The Human Dimensions of Climate Risk in Africa's Low and Lower-Middle Income Countries

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Climate change impacts are a result of the intersection between the level of climate change, and the socioeconomic conditions that characterize the locale under question. For the low income countries in the world, they face a heightened risk to climate change impacts, as a result of their low development status that increases their vulnerability and exposure. The Low and Lower-Middle Income countries in Africa are some of the most underdeveloped in the world. Their high population, limited access to sanitation, low income and low educational attainment stifle development and fuel the demographic trap. These socioeconomic conditions determine development outcomes and characterize the human dimensions of climate risk.

This thesis focused on the socioeconomic processes to the human dimensions of climate risk in the Low and Lower-Middle Income countries in Africa. This research used a set of 11 socioeconomic conditions, specific to low income and lower-middle income countries and analyzed the direct and indirect influence patterns between the socioeconomic elements. Cross Impact Balance Analysis was used to analyze and evaluate these influences and generate plausible future scenarios based on combinations of socioeconomic conditions at high, medium, or low states. The objective of the analysis was to determine what plausible combinations of socioeconomic conditions are required for favourable future development, and what levels of these conditions can pull Africa out of the demographic trap, and onto a path of sustained development.

The analysis generated 9 plausible future scenarios. These scenarios describe future development pathways that range from the status quo demographic trap that many African countries currently face, to a future scenario of sustainable development by the end of the century. The vulnerability to climate change was reduced along this trajectory, with lower challenges to adaptation in high income scenarios, compared to high exposure and vulnerability in low income future scenarios. By analyzing the scenarios in the context of the development continuum, each outcome was evaluated based on their promotion or hindrance to development and income growth, focusing on hidden variables that promote progress in key areas. The results showed the importance of sanitation, healthcare, poverty reduction, and education to promoting economic growth and development. Sanitation emerged as a hidden variable to development success for its vital role in promoting gender parity in educational attainment, as well as supporting good health in the population. While education was one of the most influential descriptors, its ability to exert positive force was controlled by the level of sanitation, a key determinant to its progress. By studying potential future conditions, we are better able to understand areas for prioritization today to chart a course of sustainable development for tomorrow.

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Many thanks to INCLU, the Best Gals of Albert Street, and Marlies Crew for pushing me to complete my thesis!

Dedication

This thesis is dedicated to my friend and ERS classmate, Emily Ruston Mann (1991-2018).

Table of Contents

List of Figures

List of Tables

List of Abbreviations

CIB - Cross Impact Balance

GHG - Greenhouse Gas

HIC - High Income Country

IPCC - Intergovernmental Panel on Climate Change

LIC - Low Income Country

LMC - Lower-Middle Income Country

SDG - Sustainable Development Goal

SSP - Shared Socioeconomic Pathway

SSA - sub-Saharan Africa

WHO – World Health Organization

Chapter 1: Introduction

1.1 Introduction

Climate change is a complex and dynamic issue with the ability to alter the earth's natural environment, and human systems. The severity of climate change impacts will vary from one place to another, across continents, countries, and communities. The expected impacts vary depending on climatic characteristics and geographical conditions. However, the extent of climate change impacts is not simply a direct result of the degree of severity of the impact itself, but rather an intersection between the level of climate change, and the socioeconomic conditions characterizing the locale under question. The way a society is organized determines its ability to adapt to climate change and abate further climate change impacts. These socioeconomic conditions characterize a society's composition, and their development status. Future risks to humans and the natural environment will be largely influenced by social, economic, and technological factors. These same factors will play a pivotal role in human responses to future changes (van Ruijven et al. 2014).

1.2 Climate Change Overview

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use" (IPCC, 2014A, p. 120). In the most recent IPCC Climate Change 2014 Synthesis Report Summary for Policymakers, the IPCC (2014), expresses that "human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history" (IPCC, 2014A, p. 2). Observed climate change and successive decades of unprecedented warming in the atmosphere and ocean has already led to impacts on both human and natural systems around the world, with greater extremes predicted for the future. Increased concentrations of anthropogenic greenhouse gas emissions are a result of industrial processes, economic activity, and population growth. "Anthropogenic GHG emissions are mainly driven by population size, economic activity, lifestyle, energy use, land use patterns, technology and climate policy" (IPCC, 2014A, p. 8). This human influence on the increase in greenhouse gas emissions has largely been driven by today's higher income developed nations. "Human influence on the climate system is clear" (IPCC, 2013, p. 15), and limiting the effects of climate change is of great importance to human and natural systems. Furthermore, the IPCC (2014) expresses confidence in the necessity of limiting climate change impacts in order to meet sustainable development targets, and promote equity and poverty eradication. Climate change is not a simple problem however, and addressing the issue and limiting its impacts will require collective action, and international cooperation (IPCC, 2014C).

