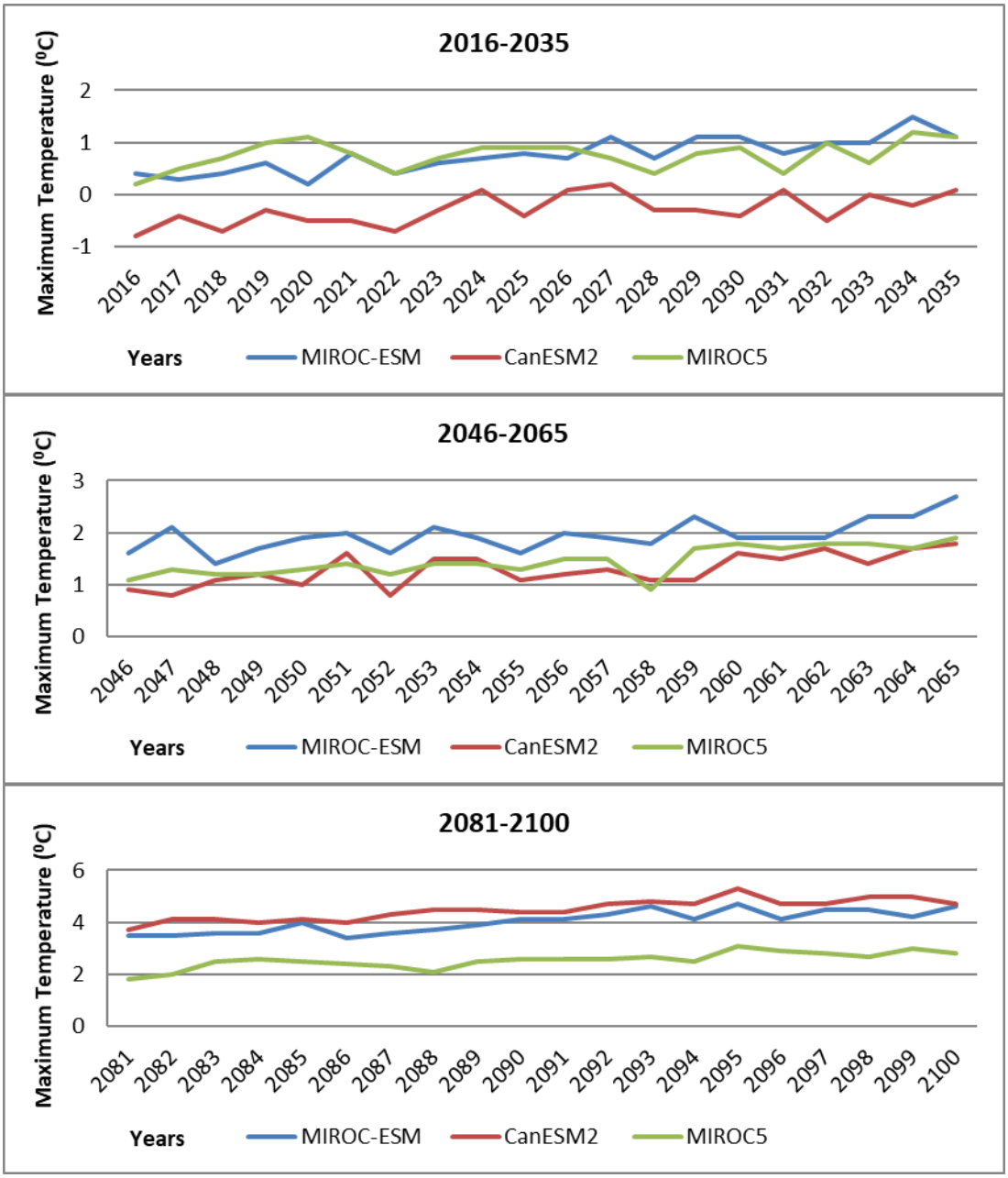

Figure 4.3 RCP 8.5 W/m-[2] mean annual maximum temperature for the eThekwini Municipality, KwaZulu-Natal (CSAG, 2016).

[1] MIROC-ESM: Model for Interdisciplinary Research on Climate Earth System Model
[2] CanESM2: - Canadian Earth System Model (Second Generation Model)
[3] MIROC5: Model for Interdisciplinary Research on Climate (Fifth Generation Model)

In Figure 4.3 above, the MIROC-ESM, CanESM2, and MIROC5 projected models shows that in general, maximum temperature anomalies will increase in a fluctuating pattern from 2016-2100. For example, from 2016-2035, maximum temperature anomalies for all three models range from -0.8-1.5°C, however, from 2081-2100, the range increases from 1.8-5.3°C.The fluctuating pattern revealed by these projected models mimics the fluctuating temperature, humidity and precipitation obtained from the SAWS (Section 4.2 and Figures 4.1 and 4.2).CSAG projections found in Department of Environmental Affairs and Tourism (2013) project a mean annual increase of less than 1°C for coastal areas from 2015-2035. This is consistent with projected maximum temperature anomalies especially for the CanESM2 model which shows an increase ranging from -0.8- 0.1°C. For South Africa, during the period 2040-2060, model ensembles project an increase of above 3°C for the coastal regions (Department of Environmental Affairs and Tourism, 2013).From 2046-2065, the projections show maximum temperature anomalies increase from a low of 0.9°C and a high of 2.7°C (approximately 3°C) (Figure 4.3).This harmonises with projections that mean annual temperature for the eThekwini Municipality will rise to between 2.5 and 3-5°C by 2065, increasing to 3-5°C by 2100 (Lewis, 2011). Between 2081-2100, an anomaly increase of 5°C is projected for model CanESM2, MIROC-ESM (4.7°C), and MIROC5 (3.1°C). Specifically, the MIROC5 (3.1°C) projection is consistent with the data published in Department of Environmental Affairs and Tourism (2013) and Joubert (2012) who state that by 2100, the coastal regions could warm up to 3-4°C.

Figure 4.4 shows that the mean annual minimum temperature anomalies for projected models will continue to increase in a fluctuating pattern from 2016-2100. During the 2016-2035 periods, the lowest projected minimum temperature anomaly is 0°C (MIROC5), while the highest is 1.9°C (MIROC-ESM). This harmonises with CSAG projections that project a positive anomaly of less than 2.5°C for the coastal regions from 2015-2035 (Department of Environmental Affairs and Tourism, 2013). During the 2046-2065 period, the lowest and highest minimum temperature is projected to increase to 1°C (MIROC5) and 3.1°C (CanESM2).The projected mean annual minimum temperatures continue to show a positive anomaly trend up to the 2081-2100 period. By 2100, the mean annual minimum temperature anomaly is expected to reach its highest at 5.6°C in 2095 (CanESM2).

The trends identified by the projected models show that they are not consistent and demonstrate that temperature anomaly trends vary from one projected model to the other. Moreover, it will be difficult to ascertain if the climate is warming faster than is being projected. Mean monthly anomaly trends for maximum and minimum temperature can be identified in Appendix 4.1 and 4.2.

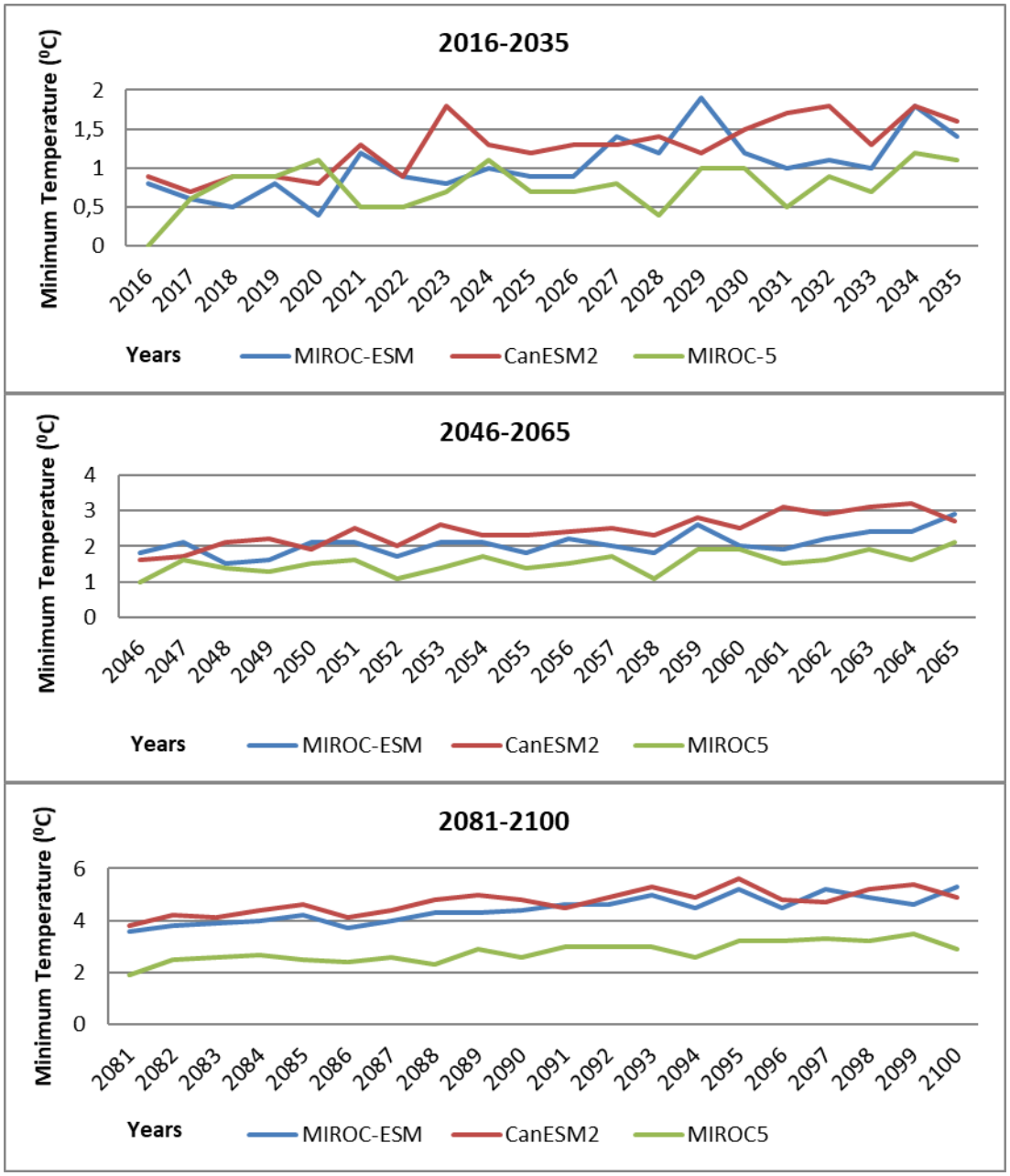

Figure 4.4 RCP 8.5 W/m-^{2} mean annual minimum temperature for the eThekwini Municipality, KwaZulu-Natal (CSAG, 2016).

The pattern for precipitation anomaly in Figure 4.5 shows a fluctuating increase; also indicating that just like in the case of past measurements (Figures 4.1 and 4.2) and future projections of other climate variables (Figures 4.3 and 4.4), precipitation will be highly variable. For example, from 2016-2035, the lowest and highest projected precipitation is a -307.8mm (2016, MIROC-ESM) and 413.1 mm (2018, MIROC5) respectively. By fast forwarding to the 2081-2100 period, an increase is expected as lowest and highest projected precipitation anomalies are -522.5 mm (2081, MIROC-ESM) and 457.9 mm (MIROC-ESM) respectively.

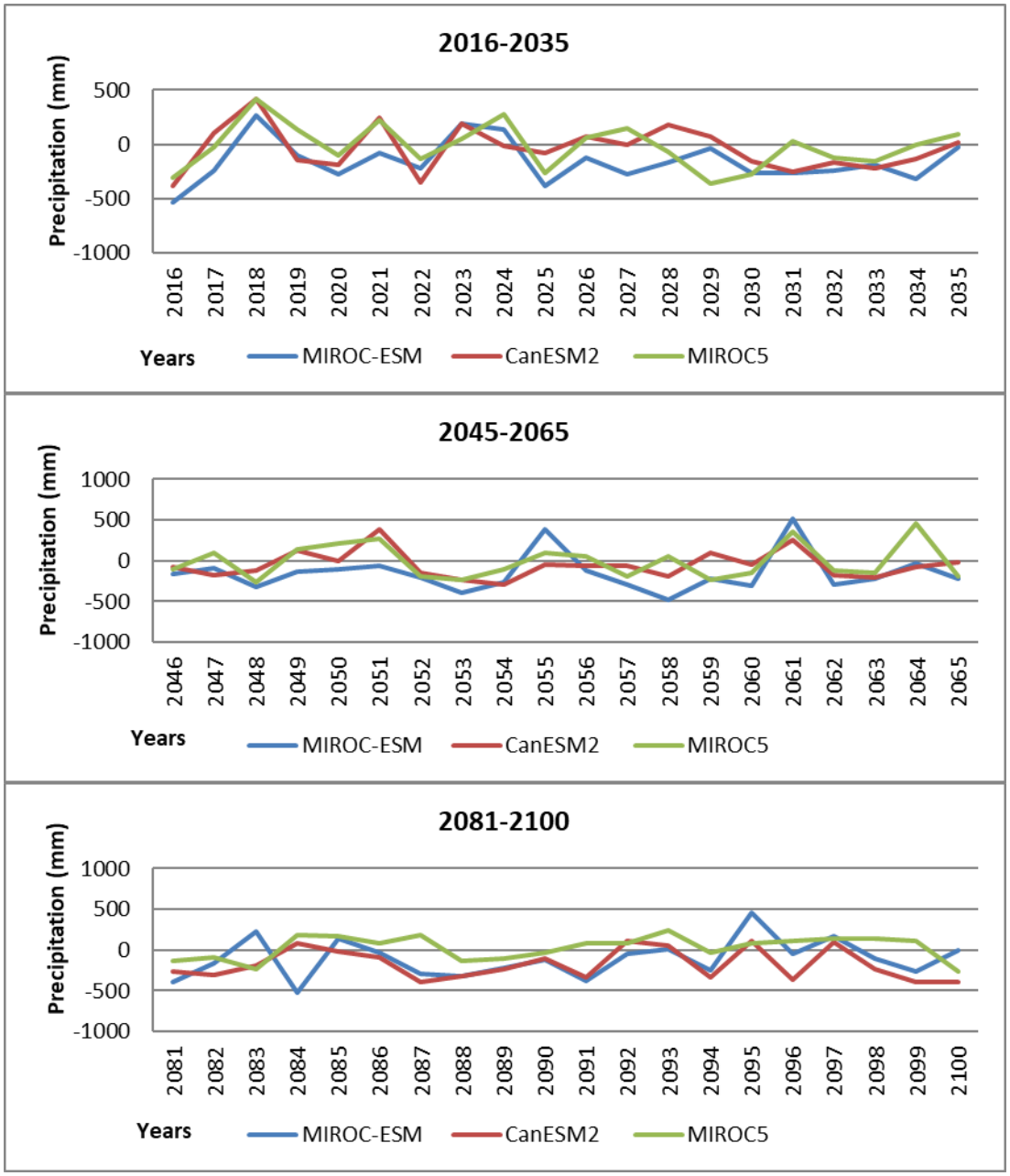

Figure 4.5 RCP 8.5 W/m-^{2} mean annual precipitation for the eThekwini Municipality, KwaZulu-Natal (CSAG, 2016).

Appendix 4.4 also shows fluctuating trends in precipitation. For example, the years 2016-2035 and 2045-2065, show negative anomaly trends for precipitation (May to August), leading up to the winter period.

The projected models have also identified dry spells (Appendix 4.5) and show that from 2016-2100, dry spells are expected to become less pronounced, and occur mostly during the last month of Autumn (May) and the winter months (June – August). The hot days are expected to create intense heat spells, which would be more pronounced in the first quarter of the year (Appendix 4.6) and expected to impact severely on urban households and their well-being.

4.6 Analysis of results

Observed maximum and minimum temperature anomalies from 1957-2014 (Figures 4.1 and 4.2), show patterns of fluctuations. It was also identified that when maximum and minimum temperature anomalies increased, precipitation and humidity anomalies decreased.