1.3 Low and Lower-Middle Income in the Context of Climate Change

The least developed nations of the world face particular vulnerability when it comes to being able to cope and respond to climate change impacts, given their reduced capacity to deal with these changes (IPCC, 2014C). Existing risks to human and natural systems will be exacerbated, and new risks will emerge as well, as a result of climate changes (IPCC, 2014C). These impacts will be felt differently across countries; however, the risks are more extreme for the least developed countries,

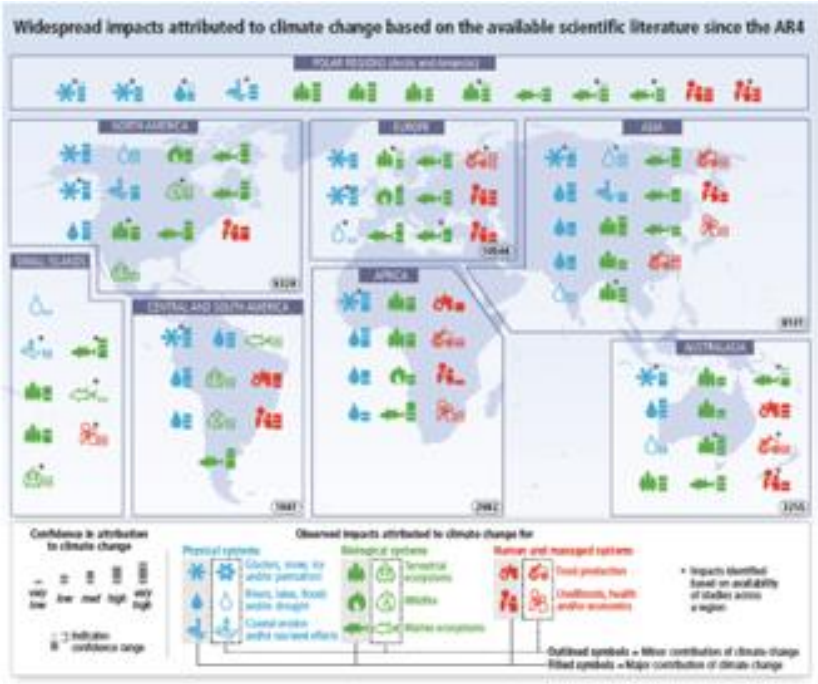


Figure 1: IPCC Map of Climate Change Impacts (IPCC, 2014A;7)

and disadvantaged people. Key risks to climate change impacts are deemed key "due to high hazard or high vulnerability of societies and systems exposed or both" (IPCC, 2014A, p. 64). Figure 1 illustrates some of the impacts attributed to climate change.

1.3.1 Defining the developing world

Low income countries share a number of characteristics that distinguish them from the developed world and render them more vulnerable to climate change. According to Todaro & Smith (2012) low income countries tend to feature high levels of poverty, high population, rapid urban migration, and adverse geographical conditions. These commonalities amongst low income countries set out what is a demographic trap whereby high population growth, leads to high poverty, low income, low quality of healthcare, and education, further promoting high population growth. High population growth rates put extra pressure on the active labour force to support increased numbers of children (Todaro & Smith, 2012). "High fertility can be both a cause and a consequence of underdevelopment" (Todaro & Smith, 2012, p. 46). These features that characterize the demographic trap many low income countries face are the same features that determine their vulnerability to climate change.

Countries defined as the least developed countries are characterized as having "low income, low human capital, and high economic vulnerability" (Todaro & Smith, 2012, p. 41). Factors such as healthcare and education often determine the capabilities of a nation. A low quality of healthcare, results in high infant mortality rates, low life expectancy, and increased vulnerability. Low educational attainment and low literacy reduce economic opportunities, and restrict development, while also impacting a country's capacity to adapt to climate change. High levels of extreme poverty limit individuals' ability to meet basic needs for survival. Urban poverty is often represented by informal settlements known as slums that lack proper sanitation and safety. These low outcomes for socioeconomic conditions put great strain on countries, making growth and development difficult, while severely limiting their ability to cope with the impacts of climate change.

1.3.2 Low income countries' contribution to greenhouse gas emissions

The socioeconomic characteristics that define low income countries are the factors that limit their capacity to adapt to climate change impacts. There are "issues of equity, justice, and fairness (that) arise with respect to mitigation and adaptation. Countries' past and future contributions to the accumulation of GHGs in the atmosphere are different, and countries also face varying challenges and circumstances, and have different capacities to address mitigation and adaptation" (IPCC, 2014C, p. 5). The same countries that face increased vulnerability as a result of their low development status tend to be at the bottom of the list of countries with high greenhouse gas emissions (GHGs). They are not the culprits of a changing climate, but they will likely bear the worst of the impacts.

"Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC, 2014C, p. 4). In low income countries, their economies are more focused on agricultural activities, and are in a transition to more industrial activities, manufacturing and services. As a result, their GHG emissions tend to be lower than developed nations. The industrialization that took place over the last century in todays' developed countries, has led to the unprecedented levels of anthropogenic greenhouse gases (GHG) in the atmosphere. "Carbon dioxide concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions" (IPCC, 2013, p. 11). A Wei et al., (2016) study used World Resources Institute and U.S. Energy Information Administration data, along with results from Zhang et al. (2008) estimated cumulative greenhouse gas emissions for the G8 countries over a period from 1850 to 2004, measuring levels at 61% for total contribution to world GHG emissions, with China, Brazil, India, South Africa, and Mexico, further contributing an additional 13% (Wei et al., 2016). Figure 2 breaks down CO2 emissions per capita around the world, with Sub-Saharan Africa, and Lower Middle-Income Countries accounting for significantly less over this 54 year period than that of high income countries. With these lower levels of GHG emissions, challenges to mitigating them are lower than much of the developed world, given their reduced contribution to GHG concentrations in the atmosphere.

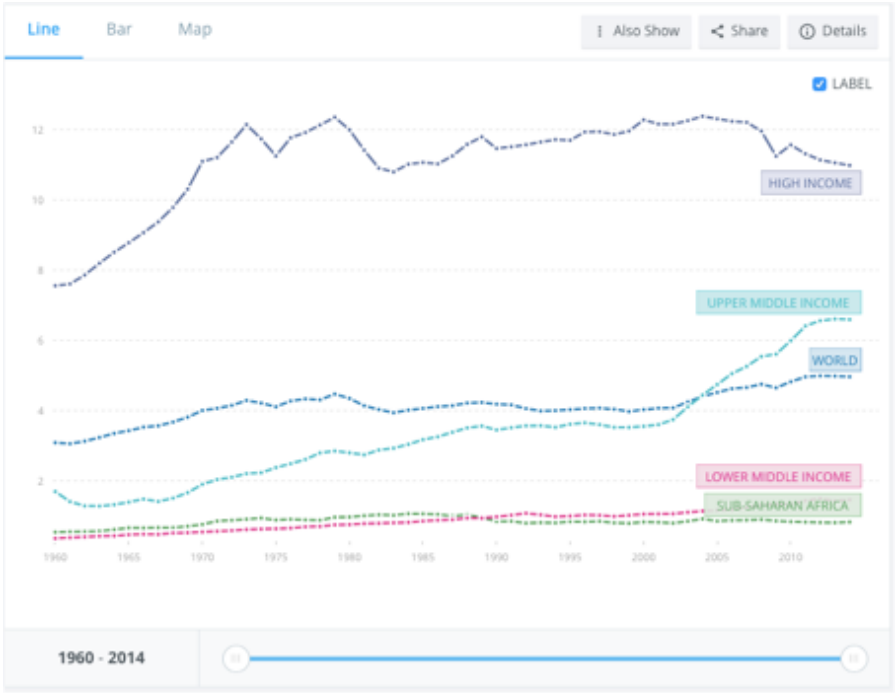


Figure 2: A Comparison of Greenhouse Gas Emissions from Country Groupings (WB, 2018)