Minimum and maximum temperature show fluctuating mean annual anomalies between the 2016-2035, 2045-2065, and 2081-2100 periods. Precipitation trends also show a fluctuating pattern but indicating a general increase from 2016-2100.The projected results also reveals that the MIROC-ESM, CanESM2, and MIROC5 projection models are not consistent in their projected trends (Figures 4.3 to 4.5). This can be problematic especially when considering mitigation and adaptation. The probability of the earth warming at a faster rate than what is projected is greater than what is statistically shown by projected models. Projected trends can be affected by factors that cause climatic variability, the change of GHG emissions and different scenario-based models (Saraf & Regulwar, 2016; Burke, Dykema, Lobell, Miguel & Satyanath, 2012; Greasby & Sain, 2011).

It is also important to assess how climate variables and their anomalies progress on a mean monthly basis. This enables identification of short-term variations at a local level. For example, the CSAG CIP graphs (Appendix 4) show the mean monthly RCP 8.5 W/m^{-2} maximum and minimum temperature, precipitation, dry spell, and heat spell changes for the 2016-2035, 2045-2065, and 2070-2090 projected periods for the eThekwini Municipality.

High temperatures and hot days can contribute to elevated heat spells. This is evident as hot days (Appendix 4.5) are projected to become more pronounced especially in the winter months. This can mean that the eThekwini Municipality will be subjected to less precipitation, increasing dry spells, which will lead to projected urban heat stress resulting in increased episodes of uncomfortable weather.

Mean monthly maximum and minimum temperature anomalies show a significant increase in the summer months (January-March) and (September-December) (Appendix 4.1 and 4.2). This is consistent with trends identified for hot days (January-March) (Appendix 4.3). Projected anomaly trends for dry spells (Appendix 4.5) are also consistent with the months that indicate a decrease in precipitation (May-August) (Appendix 4.4). Positive anomaly trends were also identified for heat spells in the summer months (January -April) (2016-2035) (Appendix 4.6). This is consistent with the positive anomaly trends identified for maximum and minimum temperature and hot days. This can mean that the eThekwini Municipality will be subjected to increased temperatures, hot days, heat spells, accompanied by less precipitation, and an increase in dry spells. This will lead to projected urban heat stress resulting in an increase of humid and uncomfortable weather.

For the projected results to be trustworthy, the use of more than one projection model is suggested to produce results that reduce errors and uncertainty (Tebaldi & Knutti, 2016; Hao et al., 2013). This suggestion sounds paradoxical and raises doubts as fluctuations from different models used in this study make it difficult to accurately identify trends (Figures 4.3 to 4.5). Such inconsistencies related to the use of multiple models using different predictor variables, scenarios and time periods can impact on projected anomaly values (Hewitson & Crane, 2006). Perhaps a solution would be the development of an integrated model that combines the strengths of all the existing models. In addition, the statistical downscaling and filtering of large-scale imagery is argued to be too large to produce accurate projections for the local scale (Bhuvandas, Timbadiya, Patel & Porey, 2014; Day, 2013).

4.7 Conclusion

To conclude this chapter, the integration of historical, current and future projections allows scientists to compare past and current observational data with future projected data (Kling et al., 2003). The trends observed in this study for temperature, precipitation, and humidity reveal that these projected variables for the eThekwini Municipality will continue to fluctuate with positive and negative trends. This is consistent with observed SAWS trends for the eThekwini Municipality from 1957-2015 and CSAG (CIP) projected mean annual anomalies for RCP 8.5 W/m^{-2} from 2016-2100.This also includes CSAG projected mean monthly RCP 8.5 W/m^{-2} graph illustrations (Appendix 4) for the years 2016-2090. The dips (troughs) and peaks show positive and negative anomaly changes, while the events within the fluctuations can be seen as interval periods that work towards the build-up of the peaks. The analysis of precipitation trends in literature is consistent with anomaly trends identified in this study. The results were highly variable with periods of increased peaks. A correlation between precipitation and humidity was found. For precipitation to occur, the temperature must be low and relative humidity high. When the temperature is high, humidity is low and there is less of a probability of precipitation occurring. However, the peaks found when comparing all three variables revealed that when humidity was low, peaks of mean annual precipitation would occur. This means that humidity does not need to be high for precipitation to occur. The results also revealed cases where temperature anomalies peaked, and precipitation anomalies instead increased while humidity decreased.

The next chapter evaluates the local household perceptions and behaviour towards climate change adaptation and mitigation in the eThekwini Municipality, KwaZulu-Natal Province.

Chapter 5

Urban Household Perceptions and Behaviour towards Climate Change Adaptation and Mitigation

5.1 Introduction

The perceptions of local residents on the subject of climate change are informed by its impacts and human experiences with changes in temperature, precipitation, and humidity on a daily basis. The understanding is that the cognitive part of the human psyche and their concerns about the impacts associated with climate change is necessary, as it has been argued that people become emotionally involved through their personal experience and knowledge of climate change (Pandve et al., 2011). The forcing that triggers behavioural responses are communication channels (newspapers, television, schools and the local municipality), and awareness through sustainable campaigns, workshops and programmes.

Residents surveyed in this study claimed that the eThekwini Municipality was not creating enough awareness nor prioritizing funds towards a more sustainable environment. The results reveal that people do apply mitigation and adaptation in their households. However, the responses indicated that people prefer short-term curtailment measures to long-term efficient measures. It was also found that people do not want to invest in long-term eco-friendly equipment that is too expensive or not budgeted for, while also not being aware of the benefits of reducing their energy and water use as a long-term intervention.

This study also used the integrated framework of the three worlds approach by Mouton (2001), namely worldview 1, worldview 2 and worldview 3, to evaluate how people perceive climate change and its impacts, while also mitigating and adapting to climate change. Worldview 1 (consisting of the social and physical world, and the production and use of knowledge), 2 (the use of theories and concepts) and 3 (our understanding of a problem, reflecting on what method or theory to explain the phenomena) enhances the study by integrating the social and physical world, in which people live in and adapt to on a daily basis, linking with theoretical concepts of transformational, integral theory and behavioural responses. This worldview approach further explain why people behave and respond to their immediate environment and what influences that decision. This is instrumental in approaching the subject matter with clarity on what method is appropriate in explaining the phenomena of climate change, from both a quantitative and qualitative viewpoint.

This chapter begins by addressing people’s knowledge and awareness about climate change and its effects. This is followed by an assessment of people's behavioural responses in terms of their use of sustainable household mitigation and adaptation approaches. The last section evaluates the eThekwini Municipality's EPCPD response to climate change and the impact of those responses in creating climate-resilient pathways in urban communities.

5.2 Urban household demographics influencing mitigation and adaptation perceptions and responses towards climate change

Household demographics are discussed in Lutz, Wolfgang & Striessnig (2015) as important denominators to understanding the interactions between people and climate change. The gender composition of the respondents was 45% male and 55% female. Of the 45% of male respondents, 17% were Indian, 11% white, 11% black, and 2% coloured. In the female category, the racial groups identified showed that there were 19% Indian, 15% black, 11% white, and 10% Coloured.

The age and location of local participants in this study did not seem to have any significant bearing on the community's ability to mitigate and adapt towards climate change. This is because the responses from the questionnaires revealed that people, despite their age, location and race, showed similarity in the manner they mitigated, adapted and responded to climate change. Lutz, Wolfgang & Striessnig (2015) state that it is important to consider household education and income because educated people are more likely to be sustainably driven at any given income level. However, 72% of the respondents had some form of education between the ages of 18 and over and were found to be in the income category of R0-R57 099. However, despite earning potential, their level of investment in greener technology in their homes was found to be minimal. Their rationale was that solar energy and water saving equipment was too expensive to invest in for their household.

Women, in particular, were more aware of the effects of temperature changes and how it impacted on their well-being on a daily basis. This is consistent with Rahman, Mohamad & Zarim (2014) who found that women were significantly more aware of the consequences and impacts of climate change in the physical, environmental and psychological domains. Education was also seen as an important indicator in this study. The educational composition shows that 31% of respondents had competed their high school education, 22% had a diploma based education, 14% had a higher degree education, 5% had acquired a postgraduate degree education, while 28% had no form of education (or had not completed their schooling career. For example, when households were asked to explain what climate change and its impacts entailed, those with a higher education, with a diploma or a degree (41% of the sample) were able to scientifically describe the process and its impacts both globally and locally compared to respondents that had a high-school education.

5.3 Community perception of climate change and its impacts

Peoples' perceptions shed light on how climate change is experienced at the local scale. Sina et al. (2016) argue that the integration of scientific knowledge, the use of projected figures and the studied perceptions of local communities provide a more sophisticated form of investigating climate change towards better adaptation strategies for current and future generations. To obtain information on urban household perceptions of climate change and its impacts, 100 questionnaires were distributed to

willing participants. Figure 5.1 shows that 98% of respondents have heard of climate change, while 2% had not.

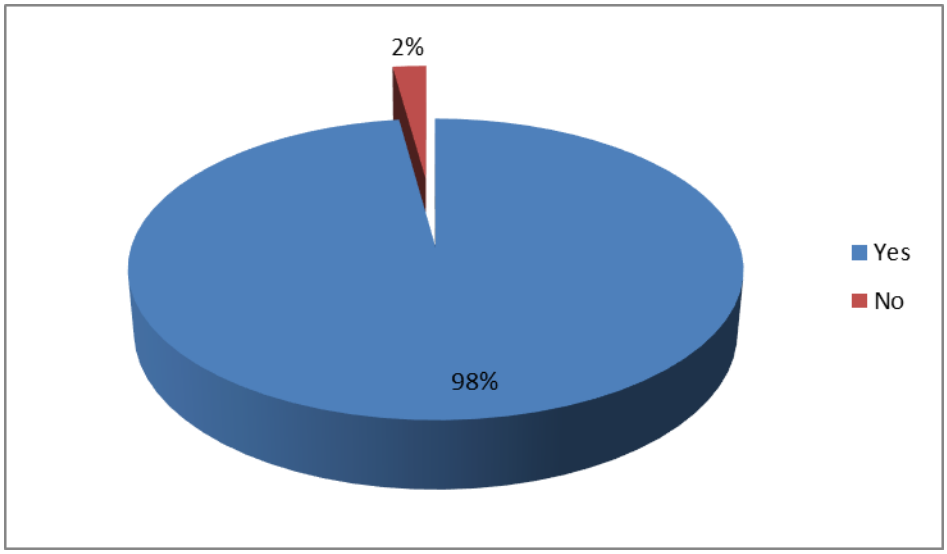

Figure 5.1 Household knowledge of climate change.

This shows that urban households are aware and knowledgeable of climate change and its impacts. This can be attributed to the different channels of communication accessible to the public domain (Figure 5.2) and other factors such as personal experience, knowledge, the ability to balance the benefits and costs associated with climate change and faith in leading societal actors (Pandve et al., 2011).

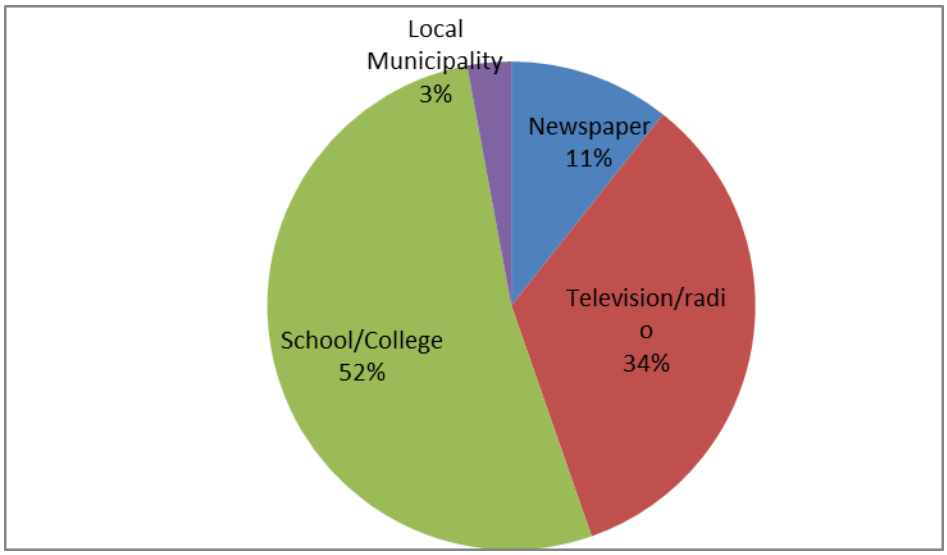

Figure 5.2 Sources of community's knowledge on climate change.

Figure 5.2 above represents the different sources of community knowledge on climate change. The most common source of information for climate change was the school/college (52%), followed by television (34%), selected newspapers (11%) and the local municipality (3%). Media channels of television and newspapers are described by Carvalho (2007) as being important sources of

information and communication of science, especially in shaping the perceptions and attitudes of people through topics like climate change (Rabe & Borick, 2012). However, this view is contested by Lewandowsky et al., (2015), questioning the accuracy of information generated in media since there are conflicting perceptions between scientists and politics.

The educational sector is also a sector that is expected to educate people on mitigation and adaptation, including the use of greener technology, changing their consumptive patterns and reducing their vulnerability to climate change (Anderson, 2012).

In relation to the community's perception of climate change impacts, 60% of respondents (Figure 5.3) believe that climate change can be harmful to humans and the environment if not controlled, 21% saw climate change as a benefit to humans and the environment if well managed, while 19% viewed climate change as completely harmful to humans and the environment. Community perceptions of the effects of climate change on weather showed that 88% (Figure 5.4) were very aware of the effects of climate change on weather, while 12% do not perceive any change. People are most likely to judge the effects of climate change on the weather events that are unusual, recent and experienced by the individual (Taylor, de Bruin & Dessai, 2014).

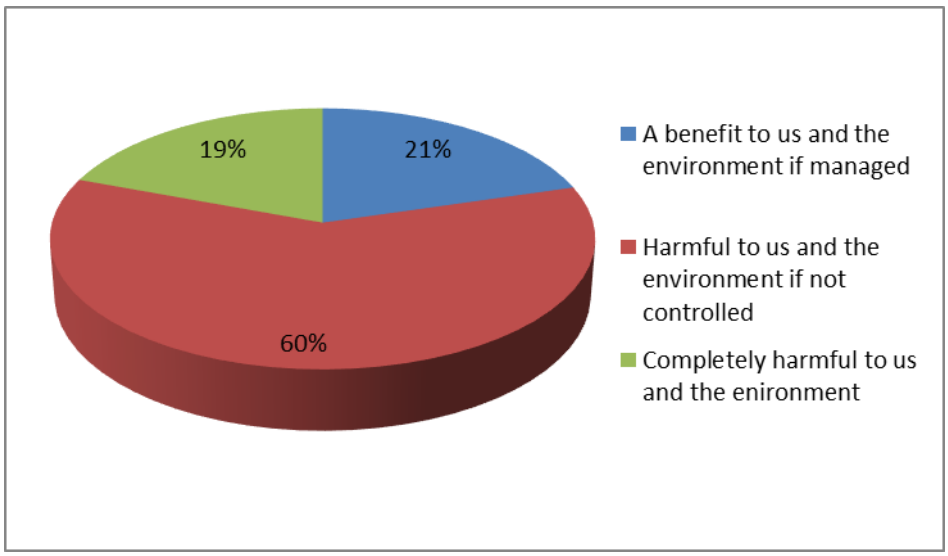

Figure 5.3 Community's perception of climate change impacts.

The variability of climate creates a distorted outlook that hinders how severe anthropocentric climate change can be in the immediate and distant future. Therefore, perceiving climate change as a threat to human well-being will have minimal effect on the audience.

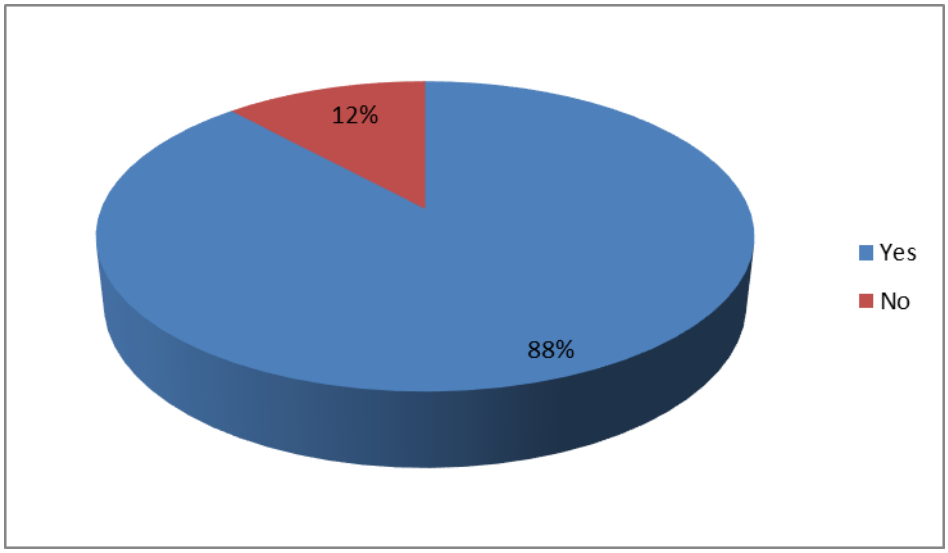

Figure 5.4 Community's perceptions on the effects of climate change on weather.