1.4 Research Context and Background

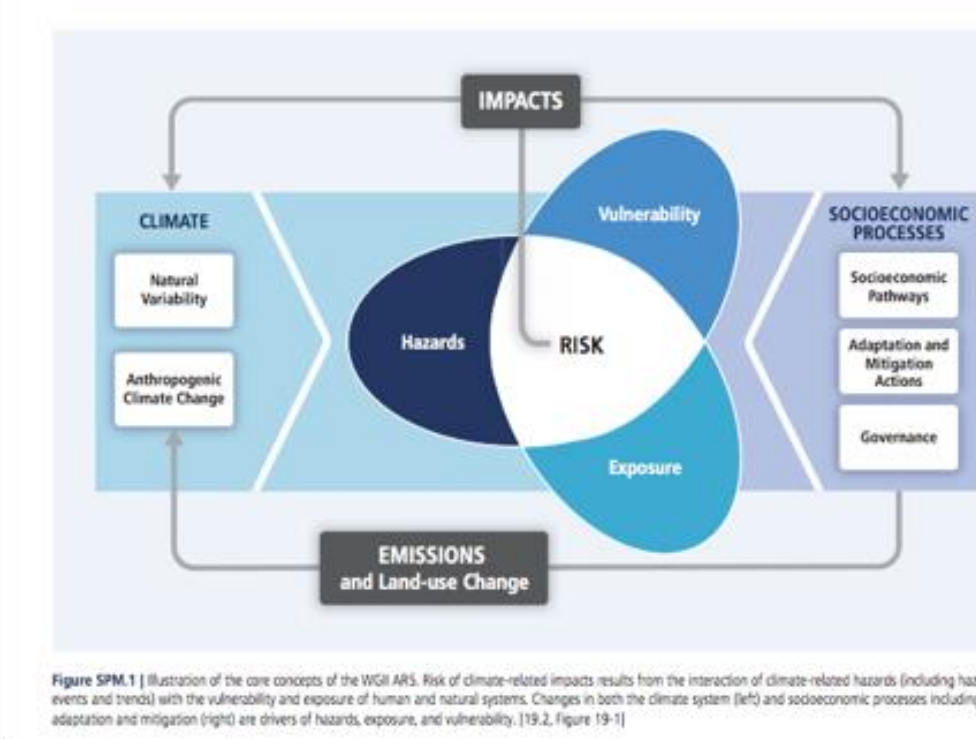


Figure SPM.1 | Illustration of the core concepts of the WGII AR5. Risk of climate-related impacts results from the interaction of climate-related hazards (including haz events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. [19.2, Figure 19-1]

Figure 3: The interaction between climate and socioeconomic processes (IPCC, 2014B;3)

It is clear that the risk to climate change is high in most low income countries. Their low development status hinders their ability to adapt to a changing climate and renders them much more vulnerable than the developed world. This risk is determined by the overlap of hazards, vulnerability and exposure. The hazards are driven by climate and weather, while vulnerability and exposure are influenced by socioeconomic processes. This research will focus on the socioeconomic processes that define vulnerability and risk as pictured in Figure 3.

Climate change impacts involve the intersection between the level of climate change and the socioeconomic conditions of a region. Shared Socioeconomic Pathways are represented in Figure 3 as one of the components to understanding socioeconomic processes. The creation of the Shared Socioeconomic Pathways "describe plausible alternative trends in the evolution of society and natural systems over the 21st century at the level of the world and large world regions" (O'Neill et al. 2013, p. 3). They enable researchers to map out different levels of socioeconomic conditions that describe plausible future conditions in

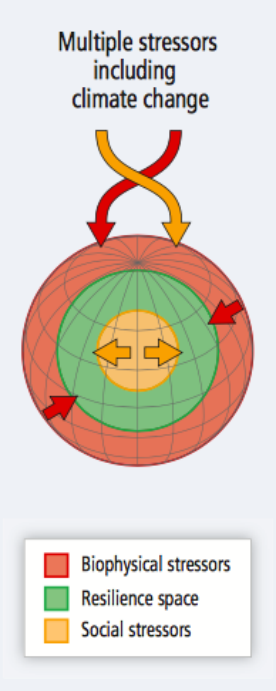


Figure 4: Representation of the World with climate stress meeting social stress and the opportunity space for resilience. (IPCC, 2014B).

society. By showcasing varying progress in socioeconomic conditions, SSPs can "illustrate the consequences of specific courses of action" (O'Neill et al., 2017, p. 171). Though SSPs are used in climate change research, they themselves are pathways for socioeconomic conditions, and act as reference pathways absent from climate change impacts. "The SSPs describe plausible alternative changes in aspects of society such as demographic, economic, technological, social, governance and environmental factors (O'Neill et al., 2017, p. 170).

SSPs "describe worlds in which societal trends result in making mitigation of, or adaptation to, climate change harder or easier, without explicitly considering climate change itself" (O'Neill et al., 2017, p. 170). Early research into the development of SSP narratives determined elements such as technology, policy, and energy to be determinants of challenges to mitigation. Challenges to adaptation stem from development objectives, poverty, inequality, and institutional factors (O'Neill et al., 20170).

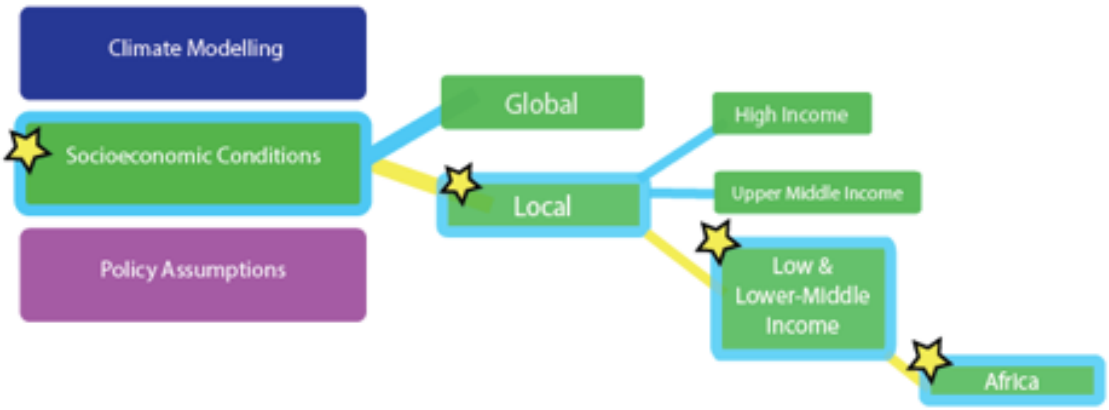


Figure 5: Integrated Framework for Climate Change Research illustrated where this study stems from. Building off of shared socioeconomic pathways, this research analyzes the socioeconomic conditions that characterize Africa's Low and Lower-Middle Income countries development. This will help frame our understanding of the human dimensions of climate risk in this region.