Most of the 88% of respondents (Figure 5.4) subjectively pointed out that temperatures in the Central Business District (CBD) of the eThekwini Municipality were much higher compared to the surrounding areas of the eThekwini Municipality. Yang, Qian, Song & Heng (2016) state that increased temperatures in the city are the result of the urban island heat (UHI) effect that is controlled by factors such as the population density of a city, human activities, and vegetation cover. This effect increases land surface temperatures, influencing energy flow into urban ecological systems, the urban atmospheric climate and human health. In order to determine whether the urban community has experienced temperature changes over the past years and whether those changes were positive (increase) or negative (decrease), respondents were asked about their experiences (Figure 5.5).

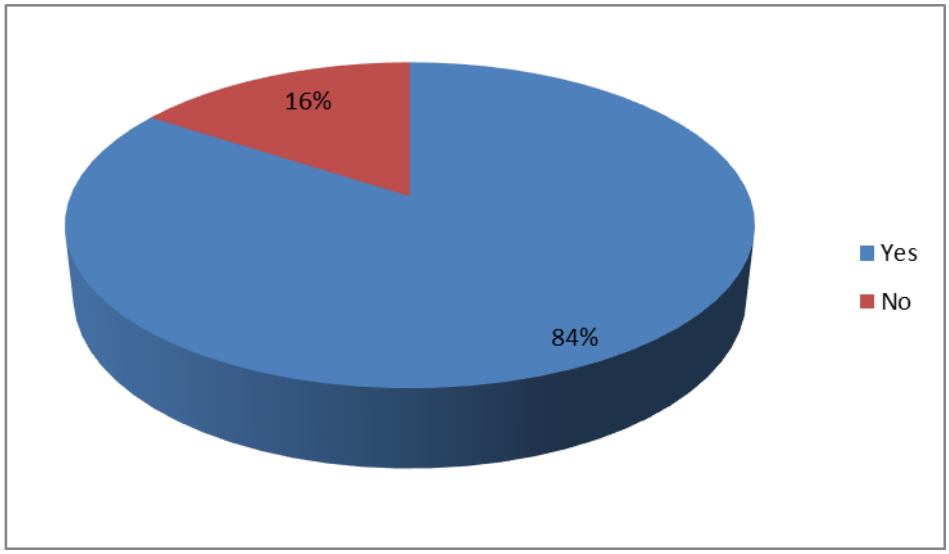

Figure 5.5 Responses on perceived temperature change.

In Figure 5.5, 84% of urban households indicated that they had experienced temperature changes, and 87% felt that changes were positive (higher temperatures) (Figure 5.6), while 16% indicated that they

had not experienced any temperature changes (Figure 5.5) and 13% felt that the changes were negative (lower temperatures) (Figure 5.6). The perceptions of respondents were that the extremity of weather conditions was a result of changes in temperature and precipitation.

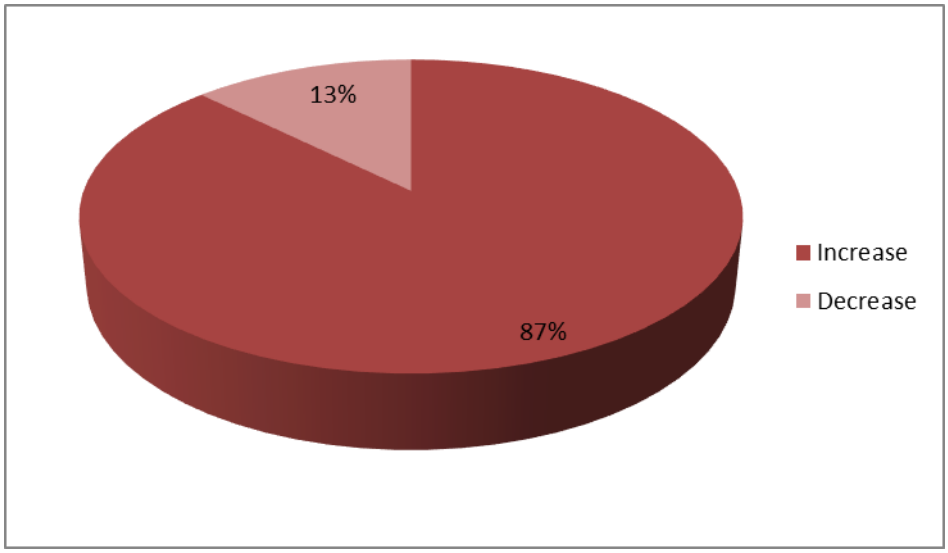

Figure 5.6 Responses on the nature of temperature change (increase or decrease).

The 87% of respondents referred to the change in the study area's historical weather patterns during the months of October, November, December, and January in 2015 and 2016, with summer months becoming hotter and winter months colder with the minimal expectance of precipitation for the eThekwini Municipality area.

Table 5.1 and Table 5.2 is a summary of responses to questions on an individual's understanding of the concept of climate change. Climate change means different things to different people, either they have observed its impacts or are knowledgeable of what the effects of climate change are.

Table 5.1 Households understanding of the concept of climate change.

1. The increase of temperature
2. Seasonal changes in rainfall
3. Colder winters
4. Extreme conditions (droughts, sea-level rise, floods and hurricanes)
5. Experiencing different weather condition, not associated with a specific region over a period of time
6.The increase of greenhouse gases in the atmosphere

7. A change is global weather patterns
8. Atmospheric chemistry that causes energy from the sun to be absorbed into the atmosphere, land and sea that is not radiated back into space
9. Variation of patterns over an extended period of time
10. Has beneficial and detrimental worth for man-kind
11. The increase of hard emissions from human activities (for example industries).
12.The boreholes are running dry
13. Lack of respect for the environment by humans

Table 5.2 Households knowledge on the impacts of climate change.

1. The impact of the greenhouse effect and more extreme and frequent weather events
2. The increase of weather (especially global increase of temperature). Meteorologists and global models predict an increase in global temperatures around the world, leading to unstable weather patterns
3. The increased severity of droughts and storms (For example monsoons)
4. Ice caps melting
5. Sea-level increase
6.The increase of veldt fires
7. Complications on human health (more frequent and severe flu spells)
8. One crop benefitting over the other (For example some crops favour hotter weather to grow, whereas some crops favour much cooler weather

The responses in Table 5.1 and Table 5.2 were not only based on local conditions but also climate occurrences occurring globally. This also indicated that people are aware of climate change and its effects. This also reveals the importance of formal education and media influence in generating information that educates people on the extremity of impacts experienced around the world.

Respondents were asked what they perceived as impacts in terms of either an increase or a decrease in precipitation, or an increased risk of floods or droughts. Thirty-four percent (34%) of respondents strongly believed that there had been a negative trend in precipitation, while 27% of respondents

agree that there had been a positive trend in precipitation (Figure 5.7). In relation to resulting impacts, 40% of respondents strongly pointed to the increased risk of drought, while 38% agree to the increased risk of flooding in the eThekwini Municipality.

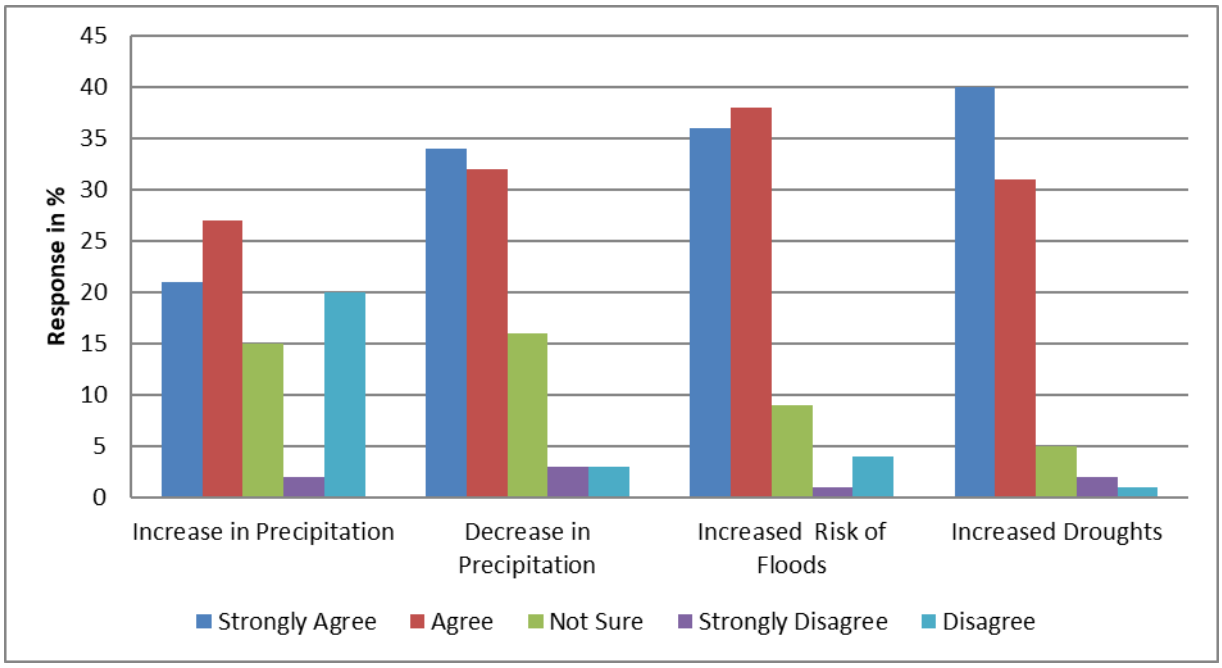

Figure 5.7 Community's perceptions of climate change impacts on rainfall, floods and droughts.

Trenberth (2005) identified human-induced climate change and global warming as causative factors to the variability of precipitation. Sada, Shrestha, Shukla & Melsen (2013) argued that several studies have identified similar trends in temperature and precipitation. Trenberth (2005) also found that when temperature increases, there is a decrease in relative humidity and precipitation, which corresponds to trends observed in the study of correlations between climate variables (Chapter 4 and Figure 4.3). Due to fluctuations identified in Chapter 4 (Figures 4.1 and 4.2), temperature, precipitation, and humidity can have less of an influence on the behaviour of the other variables, especially during extreme precipitation events. Humidity was not identified as the main factor in producing heavy precipitation in the eThekwini Municipality since fluctuations revealed precipitation to have increased while humidity mean annual anomalies remained low (Figure 4.1 and 4.2).

When respondents were asked how the effect of climate change on water availability had impacted on them and their families' well-being, 65% of respondents pointed out water shortage to be a problem, while 35% of respondents identified flooding (Figure 5.8). Furthermore, to these responses, the results revealed that people who had experienced the effects of climate change could easily identify its risks. The long-term drought had impacted on every household living in the eThekwini Municipality. For example, water restrictions inconvenienced people to accept help from relatives to cater for their needs and were restricted to using less water than usual to cook and clean. The 15% of respondents

that reportedly used water storage container as an adaptation measure to collect water for use during the period of droughts.

The 56% of respondents commented on the recent flooding in 2016, that damaged private properties, triggering motor collisions, damaging vegetation and engendered structural damage to roadways and homes (Figure 5.9) (see Appendix 6 and 7). Residents were reported to have lived with the severity of unexpected rainfall for many years. In Appendix 6, the newspaper clipping 1 shows the case of poorly maintained manholes by the eThekwini Municipality in Woodhurst, Chatsworth that was described as a health risk to the residents and the environment for the past 40 years especially after extreme incidents such as extreme rainfall and flooding. Satterthwaite (2007) says that due to concrete, hard, impenetrable surfaces in the urban area; infiltration is reduced, thereby increasing surface runoff of water. Contrary to this, infrastructure is important to the response of extreme events and minimizing the loss to life, health, and property, therefore resilience of infrastructure to events such as flooding is stressed (Carter et al., 2015).

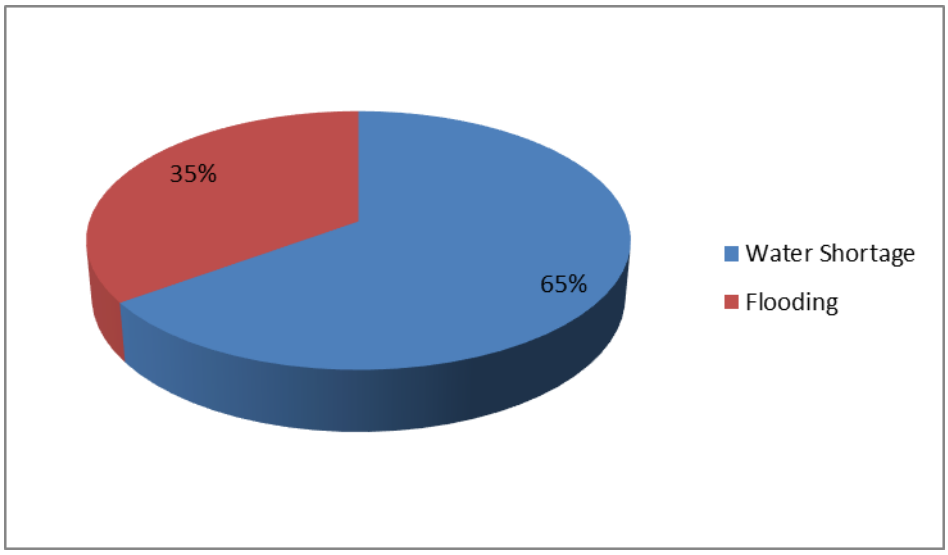

Figure 5.8 Community's responses on climate change-related water shortage on their family's welfare.

Figure 5.9 Damage to private property (Photos courtesy of Mahadew, 2016).

Temperature and humidity increases are said to impact on health and well-being, inflicting discomfort on the health of people (Argüeso, et al., 2015; Department of Environmental Affairs and Tourism, 2004). In Figure 5.10, households were asked whether they experienced any health impacts related to climate change; 22% of respondents indicated that their health was being affected by frequent changes in weather. They reported being exposed to extreme temperature variations. Some of the impacts reported include allergies (asthma and sinusitis), heat rashes, frequent migraines, nose bleedings, sensitivity to the heat from the sun, hazy vision, and frequent colds and flu. However, 78% of respondents reported no weather-related illnesses. As temperatures increase, people are more susceptible to health risks (Department of Environmental Affairs and Tourism, 2004).

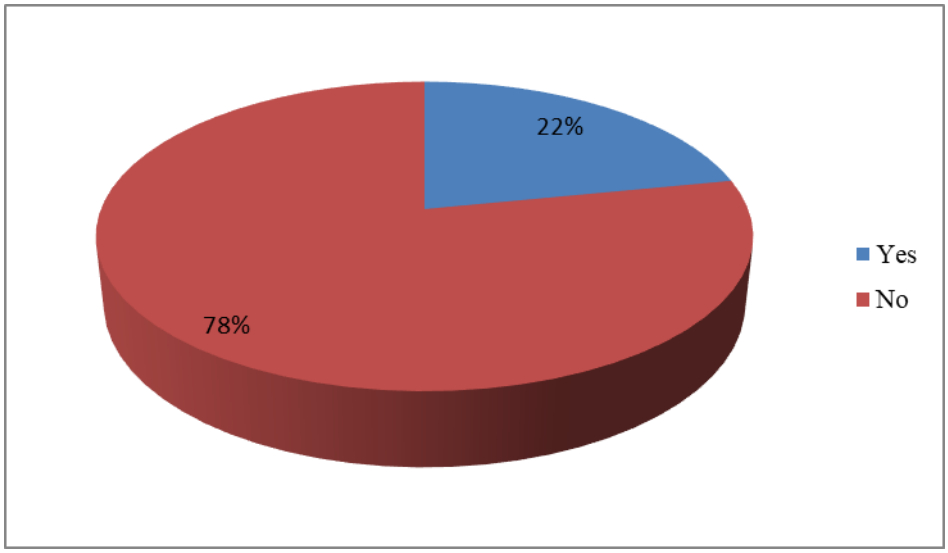

Figure 5.10 Household responses on the effect of climate change on health.