1.5 Global Socioeconomic Pathways - Research Motivation

Schweizer and O'Neill (2014) conducted an SSP study at the global level, where they used Cross Impact Balance (CIB) analysis to analyze combinations of socioeconomic trends to determine plausible future combinations. With the consistent outcomes for future socioeconomic conditions, Schweizer and O'Neill (2014) examined what socioeconomic elements play an important role in distinguishing challenges to mitigation and adaptation. Furthermore, Schweizer and O'Neill (2014) were able to identify new plausible scenario trends and determine what socioeconomic variables were driving these outcomes.

This Schweizer and O'Neill (2014) study is the motivation for this thesis. Moving from the globally aggregated scale, this study will focus in on a more localized region of a country grouping, specifically the low and lower middle-income countries in Africa. The focus for this

research will be less centered on distinguishing challenges to mitigation and adaptation based on future scenarios; instead it will analyze how these future conditions can shed light on socioeconomic characteristics that can promote development and aid in achieving the Sustainable Development Goals (SDGs).

Figure 6: The Sustainable Development Goals (UNFPA, 2016). This research will analyze how future conditions can improve development trajectories and what SDGs will be key for exiting the demographic trap.

1.6 Research Objectives

Socioeconomic conditions characterize the state of nations, they play a key role in describing the risk to climate change impacts, and they can determine development pathways. For many countries in sub-Saharan Africa they are caught in a demographic trap, with high poverty and population growth, paired with low educational attainment and low income per capita perpetuating this historic trend. This research is focused on analyzing these socioeconomic conditions with a system-theoretic approach to determine the key variables to sustainable development, while considering what elements of future outcomes could reduce the climate risk in low and lower middle income countries in Africa.

This study will consider a set of climate relevant socioeconomic conditions specific to low and lower middle income countries in Africa. The socioeconomic conditions include population, income per capita, extreme poverty, educational attainment, quality of governance, among other conditions specific to low income countries. These socioeconomic conditions are referred to as descriptors, as they describe the conditions of the system under study. Using these socioeconomic descriptors, this thesis will consider alternative outcomes for each of the descriptors based on historical information. Each descriptor will have 3-4 possible outcomes at high, medium, and low levels. Using these different states, this study will aim to determine likely combinations of outcomes for descriptors, to produce plausible future scenarios. One of the objectives of this research is to map these influence patterns (Schweizer & O'Neill, 2014) and to explore the scenarios that emerge as a result of different combinations of socioeconomic trends. The plausible scenarios can give insight into future trends to promote development, or what conditions will continue to plague the demographic trap in Africa. These illustrations of future societal conditions, can lend strategy to policy focus areas to promote sustainable development, or highlight optimal conditions to exit the demographic trap.

This project is supporting advancements in integrated climate change research and contributing to a growing body of literature and knowledge on development. This research project will contribute to ongoing research to describe the human dimensions of climate risk, with a specific focus on socioeconomic trends for low and lower-middle-income countries in Africa. Furthermore, this research will consider key socioeconomic variables that promote favourable development outcomes.

This research will seek to answer the following questions:

1. What are plausible combinations of socioeconomic conditions that illustrate possible future scenarios for Africa's Low- and Lower-Middle-Income countries' development?
2. What are the socioeconomic conditions that can pull Africa out of the demographic trap?
3. Based on the plausible combinations of socioeconomic conditions, how do these future outcomes present challenges to adaptation?

1.7 Thesis Layout

Chapter One: Provides the context for the research, overviewing climate change research and defining low income countries in the context of impacts, adaptation and mitigation of climate change. The research objectives outline the research question and area of interest.

Chapter Two: Lays the foundation for the research, detailing the study site and the 11 socioeconomic descriptors along with their associated pathways.

Chapter Three: Provides an overview of the research process and an in-depth discussion on the method; Cross Impact Balance Analysis.

Chapter Four: Analyzes the results from the Cross-Impact Balance Analysis, with a complete overview of the internally consistent scenarios.

Chapter Five: Revisits the research questions and objectives outlined in Chapter 1. The consistent scenarios will be analyzed in the context of Africa's development agenda, to determine key descriptors that could drive progress. These scenarios will also be considered in regard to their varying levels of challenge to climate change adaptation.

Chapter 2

2.1 Study Site: Low Income and Lower-Middle Income Countries in Africa

Climate change research often groups countries based on geography, focusing on particular regions with similar climatic conditions, shared topographical features, etc. This logic is well reasoned when focusing on the potential impacts of climate change to a particular region, or understanding vulnerability based on geographic features, and current climate. However, in this research the focus is on the socioeconomic conditions that characterize a society to understand how trends in socioeconomic conditions impact a region's ability to take action concerning climate change and achieve development outcomes. Given this focus on socioeconomic dimensions, the country groupings have been categorized in a similar manner, focusing on development progress.

Figure 7: Map of Africa's LICs (blue) and LMCs (yellow). Adapted from D-Maps (2017).

The country groupings are classified based on the World Bank's country classification of economies. The primary criterion in grouping nations is the gross national income per capita (World Bank Group, 2018). The gross national income (GNI) per capita is calculated by "the total domestic and foreign output claimed by residents of a

LOW-INCOME ECONOMIES ($1,025 OR LESS)

(31)

Afghanistan	Guinea	Rwanda
Benin	Guinea-Bissau	Senegal
Burkina Faso	Haiti	Sierra Leone
Burundi	Korea, Dem. People's Rep.	Somalia
Central African Republic	Liberia	South Sudan
Chad	Madagascar	Tanzania
Comoros	Malawi	Togo
Congo, Dem. Rep	Mali	Uganda
Eritrea	Mozambique	Zimbabwe
Ethiopia	Nepal	
Gambia, The	Niger	

LOWER-MIDDLE-INCOME ECONOMIES ($1,026 TO $3,955)

(53)

Angola	Indonesia	Philippines
Armenia	Jordan	São Tomé and Principe
Bangladesh	Kenya	Solomon Islands
Bhutan	Kiribati	Sri Lanka
Bolivia	Kosovo	Sudan
Cabo Verde	Kyrgyz Republic	Swaziland
Cambodia	Lao PDR	Syrian Arab Republic
Cameroon	Lesotho	Tajikistan
Congo, Rep.	Mauritania	Timor-Leste
Côte d'Ivoire	Micronesia, Fed. Sts.	Tunisia
Djibouti	Moldova	Ukraine
Egypt, Arab Rep.	Mongolia	Uzbekistan
El Salvador	Morocco	Vanuatu
Georgia	Myanmar	Vietnam
Ghana	Nicaragua	West Bank and Gaza
Guatemala	Nigeria	Yemen, Rep.
Honduras	Pakistan	Zambia
India	Papua New Guinea	

Table 1: List of the World's low and lower middle income economies. The blue highlighted LICs and yellow LMCs are the African countries that form the study site. Figures from World Bank (2018).

Low Income Countries	Lower Middle Income Countries
Benin	Angola
Burkina Faso	Cabo Verde
Burundi	Cameroon
Central African Republic	Congo, Rep.
Chad	Cote d'Ivoire
Comoros	Djibouti
Congo, Dem. Rep.	Egypt, Arab Rep.
Eritrea	Ghana
Ethiopia	Kenya
Gambia, The	Lesotho
Guinea	Mauritania
Guinea-Bissau	Morocco
Liberia	Nigeria
Madagascar	Sao Tome and Principe
Malawi	Sudan
Mali	Swaziland
Mazambique	Tunisia
Niger	Zambia
Rwanda	
Senegal	
Sierra Leone	
Somalia	
South Sudan	
Tanzania	
Togo	
Uganda	
Zimbabwe	

Table 2: List of the countries included in the study site.

country, consisting of gross domestic product (GDP) plus factor incomes earned by foreign residents, minus income earned in the domestic economy by nonresidents" (Todaro & Smith, 2012, p. 44). The World Bank uses the Atlas method to ensure accurate reporting in the exchange rates, given that GNI is calculated in US dollars. The Atlas conversion factor reduces the impact of fluctuating exchange rates, by utilizing the current rate and the exchange rates from the two previous years, adjusted for local and international inflation (World Bank Group, 2017). The World Bank uses four main country groupings; low-income countries (GNI equal or less than $1,025), lower middle-income countries (GNI between $1,026 AND $4,035), upper middle-income countries (GNI between $4,036 - $12,475), and high-income countries (GNI greater than $12,476) (WB, 2016). The current groupings for the 2018 fiscal year are categorized using GNI from 2015.

This study is focused on the low- and lower-middle-income countries identified by the World Bank. From this classification, the study site has been further refined to specifically focus on the LICs and LMCs in Africa. These countries are characterized as having developing economies (World Bank Group, 2018). The World Bank lists a total of 31 low income countries. Of those 31 listed, 27 of these countries are in Africa. There are a total of 53 lower middle income countries, with 18 located in Africa. Overall of the 84 countries listed by the World Bank as low and lower middle income, 45 are from the continent of Africa.

This categorization does not assume all low and lower-middle income countries in Africa are the same, but rather it recognizes that they share many similarities in the status of socioeconomic conditions, given their stage of economic development.