When further asked to assess the perceived impacts on a scale of very damaging, damaging or having no effect, 52% of respondents indicated that flooding was the most damaging, while 42% of respondents thought heat waves were also damaging to human health and well-being (Figure 5.11).

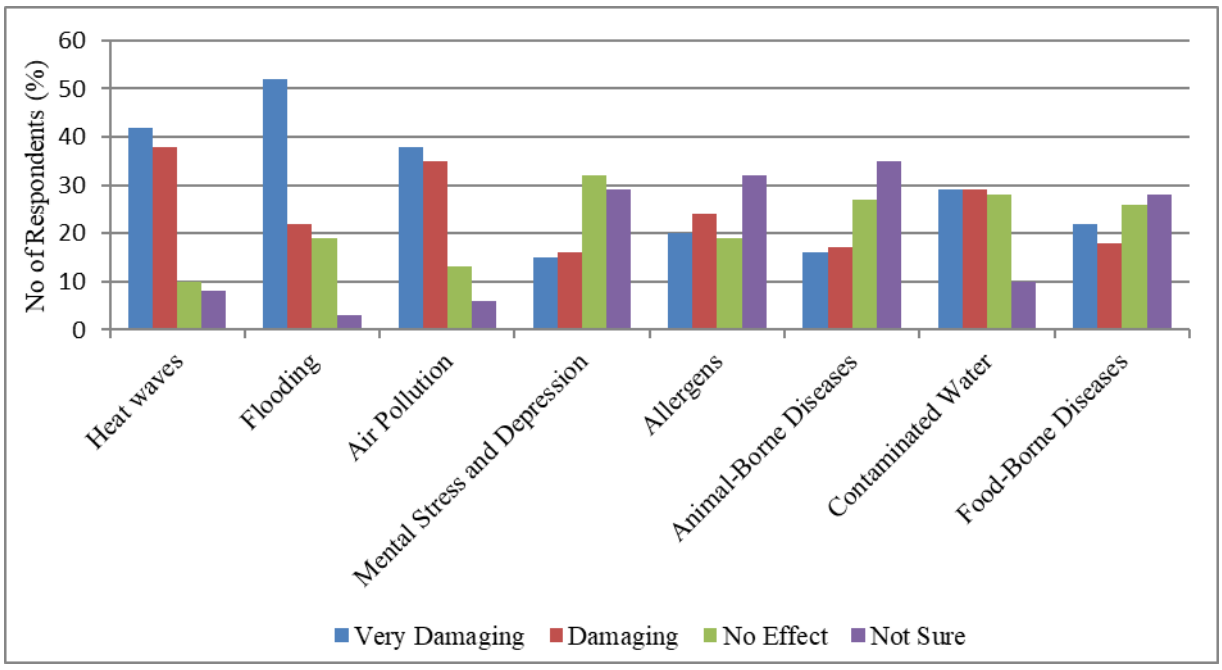

Figure 5.11 Assessment of climate change impacts to health and well-being by urban households.

Heat stress brought upon by high temperatures and humidity can also increase the discomfort levels, especially in urban areas when dealing with the Urban Island Heat effect (Argüeso et al., 2015). There were 38% of respondents that saw air pollution as a risk to their health and well-being. Higher temperatures and heat waves, together with increased ozone and particulate matter in the air can trigger discomfort amongst people, especially people that suffer from asthma (Franchini & Mannucci,

2014). Other health impact assessed were allergens, animal-borne diseases, contaminated water and food-borne diseases.

5.4 Urban household mitigation and adaptation responses to climate change

5.4.1 Mitigation and adaptation responses to climate change

Household demographics are an important aspect of assessing the vulnerability and coping strategies to climate change impacts (Pauline, 2015). Results related to sustainability practices reveal a high level of urban household adoption of mitigation and adaptation measures and their willingness to participate in water and energy saving activities.

The water and energy nexus is argued to be linked to the high amount of energy and water distributed to households. It is, therefore, important to note that mitigation strategies outlined (Figure 5.12) through the adoption of water and energy saving equipment (refrigerators, stoves, air conditioning, geysers, green faucets) can benefit individuals financially by saving energy and costs and contributing towards a more sustainable environment.

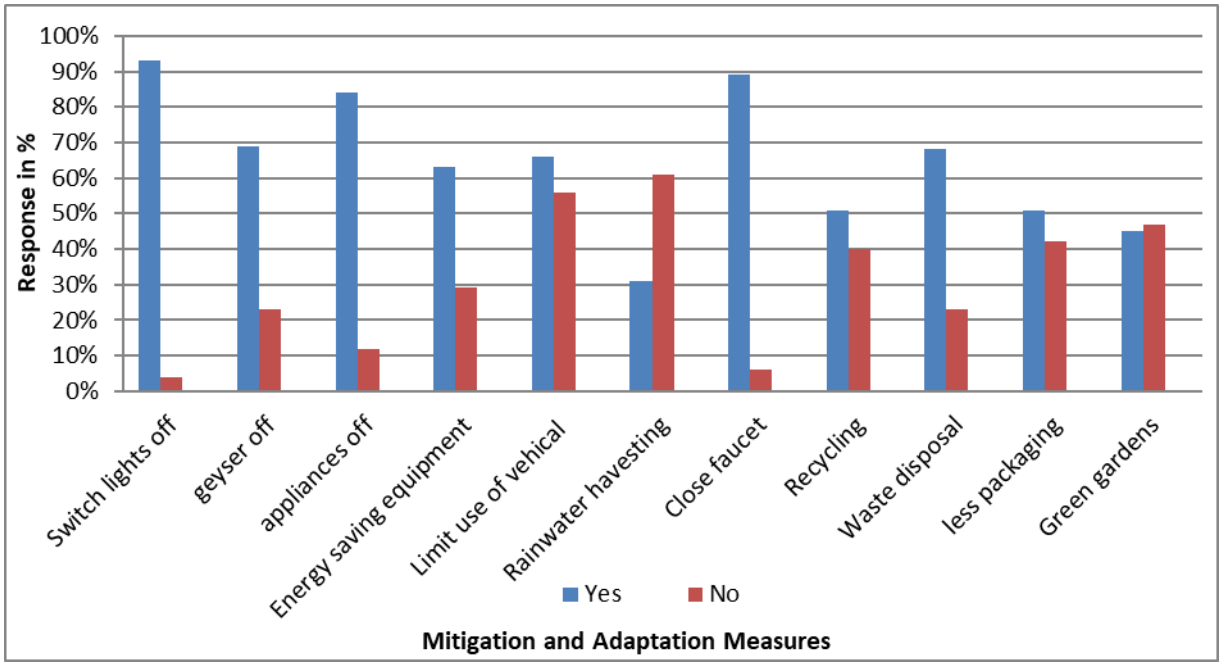

Figure 5.12 Household mitigation and adaptation approaches.

The blue bar (Figure 5.12) shows respondents who adopt sustainable behavioural practices in their households. The results showed that households are more prone to using mitigation approaches that are short-term rather than long-term. These include switching off light fixtures and appliances and turning off leaking water faucets when not in use in the household. These are contrary to pro-environmental long-term efficiency investments in energy and water saving equipment such as solar powered geysers, lighting, and eco-friendly household equipment (fridge, microwave and anti-leakage bathroom equipment).

The use of solar energy and the installation of energy saving equipment are currently being advocated in lieu of fossil fuels because fossil fuels are precursors to climate change. This solar energy equipment, amongst many, includes the installation of solar panels, energy saving light globes, and solar geysers and roof panels.

Attempts were made in this study to determine community perception and use of solar energy and water saving equipment. Respondents were asked if they would invest in solar energy and water saving equipment, the 8% of respondents said that solar energy and water saving equipment is unaffordable and they lacked the capital to purchase them. In addition, the 8% of respondents said that they were not in the position to change their current equipment and short term curtailment practices, while 5% of respondents had no knowledge on solar energy and water saving equipment.

Households were adamant that they would continue to rely on their normal electricity grid for energy supply, considering its convenience. The 8% of households surveyed were of the perception that energy and water saving equipment would be too expensive to purchase and install in a household. The results indicate that cost efficiency and communication are two important terms to consider when making the urban public more environmentally conscious.

The other measures identified in this study show that households participated in planting green gardens and water harvesting, especially during droughts (Figure 5.12). For example, green landscaping, including the planting of trees and installation of water storage container is both a mitigation and adaptation measure used towards climate change effects. Water storage container are used to capture and store rainwater for various household use, however,78% of respondents said the use of rainfall was not a coping measure used in their household, while 22% responded to using rainfall in their household (Figure5.13).

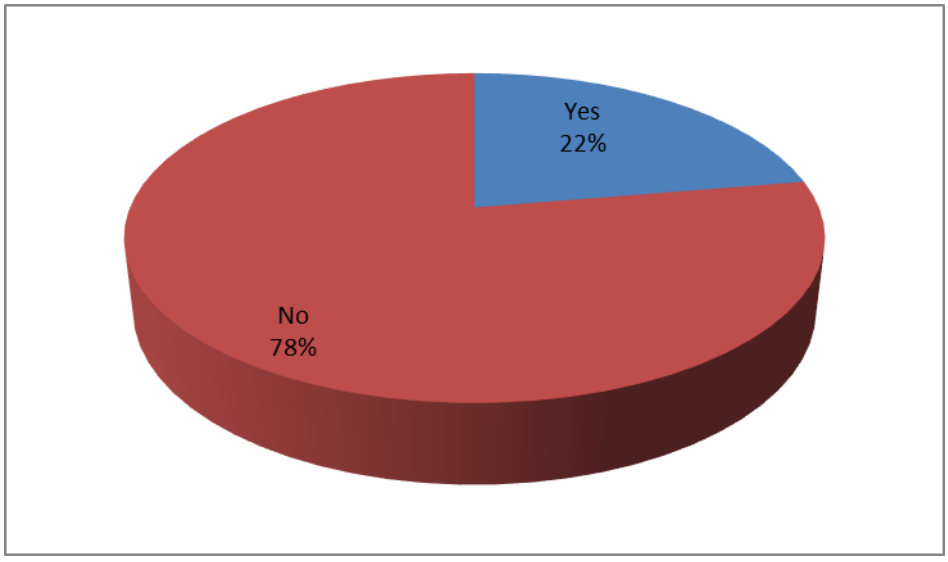

Figure 5.13 Rainfall use in urban households.

5.4.1.1Some responses in relation to the use of rainwater

Respondent 1: *I would like to obtain a water storage container, but I am renting*

Respondent2: *I believe all households rely on rainfall more than they know, the recent droughts in KZN which have had water restrictions tabled for the entire province shows our complete dependence on rainfall, some households rely more on rainfall than others based on locations but we all rely on rainfall.*

Respondent 3: *Waste water is used for watering the garden and biodegradable and food waste used as fertilizer.*

Respondent 4: *The use water more sustainably. Wash the car at the car wash. Use washing machine water to water the garden.*

5.4.1.2 Some responses towards the recycling of waste

Respondent 1: *I don't recycle my waste.*

Respondent 2: *The waste is put into trash bags and collected by the local municipality.*

Respondent 3: *Through the use of the 3 Rs- Reduce, Reuse and Recycle. Should there be water left over, it is used as compost or irrigation and for solid items i use the 3 Rs and have bins for for different waste types.*

Municipal solid waste (MSW) is the source of 18% of anthropogenic gases from landfill sites (Periathamby, 2011). The CH_4 emission contains 25 times more global warming forcing than CO_2 (United Nations Environment Programme, 2010). Cities generate 1.3 billion tons of solid waste per a year and this is expected to increase to 2.2 billion by 2025, and double in capacity for developing countries (Mukama et al., 2016). Recycling of waste is a mitigation measure to curb the amount of urban household waste in MSW landfill sites. According to ADEME (2014) (as cited in Dépoues & Bordier, 2015), recycled waste can avoid 19 million tons of GHGs in France alone.

Despite the existence of these MSW facts related to climate change, there is a disinterest amongst many urban households that see no need to recycle their waste. Those that see the importance in recycling say that they use biodegradable waste as fertilizer in their gardens, while some respondents use recycling bags provided to separate their waste, however; there are households that do not practice recycling at all. Jayasubramanian et al. (2015) encourage the use of incentives to help promote sustainable behaviour and specifically help urban households to mitigate their waste more efficiently.

5.4.2 Perceptions of adaptation toward climate change

Climate change can be dealt with by lifestyle changes (Pandve et al., 2011). Rishi, Omprakash & Mudaliar (2010) (as cited in Pandve et al., 2011) state that the cognitive part of a human-being and one's emotional well-being is important to address climate change, and if an individual is not

knowledgeable of the impacts of climate change, adaptation and resiliency will not register mentally. Adaptation can enhance both mitigation and sustainability from a socio-economic and ecological perspective. It is important to note that some adaptation measures responding to climate change are similar to that of mitigation.

Respondents were asked what measures they had taken to protect against the impact of climate change on their ability to live. One respondent said it was hard to pursue measures because the weather was so unpredictable. Responses ranged from females saying that they had invested money in purchasing Sun Protection Factor (SPF) make-up, wearing more clothing and sunscreen to protect their skin. One respondent said drinking plenty of water was sufficient to prevent heatstroke. Other responses ranged from increasing the flood barriers around their property (sandbanks) and ensuring that insurance covered assets. Understanding the lifestyle and cognitive psyche of people, especially when addressing urban households, can be used by decision-makers to address issues at a local level. The measures undertaken at the international, national and local level will only function when the local public and key stakeholders support adaptation to climate change (Pandve et al., 2011).

5.5 eThekwini Municipality's implementation of adaptation and mitigation strategies in urban areas

Climate Change work in South Africa only began in 2000, when USAID started funding the South African pilot of ICLEI's Cities for Climate Protection Campaign (CCP) (Roberts et al., 2015). Thereafter, Durban's Solid Waste Department formulated the Landfill Gas to Electricity Project at the city's largest landfill site, building capacity towards climate change mitigation and Carbon Certified Emissions Reductions (CERs) in 2010 (eThekwini Municipality, 2015) (as cited in Roberts et al., 2015, p.100). In 2004, South Africa had its first international engagement with climate science, defining the core business of biodiversity adaptation as a focal point for the eThekwini Municipality and instrumental in the development of the Municipal Climate Change Programme (Roberts & O'Donoghue (2013) (as cited in Roberts et al., 2015). The Danish International Development Agency (DANIDA) provided funding for the Urban Environmental Management Programme and funding of the Municipal Energy Strategy (Roberts et al., 2015).

The Environmental Planning and Climate Protection Department (EPCPD) are currently heading the mainstreaming of an integrated response to climate change through mitigation and adaptation in the eThekwini Municipality city's local programme. On behalf of the EPCPD, N. Hlongwa (personal communication, March 16, 2016) was interviewed on the integration of mitigation and adaptation and how gaps between both strategies are being bridged by the EPCPD. She said that it is important to understand why both actions are separated within an administrative perspective. Both strategies are performed by separate departments- the EPCPD is focused on adaptation, while the Energy Office and other departments are working with mitigation. The evolution of mitigation came about after the

Energy Office was created by the eThekwini Municipality in 2008, because of the energy shortages and blackouts South Africa was facing (Roberts et al., 2015). The Energy office's mandate was expanded with the help of donor-funded projects and interventions (Roberts et al., 2015). This was a start for South Africa creating an international platform for itself.