There is much evidence to suggest that the vulnerable and poor areas within low income nations face a particular vulnerability to volatile weather, and changing climate patterns (Tschakert, 2007). Studies suggest this is the case due to their increased level of exposure to climate impacts, coupled with a minimal capacity to adapt, and recover (Djoudi et al, 2013; Reid et al., 2010, Biagani et al, 2014). These large-scale environmental changes can be further exacerbated by socioeconomic conditions such as quality of governance, low economic growth, crumbling infrastructure, low levels of education, inaccessible technology, among other factors. This study

will utilize a set socioeconomic factors specific to Africa's low and lower-middle-income nations as defined by the World Bank.

2.2 Socioeconomic Determinants:

This study features 11 socioeconomic determinants specific to Africa's low income countries (LICs) and lower-middle income countries (LMCs). These determinants were selected through expert consultation conducted by Vanessa Schweizer and Brian O'Neill for their 2014 study on "Systematic construction of global socioeconomic pathways using internally consistent element combinations." Experts were asked to list and rank socioeconomic determinants that were most relevant to LICs and LMCs. These determinants were then researched further to determine definitions relevant and applicable to the country grouping of LICs and LMCs. These socioeconomic conditions were deemed to be important dimensions to challenges to adaptation and mitigation (O'Neill et al., 2017). Once the descriptors were defined, future trends were extrapolated based on historical data, using a number of SDGs as desired outcome states. The desirable high outcomes may reference levels attained in higher income developed countries, or goals and targets from the SDGs. Qualitative determinants of descriptors such as technology transfer, features high, medium, and low level benchmarks based on literature on measuring and describing the success of technology transfer. These states outline what constitutes a high future pathway, medium pathway, and a low trajectory.

The 11 determinants exist within a system, our study site. They interact with one another, exerting influence and being the target of the influence. These are descriptors in human systems, and they are instrumental to a society's ability to respond to climate change, and achieve desired development outcomes. Descriptors such as population, income capita, and technology transfer can be conditions that can present higher or lower challenges to mitigation depending on their states (low, medium, or high). On the other hand, extreme poverty, sanitation, and educational attainment are important descriptors for challenges to adaptation. Below is a list of all descriptors with a brief definition, along with their corresponding states describing potential future pathways.

2.2.1 Population

Population in low income and lower middle-income countries is defined using fertility levels represented by the number of births per woman. The World Bank Group (2018) webpage defined total fertility rate as "the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year." According to the UN World Population Prospects "the medium-variant projection assumes that fertility in Africa will fall from around 4.7 births per woman in 2010-2015 to 3.1 in 2045-2050, reaching a level slightly above 2.1 in 2095-2100" (UN DESA, 2017). The pathways are based on United Nations World Population Prospects (UN DESA, 2015, & UN DESA, 2017) in combination with the World Bank Databank (WBG Data, 2018) data on fertility

levels in sub-Saharan Africa (excluding high-income countries). Pathways run through to the year 2100.

Region, country or area	Total fertility (live births per woman) 1975-1980	1990-1995	2005-2010	2010-2015	2015-2020	2025-2030	2045-2050	2095-2100
World	3.87	3.02	2.57	2.52	2.47	2.39	2.24	1.97
Africa	6.64	5.72	4.89	4.72	4.43	3.90	3.09	2.14
Asia	4.10	2.92	2.30	2.20	2.15	2.06	1.90	1.81
Europe	1.98	1.57	1.55	1.60	1.62	1.69	1.78	1.84
Latin America and the Caribbean	4.48	3.06	2.26	2.14	2.04	1.89	1.77	1.78
Northern America	1.77	2.00	2.01	1.85	1.86	1.87	1.89	1.91
Oceania	2.73	2.49	2.53	2.41	2.34	2.23	2.06	1.86

Table 3: Total fertility by region for selected time periods along the medium variant (UN DESA, 2017;32)

High pathway: Fertility levels remain high, with minimal reductions from current levels. The majority of Africa's countries remain classified as high-fertility countries, where women have on average 4 or more children.

Medium pathway: There are declines in the number of children born to a woman. Fertility levels fall to approximately 2-4 children per woman.

Low pathway: Fertility levels are near the replacement mark. Levels are in line with low fertility countries, which are defined as a nation where women on average have less than 2 children.

2.2.2 Income

Income per capita is defined as a country's total gross national income divided by the population (Todaro & Smith, 2012). "Real income per capita is $48,430 in the United States, $2,930 in India, and $280 in the Democratic Republic of Congo" (Todaro & Smith, 2012, p. 37). On average high income countries have an income per capita 28 times higher than low income countries (Todaro & Smith, 2012). "Africa's poor economic growth has been chronic rather than episodic" (Bloom et al., 1998, p. 208). The ranges for pathways are based upon past minimum and maximum (2002-2014) growth rates observed in sub-Saharan African countries excluding high income. The high, medium and low pathways are based on data from the World Bank.