5.6 The linking of adaptation and mitigation efforts to sustainability goals to create resilient urban communities by the EPCPD

In addition to the discussion with N. Hlongwa (personal communication, March 16, 2016; Section 5.5) she was furthered asked to provide an overview of how mitigation and adaptation are being integrated into the work performed by the EPCPD in the eThekwini Municipality. She indicated that the climate change work that is performed by the EPCPD is aligned with international and national policies related to climate change, resilience and sustainability. This appears in the Durban Climate Change Strategy (DCCS) responding to mitigation and adaptation in the policy section, which mentions the 2015 Sustainable development goals. Furthermore, all work done by the local government or department has to be supported by appropriate legislation and policy. Therefore, strategic climate change documentation formulated is aligned with international and national policies. N. Hlongwa (personal communication, March 16, 2016) further indicated that all themes and objectives outlined in the strategy are aligned with the sustainable development goals of the country. Sustainability goals often carry much emphasis towards implementation of climate change mitigation and adaptation objectives. The department's objectives and approaches adopt a no regrets approach to adaptation with a mandate being centred on biodiversity (N. Hlongwa, personal communication, March 16, 2016). One of the approaches used by the municipality to promote adaptation and resilience to climate change is the community ecosystem-based adaptation approach further expanded in Section 5.6.1.

5.6.1 Community ecosystem-based adaptation approach

The focus on urban areas and sustaining urban resilience towards growing uncertainty presents a framework for the ecosystem-based adaptation (EBA) to act as a transformational adaptation strategy (Kates et al., 2012), that is current and cost-effective in helping a city work at building their adaptive capacity towards climate change. Moreover, technologically, it will increase urban resilience through behavioural changes and how individuals cope with a changing climate by creating hazard risks reduction, coastal defence, proper storm water management, reduced impacts from storms, food security and carbon sequestration in the city (Laros, Birch, Clover & ICLEI-Africa, 2013).

The Secretariat of the Convention on Biological Diversity (2009) identifies the Ecosystem-based approach as the means to:

"*Integrating sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. Its main objective is to provide resilience to those ecosystems and people that are affected by climate change. Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies*" (as cited in Laros et al., 2013, p.9).

This provides the foundation for the adoption of the community ecosystem-based adaptation approach (CEBAA) in the eThekwini Municipality. The eThekwini Municipality socio-ecological profile and limited human and financial resources make adaptation a desirable need, but the EPCPD saw the need to broaden the concept of adaptation to include mitigation, transitioning into a low-carbon society to address development, energy, and reduction of GHGs (Roberts et al., 2015).

The EPCPD and their use of CEBAA together with community participation have provided both socio-economic and environmental benefits in the areas of interest which include assessing livelihoods and demographics, food security, infrastructure and services, and water and sanitation (N.Hlongwa, personal communication, March 16, 2016). EBA is still a developing theme especially in cities and much of the literature identified focus on biodiversity, coastal areas, agriculture and forestry (Geneletti & Zardo, 2016). However, there is little evidence to support how effective EBA green infrastructural measures are to climate change in urban areas, and while also being a relatively new concept in cities, there is little evidence of EBA measures identified in urban plans and policies (Geneletti & Zardo, 2016).

5.6.2 Constraints to urban communities integration of adaptation and mitigation toward climate change

People use their environment to build an identity and change according to the sense of place, therefore individuals search for motivations to change their lifestyle and find solutions that are likely to be sustainable from the influence of other individuals and local government (Marshall et al., 2012). Individuals seek shared views and opinions for internal (how a person feels) and external (a measure of what a person does) validity and it is argued that international and local governance shape responses and perceptions of individuals (O'Brien & Hochachka, 2010). The generation of knowledge and effects experienced by individuals do not address climate change (Allen & Crowley, 2015). This is so because risks experienced by individuals are driven by emotion and people look to each other for shared opinions and views (Kahan et al., 2012).

Institutional changes are also minimal when addressing behavioural change (O'Brien, 2008). A change in how a person responds to climate change is dependent on the influence of local government (IPCC, 2014). The influence of the local eThekwini municipality on urban communities in the implementation of mitigation and adaptation strategies towards climate change was found to be minimal. The eThekwini Municipality and its involvement in Community Ecosystem-Based

Adaptation Approach (CEBAA) are primarily in the rural and peri-urban areas. Respondents were very emotional when asked about how influential local government has been in the creation of awareness and educating urban dwellers. They did not believe the local government did enough to bridge the knowledge gap on mitigation and adaptation in the urban communities of the eThekwini Municipality. The common perception was that nothing in the process of education or awareness was being done. However, some households did respond that the eThekwini Municipality created awareness on efficient water use, especially during the harsh drought conditions in the year 2016. Respondents were aware of measures taken by the eThekwini Municipality to impose water restrictions and decrease water use. A worker from the eThekwini Municipality said that there are always signs within the building to switch the lights and computers off, and emails sent out to remind people of the consequences of climate change.

Every household agreed that environmental events (programmes and workshops) could help individuals mitigate and adapt towards the impacts of climate change. The same respondents interviewed said that they have not attended any programmes or workshops to date. The respondents were asked if they knew of any ecosystem-based or sustainability programmes in the eThekwini Municipality and a majority of the households sampled in this study responded to having no knowledge of such activities in their area.

Many households believe that the eThekwini Municipality does not engage enough with urban communities and households to create awareness, while others had no interest in such events. Respondents said that when the environment is compared with social and economic issues, the environment is neglected. Environmental programmes are not given as much emphasis and not implemented efficiently. Here are some responses in relation to awareness towards climate change adaptation and mitigation programmes by the eThekwini Municipality.

Respondent 1: *I don't know of them. Not enough marketing, promotion and/or awareness created.*

Respondent 2: *Never heard of any programmes mentioned above. There is a lack of communication between the municipality and communities*

Respondent 3: *Awareness won't be created as campaigns don't run effectively.*

Respondent 4: *I think environmental issues are a very low priority and the local government is more focused on serving its personal needs/agendas, unemployment, transformation, job creating and crime.*

Respondent 5: *Environmental programmes get less coverage than political issues*

Respondent 6: *There is a lot of corruption and money laundering.*

These selected comments from members of the urban community indicate the general feeling that training and community empowerment in relation to climate change adaptation and mitigation in urban areas are given low priority and is one of the constraints to the urban communities' integration of adaptation and mitigation toward climate change. On the political front, there are claims of high corruption and people seem to have lost interest in the local government, especially on the subject of climate change and its impacts.

5.7 The role of workshops and international engagements

In a world built around the topic of global warming and climate change, South Africa's active commitment is gaining recognition. South Africa was selected to host a three-day workshop for Climate Reality Global Leadership Corps in Johannesburg (South Africa) 2014. This workshop trained over a 1000 Climate Reality Leaders, from Africa and other parts of the world. The workshop was created to promote the importance of climate resilience and use of mitigation and adaptation at a local level. As a selected participant at this workshop, this study was given an opportunity to acquire first-hand knowledge on the magnitude of climate change and its projected impacts on the rest of the world from other high-level delegates and speakers. Hands-on proactive training was also provided on various methodologies on how to educate and create awareness on the current situation of climate change, which could be implemented locally in the eThekwini Municipality. These methodologies included the use of visual presentations and demonstrating the impact of climate change on local communities using emotive images and language.

A similar workshop and conference were held in 2015, the Durban Adaptation Charter Workshop (DAC), where delegates were invited to participate in talks on climate change in cities. The DAC can be summarized as an agreement by local government to promote and prioritize climate change adaptation efforts. The DAC agreement, which was formulated in 2011, during the UNFCCC, COP17 in the eThekwini Municipality, was signed by a total of 331 city leaders and the local government officials, representing over a thousand local government bodies from 45 countries around the world (ICLEI, 2015). The DAC Workshop was created to promote local policy and action in the form of mitigation and adaptation towards building climate change resilience. Again, as a delegate present at the 2011 workshop, a great opportunity was provided for this study to gain insight on local governmental action in cities and mitigation and adaptation measures adopted towards urban resilience in cities around the world. Climate Reality's climate change communication-focused training and post-workshop to support DAC 2015 (ICLEI, 2015) provided delegates with proper training on using visual materials and emotive language in their presentations to create awareness on mitigation and adaptation in cities and local communities.

On a local scale, many of the delegates interviewed for this study expressed the need for local governmental and municipal action in creating awareness amongst all individuals, especially amongst

the poor. This would mean more attention would need to be applied by local government on building adaptive capacity in cities and especially in urban areas. In relation to the need for community participation on discussions relating to climate change, two selected questions by delegates at the DAC conference were as follows:

Delegate 1

"*Understanding and mitigating climate realities would demand access to the decision-making forums, access to information so as to contribute towards providing the solutions. How do we bring vulnerable members of our communities submerged in silence on board, after all, it's a right?"*

Delegate 2

"Why is it that climate change issues are still geared towards rural areas, yet the population of the world, since 2007, is now moving into urban areas from rural areas?"

Climate change is a global, national and local issue and these geographical units are all impacted on by climate change. This explains why DAC emphasized vividly on the creation of partnerships, through various communication channels, that can put together community-based adaptation programmes while highlighting regional scale implementation to expand African network of local adaptation, implementation, climate networks, and learning capacity building through peer to peer exchange.

This type of assessment demonstrated the direction in which local government and various organizations are moving in. It demonstrated that collective action can be of success at the local level when climate science and its solutions to climate change is communicated amongst individuals that can enhance the movement in their locality and local policy towards change

5.8 Conclusion

People living in the eThekwini Municipality are very aware and have a good knowledge of the impacts of climate change. Many of the respondents interviewed had either observed or experienced risks associated with climate change impacts. Experiences of the impacts of climate change allowed the respondents to elaborate further on how they perceived the risks to affect their daily lives. The impact of a changing climate on weather is experienced differently by individuals. For example, some respondents felt that temperature was increasing, while others perceived temperatures to decrease.

The results also reveal a high application of sustainability practices related to climate change mitigation and adaptation at the household level and in their personal lives. Short-term mitigation and adaptation measures in the form of curtailment measures are desired over the efficiency of long-term investments in sustainable energy and water saving equipment. This is because people look for affordability and want to be educated about such measures. The short-term measures include among

others, switching off light fixtures, switching off appliances, and turning off leaking water faucets when not in use in the household. These are contrary to pro-environmental long-term efficiency investments in water and energy saving equipment such as eco-friendly technology in the form of solar geysers, energy saving light bulbs, eco shower heads and tap fixtures. Health wise, people identified the weather as a reason for the illnesses that they were experiencing. For example, nosebleeds, allergies (sinusitis and asthma), dizziness and sensitivity were identified by respondents as common occurrences when exposed to the sun. As a result, people are investing in the more frequent use of sunscreen and SPF products, limited exposure to the sun and drinking plenty of water to prevent heat stroke. Despite the eThekwini Municipality EPCPD championing the integrated adaptation and mitigation efforts in the eThekwini Municipality, there is a gap in training related to urban climate resilience, community participation in local environmental events and dissemination of the ecosystem-based adaptation approaches to the local community.

Chapter 6

Conclusion and Recommendations

6.1 Introduction

At the outset of this study, climate change has been highlighted as a global problem which continues to be a subject of debate amongst different authors, governments and organizations. Despite the existing debate on the reality of climate change, there have been noticeable changes in climate variables such as increases in temperature, precipitation and humidity, leading to negative impacts and risks such as among others, heat waves, floods and droughts. These have largely been attributed to anthropogenic causes and some contribution from natural causes. Though efforts have been made to project future climate change and related impacts, these are still controversial due to the generalities and coarseness of global models. Even locally downscaled models are fraught with inconsistencies related to variability in their results, and thus compounding accurate projection of future temperature, precipitation, and humidity changes at the urban level (Feijt et al., 2014). Despite these complexities related to climate change projections, it is still important to adopt a precautionary stance by evaluating past climate variability, determine current community perception, mitigation and adaptation, and explore future changes in climate so as to inform local management efforts towards reduction of impacts.

The key concepts that provided an in-depth discussion and informed the findings of this study, explored the behaviour of physical attributes of greenhouse gases, solar radiation, cloud cover, humidity, precipitation etc, that contribute to temperature increase and precipitation fluctuations. With this knowledge, the use of projected statistics of the eThekwini Municipality provided a detailed view of how temperature and precipitation in the eThekwini Municipality would change between 2016-2100, as well as how hot days, heat stress and dry spells progressed because of temperature increase.

Analysis of these concepts in turn shed light on the behavioural responses and how people approached climate change adaptation and mitigation. The integral and transformational theories also assisted in evaluating community behaviour towards adopting specific measures towards adaptation and mitigation. These theories also provided a basis to examine local government initiatives towards combating climate change in the urban community within the eThekwini Municipality

It is against this backdrop that this study embarked on evaluating local climate change projections and public behaviour towards adopting integrated climate change mitigation and adaptation approaches at a household level in the urban areas, eThekwini Municipality, KwaZulu-Natal Province.

The sections and subsections that follow are a summary of the key findings related to the aim and objectives of this study.

6.2 Summary of key findings in relation to the aims and objectives of this study

6.2.1 Aims

The primary aim of this study was to evaluate local climate projections against past, current and future trends. This included trends from the 1950s to 2014 and projections from 2016-2100. A secondary aim was to evaluate public behaviour towards adopting integrated climate change mitigation and adaptation approaches at a household level in urban areas, the case of the eThekwini Municipality, KwaZulu-Natal Province**.**

Both aims have been achieved and presented in chapters 4 and 5. These are further elaborated in the achievement of specific objectives related to the aims of this study as presented in the subsections that follow.

6.2.2 Objective 1: To determine past and current trends in temperature, humidity and precipitation

Trends for maximum and minimum temperature anomalies, together with precipitation and humidity from 1957-2014, are presented for the eThekwini Municipality (Figures 4.1 and 4.2). Maximum and minimum temperature trends were found to fluctuate between positive and negative anomalies. Precipitation and humidity anomalies show a similar fluctuating trend. Babatola (2013) observed a similar trend in mean annual anomalies for relative humidity and precipitation, concluding that the relative humidity in the air most likely influences the amount of precipitation. This relationship is also significant between temperature and precipitation. Trends identified in this study show an inverse relationship between the three climate variables. When temperature anomalies are positive, a negative trend develops for precipitation and humidity, signifying a period of drought and dry conditions, consistent with Trenberth (2005). However, the fluctuations also presented evidence of non-correlating trends between temperature, precipitation, and humidity (Chapter 4 and Section 4.3).

The integration of historical, current and future projections allows scientists to compare past and current observational data with future projected data, placing modelled data in the context of what had already occurred (Kling et al., 2003). The trends observed in this study reveal that the eThekwini Municipality climate will continue to fluctuate with positive and negative trends, requiring a cautious approach towards the implementation of mitigation and adaptation measures. Due to such fluctuations, it would be better to plan for worst-case scenarios using RCP projections.

6.2.3 Objective 2: To determine 8.5 Wm^{-2} projected changes in temperature, precipitation, and humidity

In order to understand the relationship between the global and the local climate variables, GCM projections are instrumental to this course. However, the argument is that GCM are coarse gridded data, inconsistent and not fine enough to project the local environmental conditions accurately. For this reason, statistical downscaling has been deemed as an alternative on the ground that it is a communicative tool to provide local institutions with data and information for decision-making and to inform integrated urban mitigation and adaptation strategies. However, in theory, questions are posed regarding the uncertainties that accompany the accuracy of numerous downscaling methods and applications. Despite the existence of these questions, the locally produced projections for temperature, precipitation and other climate variables provide us with scenarios to compare the past climate with the future climate.

Using ensemble models to analyse RCP 8.5 W/m^{-2} projected changes for temperature and precipitation from 2016 to 2100, the results reveal that there is a link between the global climate and its effects on the local climate. The trends show fluctuating projected changes in temperature, precipitation, and humidity for the eThekwini Municipality (Figures 4.3 to 4.5). It was found that the climate variables identified in this study had an inverse relationship with each other, but also that fluctuations of each variable can progress significantly without correlating with another climate variable (Section 4.3). This was present in the MIROC-ESM, CanESM2, and MIROC5 projection models (Figures 4.3 to 4.5). Projected RCP 8.5 W/m^{-2} results (Appendix 4) also reveal that the eThekwini Municipality can expect more intense and hotter days, heat stress and dry spells that can, directly and indirectly, impact on human communities (uncomfortable conditions and increased health hazards such as asthma, dizziness, nose bleeds) and the environment. Increase in dry spells will result in severe droughts during months when precipitation is projected to decrease, namely in March, April and May (Appendix 4.4 and 4.5).

6.2.4 Objective 3: Correlate projected and current trends in climate change

Projected temperature and precipitation show fluctuating anomaly trends from 2016 to 2100 (Figures 4.3 to 4.5). This is consistent with results from the SAWS, which also show past fluctuating climate anomaly trends (Figures 4.1 and 4.2). It was found that temperature, precipitation, and humidity have an inverse relationship. However, there were periods when temperature and precipitation anomalies were high, and humidity was low. The fluctuating trends will make the urban environment highly vulnerable to impacts related to climate change such as heat stresses, flooding, arid and dry spell conditions. This is also consistent with the mean monthly graphs found in Appendix 4.

6.2.5 Objective 4: Evaluate community perception, mitigation and adaptation strategies towards climate change

This objective was achieved as presented in Chapter 5. In Figure 5.11, respondents showed that their main concern was flooding, heat waves, and air pollution, which they thought was very damaging to their health and well-being. Respondents said they felt temperatures have been increasing and decreasing in a fluctuating manner in the past few years. This is consistent with analysed temperature data obtained from SAWS (Figure 4.1). The climate impacts associated with the eThekwini Municipality were droughts, unexpected extreme flooding, and intense heat waves. Many respondents reported that an extreme change in weather decreases their capacity to function appropriately, especially when living in the city or its surrounding urban areas. Others mentioned damage to private property by extreme rainfall as a consequence of climate change (Figure 5.9).

Mental-stress and depression, contaminated water, animal and food-borne diseases were also identified as health risks related to climate change in urban areas. The urban heat island effect is a common impact that occurs in the city and outlying urban areas as a result of limited vegetation cover, urbanization, infrastructural growth, that promotes retention of heat and heat stress that can prove to be very hazardous to human well-being, especially to the elderly.

Sustainability in urban areas is still a developing theme. Respondents showed willingness to adopt sustainable practices in terms of trying to be more sustainably active in their households (Figure 5.12). Respondents were more engaged in short-term curtailment efforts of recycling, rainwater harvesting and switching off unnecessary equipment in their households (Figure 5.12) as opposed to long-term mitigation measures such as the installation of solar energy and water eco-friendly technology, in terms of household lighting, fridges, ovens, green faucets with sensors, etc. They believed that long-term energy saving equipment was not affordable or that they did not feel it was convenient enough to change from one source to another, while other respondents were not aware of such water or energy saving equipment (Figure 5.12).

The implementation of adaptation measures in the eThekwini Municipality was found to be minimal. The constraints identified by the eThekwini Municipality were linked to minimal funding and climate change awareness amongst urban communities. The CEBAA initiative is still foundational research, while EBA does not incorporate urban household awareness and effective knowledge, and skills transfer to build adaptive capacity. Respondents believe that the eThekwini Municipality does not engage enough with the urban areas. The environmental aspect is a neglected area when engaged with socio-economic issues of unemployment, poverty, and health. People were not aware of any mitigation and adaptation programmes located in their locality, and further responding with a lack of communication of the eThekwini Municipality to urban household environment. Environmental

campaigns were disfavoured, as they are not conducted effectively and due to a limited understanding of the environment, environmental issues are of low priority to urban households.

Climate change impacts and adaptation responses at a household level is important for adaptation research because households determine how it is that they will respond towards climate change (Elrick-Barr, Preston, Thomsen, 2014). Elrick-Barr et al. (2014) critically denote that very few studies have looked at factors external to the household sector and its influence on adaptive capacity. In pursuit of integrated mitigation and adaptation, the enhancement of society's ability to respond effectively to climate change risks is through sustainable development (IPCC, 2007). This will help determine factors under mitigation and adaptation that will increase the response capacity of individuals (IPCC, 2007).

6.2.6 Objective 5: Local governmental action and responses to climate change

Urban governance operates in silo with various local government agencies collaborating in a limited capacity that is not in alignment to invoke change at a local level (Aylett, 2015). In addition, the mainstreaming of urban household adaptation plans into research and practice is challenging because local governing institutions are the key actors driving local climate change action with little or no input from local communities (Elrick-Barr, Preston, Thomsen, 2014). Each sector in government sees mitigation and adaptation separately and not coherently as integrated. Local government is being recognized, especially in climate and governmental literature as drivers of change. The eThekwini Municipality have engaged in much discourse on the practice of EBA towards the adaptation agenda of climate change in alignment with international and national policies. The urban communities of the eThekwini Municipality, however, are not aligned with the objectives of the approach since EBA is still an evolving concept used to meet the sustainable goals of the country. Despite its benefits outlined in Section 5.6.1 of Chapter 5, it was apparent that the urban areas of the eThekwini Municipality were not aware of the evolving theme of EBA and nor was it lessons learned from a household perspective from local governmental interaction with local residents in their community's.

It was also identified that people show signs of appreciation for their environment when they are motivated to express themselves with others through shared opinions and views for internal and external validity. The presence of environmental and sustainability workshop events and programmes towards building urban resilience was examined. If such workshops were accessible geographically to people, then people would be more receptive to understanding what it meant to undertake mitigation and adaptation in their urban households to build resilience against climate change. It was found that people looked for direction and motivation from local government most specifically, but their opinion was challenged to the minimal effort that targeted urban communities in the eThekwini Municipality.

Respondents did not feel the local government was creating enough awareness and some did not care due to personal socio-economic circumstances. It was discovered that there is a communication barrier between the local government and urban community households. Despite the eThekwini Municipality, leading the way to a greener environment and experimenting with EBA in the eThekwini Municipality, the urban household communities felt they were being excluded from the debate. In light of this argument, cities are seen as drivers in the debate on climate. The motivation for the dissemination of mitigation and adaptation knowledge to urban households can be achieved through the efforts of locally championed climate change programmes and workshops that train delegates to break down the knowledge gap and create awareness in urban communities.

6.3 Limitations

This study was not conducted without limitations, some of these include:

- It was not possible to sample different sections in and around the urban areas of the eThekwini Municipality due to time constraints and lack of finance (this study was self-funded). This explains why the purposive and snowball sampling was used to cover a broader extent of the eThekwini Municipality.
- The use of a referral system and email as a communication tool was challenging because some respondents partially completed the questionnaires
- There were delays associated with self-completion of questionnaires via email correspondence probably because of limited access to Wi-Fi connection or the availability of a computer.
- Many respondents thought that doing a mixed response questionnaire of qualitative and quantitative open and closed questions was time-consuming, and so the respondents preferred closed-ended questions to open-ended questions.

6.4 Recommendations

6.4.1 Recommendations towards community participation and awareness

Despite the advancement made by the local government and local communities in mitigating and adapting to climate change and its impacts, there is still need for more to be done in residential urban areas. The recommendations are:

- It was found that urban households are not a priority in terms of instituting mitigation and adaptation approaches by the local eThekwini Municipality. The CEBAA projects which are managed and monitored by the EPCPD is predominantly focused on building sustainable capacity in the rural and peri-urban areas of the eThekwini Municipality. The urban communities and households in the eThekwini Municipality should be included in a city-wide campaign since they are the main contributors in generating GHGs and global warming.

- Awareness and communication between the local eThekwini Municipality and urban households are lacking. Households have no recollection or knowledge of local government interventions or resilient building of urban communities toward climate change effects. There is evidence of little or no awareness on the local eThekwini governmental website and information about sustainable workshops and programmes being held in various locations. This study showed that people do not frequent such websites or are not aware of how important it is to their well-being. The reason is that people do not see the climate change agenda as important. Households, in particular, are not made aware of how important sustainability is and by investing in long-term benefits of using energy efficient technology that is solar powered and water saving measures such as water harvesting that help to mitigate against climate change. It is important that the government subsidise such technology and make it available at an affordable price to households.

Since local communities had little knowledge about local climate events or workshops, this gap can be bridged by advertising such events through local indigenous media channels to reach the majority and at appropriate times when the majority are available.

6.4.2 Recommendations for further study

- There are a number of additional areas for further research that have been highlighted by this study. These include the further investigation into the correlations between the nature of climate variables including temperature, precipitation and humidity, and how those trends are projected in the current, intermediate and distant future up till the year 2100. This will help to better quantify and determine the intensity of anomalies in the identified trends. There were isolated cases where the relationship between temperature, precipitation and humidity did not follow the norm where high temperatures relate to low humidity and low rainfall. This also requires further research to shed light on this abnormality.
- The inconsistency in projecting climate trends by selected models is an area that needs attention. As argued in this study, there is a high possibility that the earth could be warming at a faster rate than what is projected. There is thus a great need for the development of an integrated, accurate and consistent model.

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APPENDICES

APPENDIX 1

Research Questionnaire

The University of Kwazulu-Natal (Howard College), the College of Agricultural, Earth and Environmental Sciences

Dear Sir/Madam

I, Miss Preshantha Naicker, am a 2nd year full-time registered masters student from the University of KwaZulu-Natal (UKZN), part of which requires conducting a questionnaire researching on the topic in: Evaluating local climate projections and drivers of public behaviour towards adopting approaches at a household level that integrate adaptation and mitigation in urban areas.

The aim is to evaluate local climate projections against current climate trends and to further assess the integration of community adaptation and mitigation strategies

I would be very grateful for your response which will enable me to complete my research dissertation.

Thank you for taking the time to complete this questionnaire

Miss P. Naicker

Questionnaire No:	**a**			

Part 1: Socio-economic characteristics/demographics

Pre-filled information:

Q.1: **Date of interview**

Day	**Month**	**Year**
		2016

Q.2: **Place of interview** (*write name of the place where the interview is conducted below*)

Place name: _____

Q.3: **What is your name?** (*Respondents' initials – for referral purposes ONLY*)

Name / Initials: _____

A.1: **What is your date of birth?**

Please write the respondent's date of birth in the spaces provided below; Example 22, 04, 2016.

Day	**Month**	**Year**

A.2: **Is the respondent male or female?**(**Sex**)

#	**Sex**	**Tick (✓)**
1	Male	
2	Female	

A.3: **What is your age in completed years (age range)?**

Please tick (✓) the appropriate box provided next to the age category in which the respondent fits.

#	**Age range**	**Tick (✓)**
1	18-29 years	
2	30-39 years	
3	40-49 years	
4	50-59 years	
5	60-69 years	
6	70 years and over	

A.4: **Which population group does the respondent belong to?** (**Race**)

#	**Race**	**Tick (✓)**
1	Black	
2	Coloured	
3	Indian/Asian	
4	White	
5	Other	

A.5: **What is your highest level of completed education?**

#	**Level of education**	**Tick (✓)**
1	Primary	
2	Less than matric (secondary without matric)	
3	High-school certificate / matric	
4	Diploma	
5	Degree	
6	Post-graduate degree	
7	None / no schooling	

A.6: **What is the respondent's estimated monthly income amount? (Optional)**

#	Income category	Tick (✓)
1	R0- R4 543	
2	R4 544-R9 886	
3	R9 887-R21 002	
4	R21 003-R57 099	
5	R57 100 and over	

2. General issues pertaining to weather variability and Climate change

2.1 Have you heard of climate change?

1. Yes (go to 2.2) ☐

2. No (go to 2.5) ☐

2.2 How do you view climate change? Please select one of the following:

1= Benefits us and the environment	2= Can benefit us and the environment if well managed	3= Can be harmful to us and the environment if not controlled	4= Completely harmful to us and the environment

2.3 Where did you hear about climate change? Please select one the following

1= Newspaper	2= Television/Radio	3= School/College	4= Local Municipality	5= Other

2.4 What is climate change to you?

……

……

……

2.5 Are you aware of the effects of a change on weather?

1. Yes (go to 2.5.1) ☐

2. No (go to 2.7) ☐

2.5.1 What are these?

.....

2.6 Do you suffer from any weather- related illnesses, or find a change in weather affecting your health?

1. Yes ☐

2. No ☐

2.6.1 And if yes, what?

.....

.....

2.7 Please rate the following climate impacts on health and wellbeing that is/was a problem to you and your community?

Indirect Impacts	1=Very Damaging	2=Damaging	3=No effect or not relevant	4=Not sure
1. Heat waves				
2. Flooding				
3. Air pollution				
4. Mental stress and depression				
5. Allergens (spring pollen				
6. Animal borne diseases				
7. Contaminated water				
8. Food-borne diseases				

2.8 Have you in the last few years experienced any change in temperatures in the area?

1. Yes (go to 2.8.1) ☐

2. No (go to 2.9) ☐

2.8.1 If yes, please select one of the following.

1. Increased temperatures ☐

2. Decreased temperatures ☐

2.8.2 Explain?

……

……

2.9 Do you rely on rainfall for household use?

1. Yes ☐

2. No ☐

2.9.1 If yes, how?

.....

.....

2.10 Please rate the effect of climate change on the following aspects of rainfall:

Direct Climate Impacts	1=Strongly agree	2=Agree	3=Not sure	4=Strongly disagree	5=Disagree
Increased precipitation					
Decreased precipitation					
Increased risk of floods					
Increased risk of droughts					
Others, please specify					

2.11 Has the risk of droughts, less rainfall or more rainfall impacted on you and your family's life in any of the following ways?

1. Water shortage ☐

2. Flooding ☐

3. Other (go to 2.12) ☐

2.12 How else has less or more rainfall impacted on you or your family?

2.13 What measures have you taken to protect against the impact of a change in weather on your ability to live?

……
……..

2.14What has the eThekwini Municipality done to educate/help you protect against the impacts of climate change/ or change in
weather?.....
.....

2.15 Are you aware of any community-based programmes in the area by the EThekwini Municipality on climate change adaptation and mitigation?

1. Yes (go to 2.16) ☐

2. No ☐

2.16 Are you involved in the programme or any other programme by the EThekwini?

1. Yes ☐

2. No ☐

3. Adaptation and mitigation

3.1How sustainable is your household? Please select from the following categories.

#	Energy saving	Yes	No	Do not use
1	Switch off lights			
2	Switch of geyser when not in use after heating			
3	Switch off appliances when out of house or going to bed			
4	Using energy saving equipment			
5	Using the vehicle less			
6	Using stove, microwave and extra lighting less			
7	Collecting of rain water			
8	Turning off tap when washing dishes and in the bathroom			
9	Using water saving equipment			
10	Recycling all material (cans, bottles, plastic, etc)			
11	Collection of waste weekly			
12	Buy products with less packaging			
13	Green gardens (planting of vegetables, trees, etc)			
14	Other			

3.2 What do you think is lacking in creating a greener environment?

3.3 Do you have solar energy and water saving equipment installed in your home?

1. Yes (go to 3.3.1) ☐

2. No (go to 3.3.2) ☐

3.3.1 If yes, what?

3.3.2 If no, why not?

3.4 Are you aware of how to recycle your waste?

1. Yes (go to 3.4.1) ☐

2. No (go to 3.5) ☐

3.4.1 If yes, how do you recycle your waste (including liquid, edible and solid materials)?.....
.....

3.5 Do you think environmental programmes/conferences/workshops, which can help you adapt to weather changes and becoming more sustainable, is important?

1. Yes ☐

2. No (go to 3.5.1) ☐

3.5.1 If no why?

3.6 Have you attended any of these?

1. Yes ☐

2. No (go to 3.6.1) ☐

3.6.1 If no, why?

3.7 Are there any local municipality sustainable living awareness programmes you know of?

1. Yes (go to 3.7.1) ☐

2. No (go to 3.7.2) ☐

3.7.1 If yes, do you participate in them?

3.7.2 If no, why?

3.8 Do you think that the local government creates enough awareness on environmental and social issues in the urban areas?

1. Yes ☐

2. No (go to 3.8.1) ☐

3.8.1 If no why?

APPENDIX 2

Interview Questions to the eThekwini Municipality

For research purposes, please answer the following questions: How is the Environmental Planning and Climate Protection Programme bridging the gap between adaptation and mitigation?

1. Urban areas are considered the main drivers, and as well as the most vulnerable in the climate change debate. The linking of adaptation and mitigation objectives to sustainable development has become propaganda for local government in shaping resilient communities around climate change, and household behaviour. How are the Environmental Planning and Climate Protection Programme linking adaptation and mitigation efforts to sustainable development goals to create resilient urban communities?

2. What community-based programmes have been implemented by the Environmental Planning and Climate Protection Department, to adapt and mitigate towards climate change?

3. What has been the success rate of the approaches adopted my local communities?

4. Are such approaches being adopted by urban communities?

5. How have the community-based approaches benefitted local communities, with reference to urban areas?

6. How is the programme preparing and educating urban communities in adopting sustainable approaches to mitigate and adapt against the harmful effects of climate change?

7. Has an assessment been carried out by the Environmental Planning and Climate Protection Programme to determine behavioural responses in response to effects of a changing climate in urban areas? What constraints hinder the efforts of the Environmental Planning and Climate Protection Programme in the successful implementation of adaptation and mitigation in the eThekwini Municipality?

Source: Naicker, P., preshantha.naicker@yahoo.com. (2016). Environmental Planning and Climate Change Programme.[email] Message to N. Hlongwa (Nongcebo.Hlongwa@durban.gov.za). Sent 16 March 2016: 4:46 PM. Available at: https://mg.mail.yahoo.com/neo/launch?.rand=2c3m18j51sb88

APPENDIX 3

Durban Adaptation Charter (DAC) 2015

Science

1. How to effect behaviour change?

2. What are the governance mechanisms available to contain the known? How much of poverty is created through business as usual?

Solutions

1. Are we not asking too much from the poor when they are not the real culprit? How can we mobilize our communities to fight the multinational companies responsible for the destruction of the environment?

2. What can be done to reverse the affected communities by loss of fertility in the soil due to sea level rise?

3. What do we do to countries that continuously produce dangerous emissions?

4. How do we help local communities to effectively deal with waste management as it seems to be one of global warming

5. How are we capacitating and influencing political leaders to do business differently, because it cannot be business as usual (local government)

6. What can we do to change the way politicians think about/towards climate changes (local)

7. Are there funding opportunities for local governments to apply for around impacts and implementation of mitigation strategies? Are there substitute crops that could be used -perhaps research could be done around alternative crop use or ensure more 'resilient' crops? Due to South Africa's geographic location, we are more vulnerable to the impacts of GHG increases. Is S.A prioritized for adaptation through national government (local)?

8. How can state and non-state actors be compelled to act fast on the solutions to move the catastrophe and not business as usual? What is the possibility of enacting international laws to checkmate carbon economics and investigate factors of climate change (on pollution)? (Local)

9. From what is already noted by countries regarding climate change, it seems as if research on how to adapt, especially agricultural research on different crops is still lacking. Is there any work that is being

done to encourage the scientist to come up with methods of improving agricultural yield in this changing weather?

10. With your experience through working with municipalities especially local ones in rural areas, do you see any important initiatives into adapting to climate change?

11. How can governments best address civic education to the most disadvantaged communities that earn less than 1 dollar a day, and the main thing they are focused on or concerned about is surviving another day. How to explain to them about climate change and make them understand and take the right precautions

11. The problem should be solved from implementing the solution and passing of it into law with relevant penalties for the offenders. What has the climate change department done to pass the solution as a daily practice of law?

12. How can nations balance the need for development without negativity affecting the environment (local?)

13. There is a need to link governance issues and its impact on environmental management. Mining of resources may be linked to poor governance issues as the population strive for survival

14. I think we are now aware of the risks, vulnerabilities and what needs to be done. The big question is, "how?"Do we influence policy to have a quick turnaround mind-set and starting to move as a unit towards the right path of reducing climate change? How do we leap frog?

15. What climate vulnerabilities are we talking about? How are the community's needs brought on board for the adaptation process? (Community adaptation)

16. What are the great economics doing to maintain/reach the acceptable GHG emission levels? What are their percentage emission and targets with time? Great economics-their economy and political interests heavily rely on emissions. Poor/developing states regime extraction of national resources as their population is growing fast. Are you sure we will win the battle? (Mitigation-national policy issue)

17. Integration is important when dealing with climate change. How can we improve/reduce the current vulnerabilities if we continue working silos and how can we break this?

18. Can the impact of floods be mitigated by having adequate storm water drainage infrastructures?

19. What tools can be used by the municipality to identify sensitive /vulnerable areas in our communities?

20. How do you ensure "real" local ownership on participation to climate change in terms of leap frogging?

21. Understanding that Africa is least contributing but most affected by climate change, what is the sense of will (political or otherwise) towards Paris, is the African voice towards mitigation to protect future generations? (Africa's influence in cop 21)

22. Why is it so difficult to hove positive political decisions about what we know?

23. understanding and mitigating climate realities would demand access to the discussion making forums, access to information so as to contribute towards providing the solutions, how do we bring vulnerable members of our communities submerged in silence on board, after all, it's a right?

24. A statement: The presentation says the same as we have said in the environmental movement of the 1960s- we need to stop saying it and take action, rather than wait for local level to do this

25. Why is climate change still geared towards rural areas, yet the population of the world, since 2007, is now moving in to urban areas than rural areas

26. What is finally going to happen if North and South are still not agreeing on the measures to reduce GHG emissions?

27. How do we simplify the concepts in climate change to accommodate buy-in from local level?

28. If we are aware of the impacts of 0.8 Degrees Celsius, how can we go all the way to Paris to agree to a value above this?

29. What works faster like a leap-frog, adaptation or mitigation?

30. Can you elaborate on the contribution urban settlements make into the hydrological cycle?, including its impact/contribution to climate change events?

31. How to best get political will on local level action towards climate change?

32. The ruling party and the political party need to commit to climate change and actively participate. When will the national climate change plan be enacted?

33. Africa is growing, most countries are getting oil and their economies are becoming oil dependent. Therefore, how is it possible to engage with both the opportunity of attaining oil and climate change impacts?

34. A changing climate will also bring new opportunities to new areas, which otherwise experienced a different climate. Is this not a great opportunity for Africa?

35. Climate change mitigation is every one’s solution. Let us not only look at government. Let's change our attitude.

36. How can Africa get assistance in terms of financing all local projects meant at addressing Climate Change related projects?

37. Please ask the audience what our emotional response really is? Comment: without acknowledging peoples emotional responses you cannot identify their values and how to create actual change within people

38. How is the Climate Reality Project going to support innovative sustainability initiatives already making an impact on youth employment? Can a project like better world Cameroon: www.betterworld-cameroon.com becomes possible partners?

39. On the subject of CC on hand, what can be said about the contribution of political power, which is a matter of fact the bone of contention in most African countries?

40. What capacity building projects are there to assist local authorities to implement adaptation measure?

41. Even if Africa's behaviour changes for the positive, how can it change the global situation if the major polluters are not in Africa? Can we (the humans) effectively have green industries and transportation that will respond to the immediate need of stopping the greenhouse gas emissions?

42. Many municipalities struggling to deliver on their service delivery mandate, lack skills, resources, systems. How do we make the solutions viable for local government to start implementing? What do the solutions mean for the local government fiscal framework?

43. What is the status for climate change and global change?

44. Why is the IPCC through the conference of parties not funding drought and water scarcity programmes /projects in Africa in terms of policy?

45. What instruments are required for the leap frog interactions and how practical is this? How do we leap frog?

46. How can I become a member of the Climate Reality Project? What are the main activities of the Climate Reality Project? Does the Climate Reality Project help to sponsor or carry out climate mitigation projects in (member) communities?

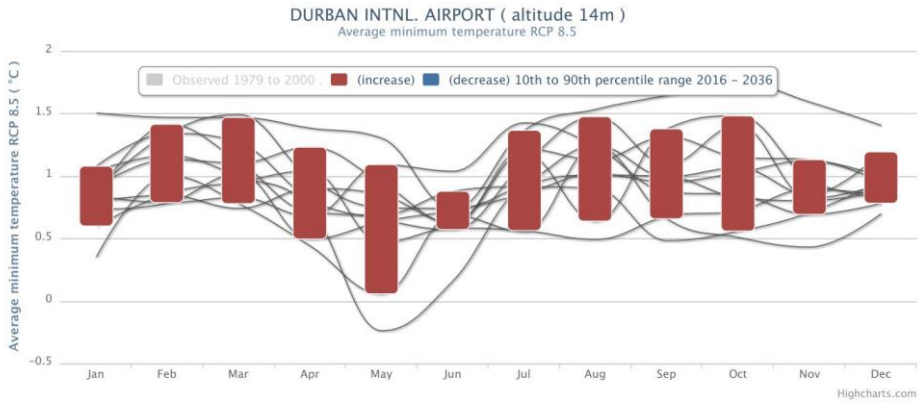
47. How best to get political will on local level action towards climate change?

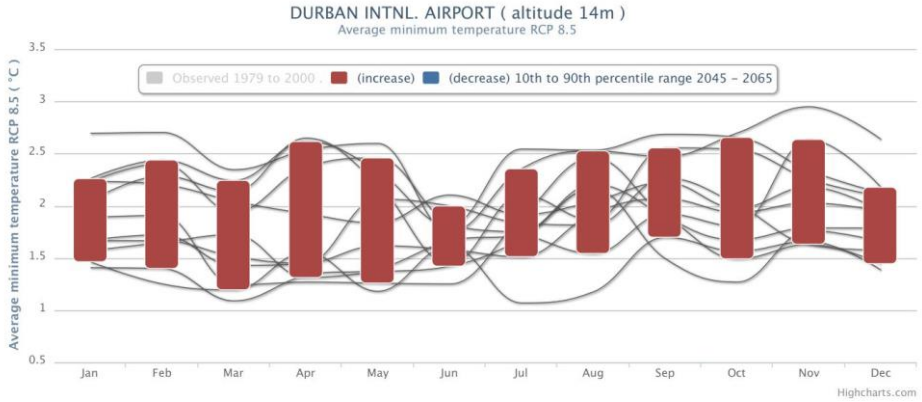
APPENDIX 4

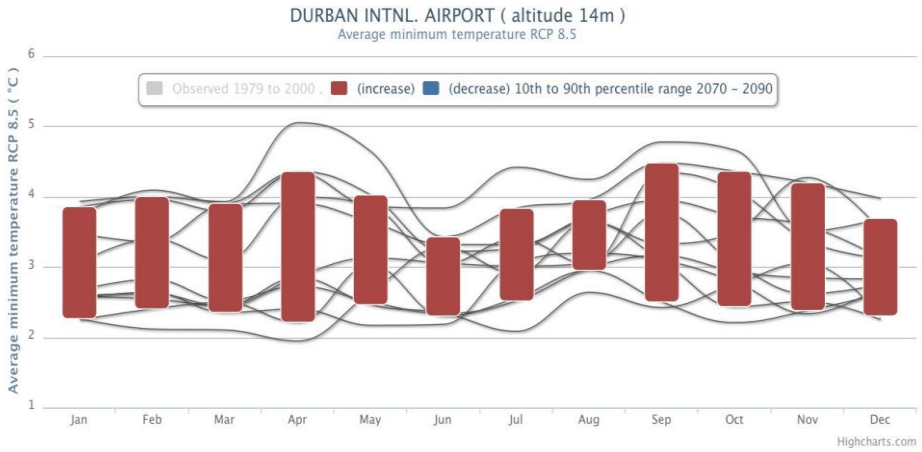
Projected Climate Variables from 2016-2090

4.1 RCP 8.5 W/m^{-2} projected maximum temperature for eThekwini Municipality, KwaZulu-Natal (Source: CSAG, 2016).

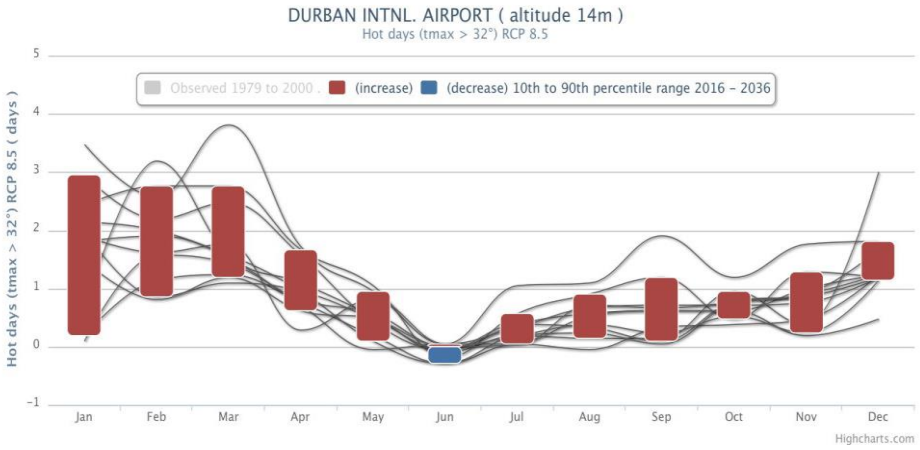
4.2 RCP 8.5 W/m^{-2} projected minimum temperature for eThekwini Municipality, KwaZulu-Natal (Source: CSAG, 2016).

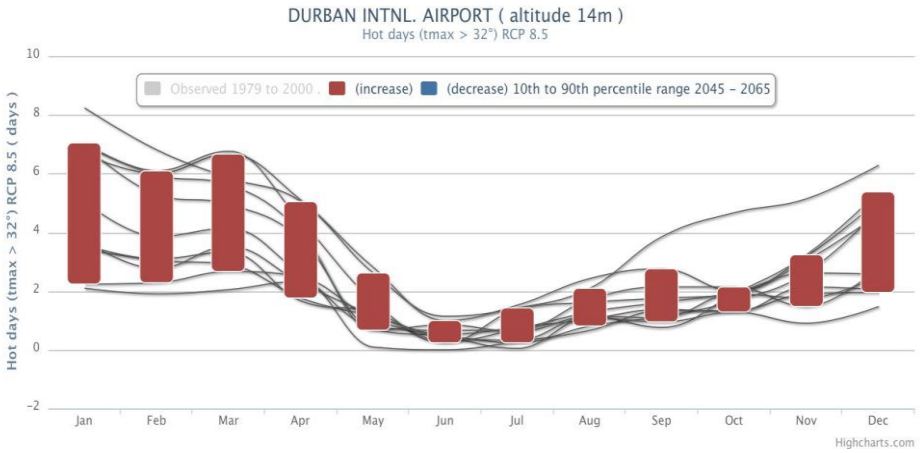


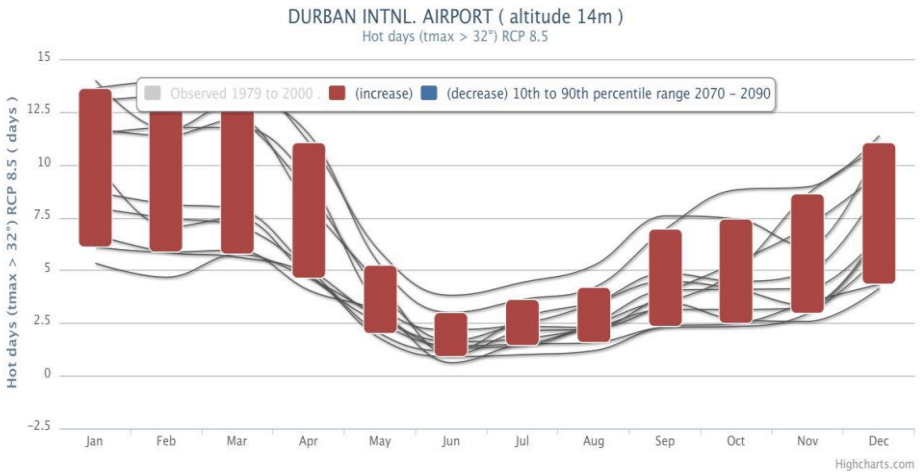




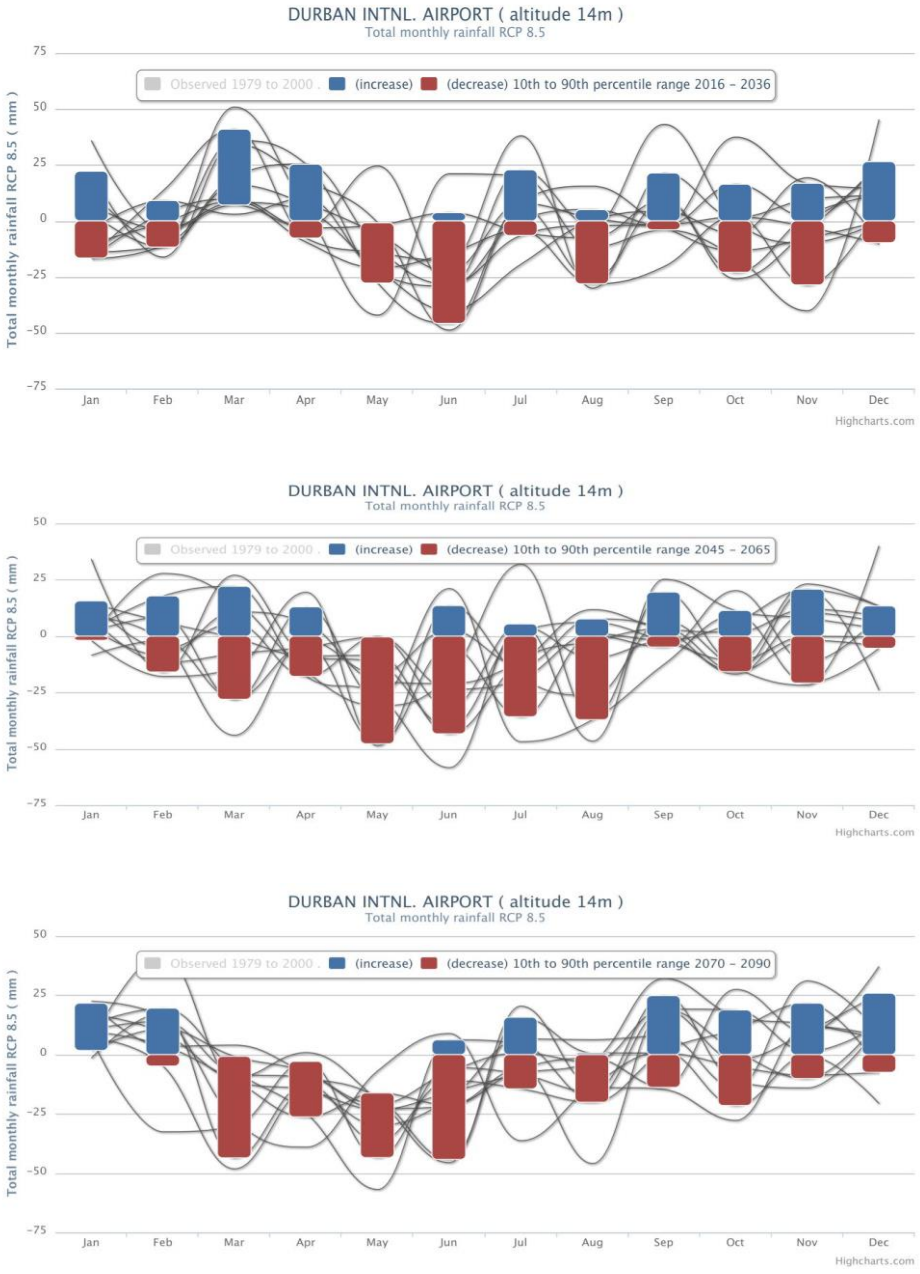
4.3 RCP 8.5 W/m^{-2} projected hot days for eThekwini Municipality, KwaZulu-Natal (Source: CSAG, 2016).



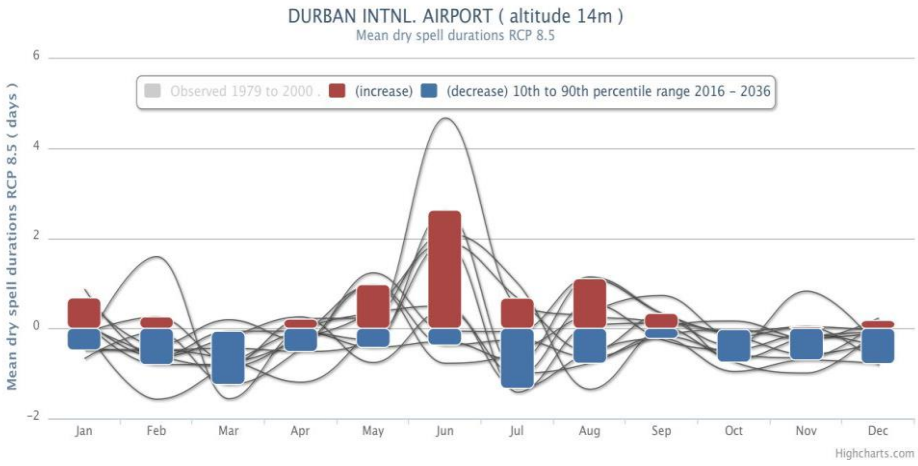


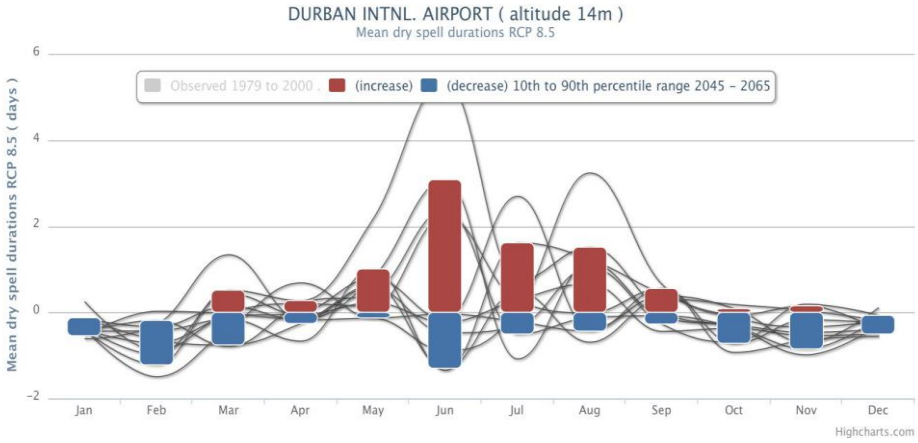


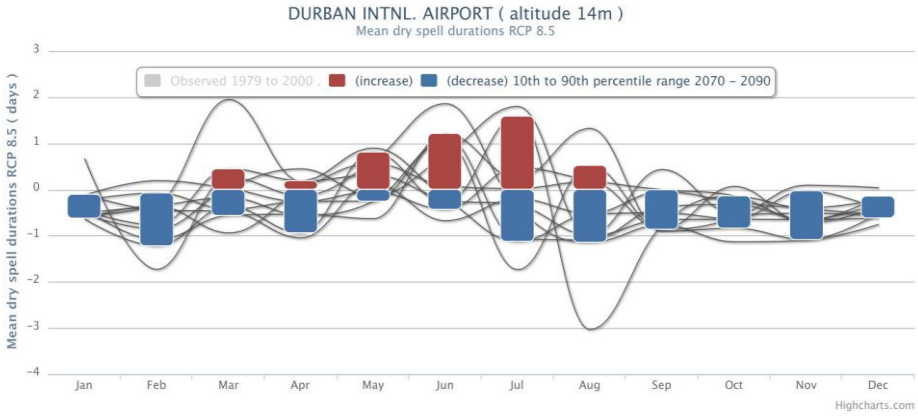
4.4 RCP 8.5 W/m^{-2} projected precipitation for eThekwini Municipality, KwaZulu-Natal (Source: CSAG, 2016).



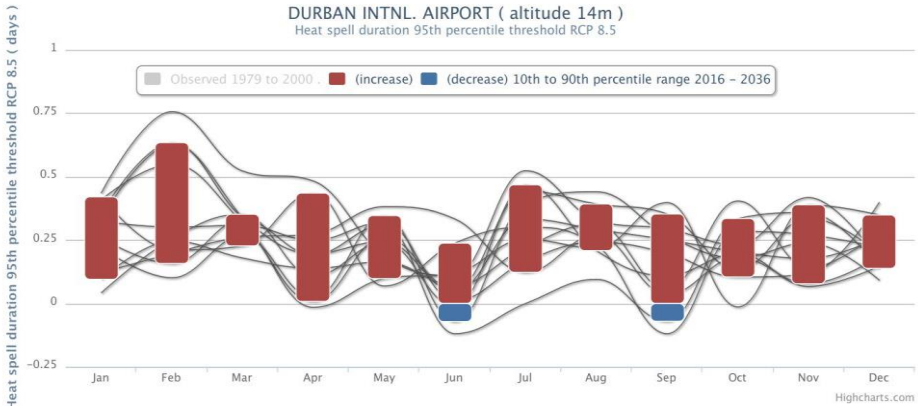
4.5 RCP 8.5 W/m^{-2} projected dry spells for eThekwini Municipality, kwaZulu-Natal (Source: CSAG, 2016).

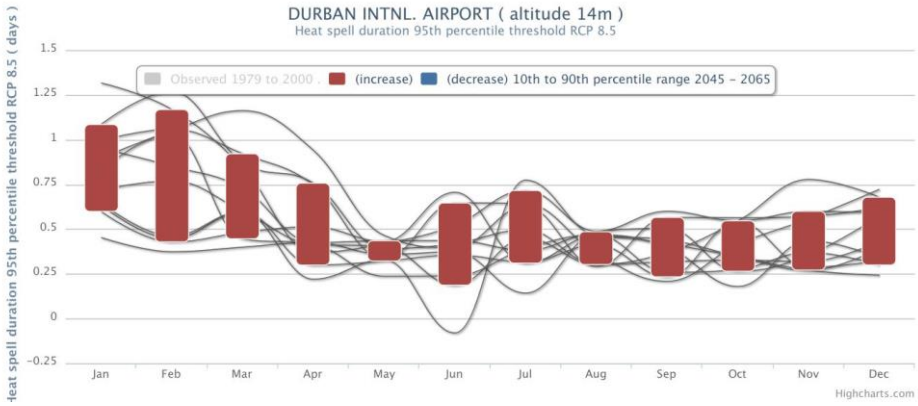


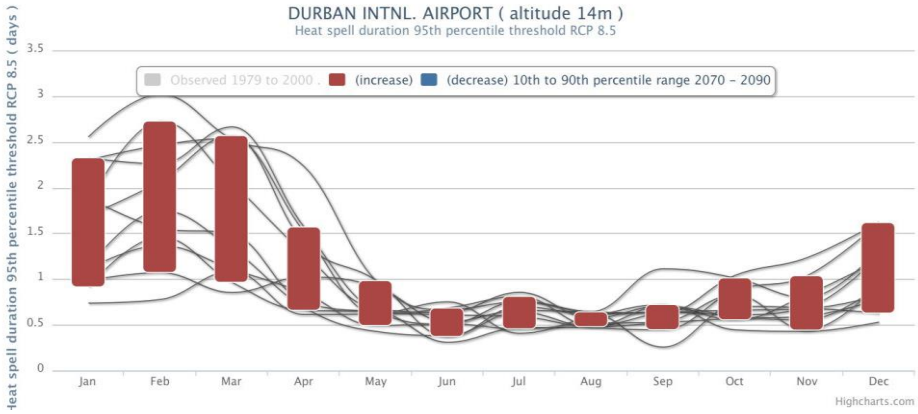




4.6 RCP 8.5 W/m^{-2} projected mean heat spells for eThekwini Municipality, KwaZulu-Natal (Source: CSAG, 2016).







APPENDIX 5

Ethical Clearance for Gatekeepers Permission to Conduct Research in eThekwini Municipality

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

17 March 2016

To whom it may concern

I, .Preshantha Naicker, a full-time Masters student registered in the School of Agricultural, Earth and Environmental Sciences formally requests permission to interview staff in the Environmental Planning and Climate Protection Department, and use the data collected in the Masters dissertation entitled as: Evaluating local climate projections and drivers in public behavior towards adopting approaches at a household level that integrate adaptation and mitigation in urban areas

The aim is to evaluate local climate projections against current trends and to further evaluate community adaptation and mitigation strategies:

(1)To determine current trends in temperature, humidity and precipitation
(2) To determine projected changes in temperature, humidity and precipitation
(3) To correlate projected and current trends
(4) Evaluate community adaptation and mitigation strategies
(5) To determine what forcings drive public behavior to adopt adaptation and mitigation strategies

The dissertation will acknowledge the University of KwaZulu-Natal and will be shared with the University of KwaZulu-Natal if requested.

Thank you and kind regards

Preshantha

Should you require any further information, please do not hesitate to contact me or my supervisor. Our contact details are as follows:

NAME: Preshantha Naicker
School of Agriculture, Earth and Environmental Sciences
Email: preshantha.naicker@yahoo.com
Supervisor: Dr S Njoya

Telephone: 0312603161

Email: Njoya@ukzn.ac.za

Permission to use information/data granted by:

Name: Dr D Roberts

Signature:

Date: 25/3/2016

Department: EPCPD

ENVIRONMENTAL PLANNING AND CLIMATE PROTECTION DEPARTMENT
20 MAY 2016
RECEIVED BY:

School of Agriculture, Earth and Environmental Sciences, University of KwaZulu-Natal, Howard College Campus, Durban 4041

APPENDIX 6

Newspaper Clippings 1

Woodhurst residents face health risks after storm

An elderly Woodhurst couple who has been fighting a losing battle for the past four decades is calling for the municipality's intervention.

The recent heavy downpour has led to an overflow of water, faeces and dirt at the couple's Leo Avenue home.

According to Jessica Mothilal, her parents have been residing at their house for the past 43 years and have had to bear the consequences of having manholes on their property.

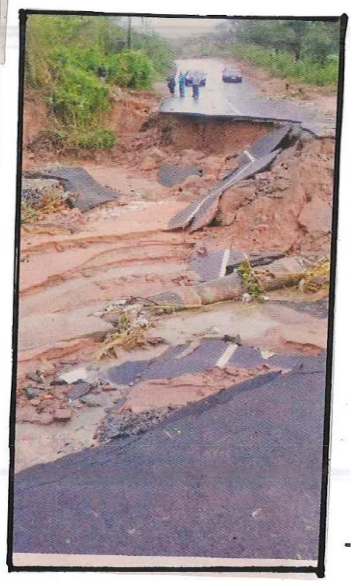
"Each time there is a storm, we experience the same problem. We have been requesting for the municipality to address the issue for the past 40 years. When we do report the matter, they come over and clean up the area and the problem is fixed temporarily until there is a storm again. We are pleading for the municipality to remove or reposition the manholes. It has been one week since the last storm and the problem has not been addressed.

"This issue poses numerous health risks not only to my family but to our neighbours as well. My 78-year-old father has to clean up the area using basic detergents, which unfortunately cannot eliminate the health risks associated with the waste that emanates from the manholes.

"With the high rates that we pay, we deserve proper and a respectable service. We are requesting for the municipality to resolve this issue before we face another storm."

A comment from the municipality could not be obtained at the time of going to print. However, the feedback received in regards to this issue will be published when it becomes available.

The faeces that that were found on the couple's property.



Source: The Rising Sun, (2016). Damages to Urban Infrastructure after Storm, 2 Aug. p5.

APPENDIX 7

Newspaper Clippings 2

Search for flood victim ends tragically

(continued from page 3)

into the raging water on Silverglen Drive. I immediately went to the scene. My friends and I, together with residents and members of the Silverglen CPF, began searching for her. There were no other authorities at the scene assisting us. We went to the nearest police station and asked for torches to assist us in the search for my mum, however, we were turned down and not assisted," said Duerelle, who had lost his dad after a short illness about eight months ago.

The family further claimed that there was no disaster plan put into place by the relevant authorities to handle an incident of this nature. The family, friends and residents battled for many hours in the storm in search of Pillay and believe that if search dogs were sent out earlier, their beloved mum would have been found sooner.

"We knew that there was little chance of her being alive, however, we continued the desperate search for her with no help from authorities. I tied a rope around me and had some of my friends and family anchor it around them before jumping into the river to search for my mum in the vehicle, which was badly damaged. Although we will never receive justice

the safety of others. We call on the relevant departments to stabilise the roads in Chatsworth, enforce a strategic disaster plan, and clean up the drainage systems and shrubbery and trees around drainage systems to stop the recurrence of blocked drainage which causes flooding," he added.

Pillay's nephew, Neville, 43, said another concern which needs to be adequately addressed is illegal dumping and littering, which are both a major cause for concern in the Chatsworth area.

"Clogged drains cause flooding and overflowing water causes major damage to properties. When there is loss of life because people have not been responsible enough, it angers me. We will not sit back and watch this happen to another innocent person. We, as a community, have to stop being apathetic and start taking responsibility. The relevant authorities also need to take responsibility and have volatile areas examined and repaired or restructured to ensure the safety of residents," he added. Pillay was laid to rest at the Mobeni Heights Crematorium last Thursday.

The car that Priscilla Pillay was driving at the time of the incident.

Heavy rains cause havoc in Chatsworth

The recent heavy rains which began last Sunday caused havoc in Chatsworth. This led to flooded homes, structural damage and motor vehicle collisions in various parts of the Chatsworth area.

The eThekwini Municipality Disaster Management team were on the ground, monitoring and evaluating the damage caused to homes and roads around the city. Seen are one of the damaged roads and houses. For more pictures of the damages, visit www.risingsunchatsworth.co.za

Source: The Rising Sun. (2016). Damages to Urban Infrastructure after Storm, 2 Aug. p29.