High pathway: Income per capita increases by more than 2.88% annually. The high pathway is based on SSA's best long-term period of economic growth (2003-2014), which was a 10-year stretch averaging 2.88%. If this average rate were maintained or exceeded between now and 2100, at the end of the century, SSA's GNI/capita would be about $18k/person. That would put all of SSA in the high-income range, though still significantly behind most of today's high income nations.

Medium pathway: Income per capita increases and falls within a range between the high and low pathways. Countries would reach the upper-middle income classification by the end of the century.

Low pathway: The low pathway is a pessimistic outcome, based on periods of below average historical performance (1981-2002). Growth is below 1% by the end of the century, with periods of growth averaging 0.23%. By 2100, SSA reaches $2000 per person, so the entire region is classified as Lower Middle Income according to today's definition.

2.2.3 Agricultural Productivity

Agricultural productivity is defined as the value of agricultural outputs per unit of input to production. We measure productivity as total factor productivity, which compares output to a measure of all types of inputs taken together (labor, capital, land, other goods, etc.). In sub-Saharan Africa total factor productivity has increased at an average rate of about 0.62% per year. Over the last five decades, TFP growth in sub-Saharan Africa has been slow (Rezek, 2011). According to Fuglie (2010) the countries in sub-Saharan Africa fall into the low-growth category. The pathways below are based off Fuglie (2010) data and Rezek, Campbell & Rogers (2011) data from LICs and LMCs. The data is not specific to this study site, because it is useful to know how Africa's LICs and LMCs preforms compared to other lower income countries in the world.

	Agricultural Output Growth						Agricultural TFP Growth					
Agricultural Growth	61-69	70-79	80-89	90-99	00-07	61-07	61-69	70-79	80-89	90-99	00-07	61-07
	(average annual % over period)											
All Developing Countries	3.16	2.82	3.47	3.65	2.99	3.23	0.18	0.54	1.66	2.30	1.98	1.35
Sub-Saharan Africa	3.06	1.32	2.63	3.21	2.81	2.58	0.36	-0.07	0.57	1.17	1.08	0.62
Nigeria	3.42	-0.89	5.07	5.36	3.26	3.24	-1.04	-2.21	1.80	3.78	2.51	0.99
Western (except Nigeria)	3.11	2.00	3.21	4.16	2.45	3.00	-0.08	-0.62	1.43	1.36	0.40	0.53
Sahel	1.84	1.03	2.47	3.34	3.09	2.35	-0.71	-0.65	0.76	0.16	0.68	0.05
Central	2.50	1.95	2.47	0.68	0.71	1.67	-0.65	-0.69	0.28	-0.56	0.04	-0.32
Eastern	4.00	2.42	2.43	1.54	2.94	2.60	0.93	0.38	0.20	-0.22	1.34	0.47
Horn	2.52	2.02	0.80	3.21	3.53	2.36	0.06	0.49	-1.08	0.68	1.77	0.34
Southern	3.12	1.20	1.22	2.16	2.09	1.90	0.65	-0.28	-0.23	1.11	0.81	0.38

Table 4: "Agricultural output and productivity growth for global regions by decade" (Fuglie, 2010;88)

High pathway: Significant, steady, and sustained increases to agricultural productivity. Agricultural productivity increases more than 1.5 % per year, leading to an increase in productivity of a factor of at least 4.5 by the end of the century.

Medium pathway: Agricultural productivity increases at a pace consistent with historical trends, from 1.0% - 1.5% per year, leading to an increase in productivity of a factor of between about 3.0 and 4.5 by the end of the century.

Low pathway: Agricultural productivity increases are slow and feature negative growth at times. Agricultural productivity increases less than 1.0% per year, leading to an increase in productivity of a factor less than 3.0 by the end of the century.

2.2.4 Urbanized Population

Urban areas vary from one country to another, and can be defined according to political boundaries, population size, economic activity, density or the presence of urban infrastructure such as sanitation services, electricity, maintained roadways, etc. (UNICEF, 2012). Urbanized population in low income and lower-middle income countries are represented using four pathways defining the pace of urban population growth, the level of planning associated with urbanization, and the type of settlement whether it is urban, rural, or informal. "The pace of urban population growth depends on the natural increase of the urban population and the population gained by urban areas through both net rural-urban migration and the reclassification of rural settlements into cities and towns" (UNICEF, 2012, p. 10). The rate of urban population growth is determined by the increase in urban population minus the increase in total population, and as such there are positive rates of urbanization when the urban population growth outpaces total population growth. "The spatial pattern of an urban area and growth typology are a consequence of the interaction of physical and socioeconomic factors (Bürgi et al., 2004)" (Tian & Wu, 2015, p. 24). Descriptions are presented in qualitative terms.

Rural: The population remains predominantly rural, as urbanization occurs slowly or stalls. Economic activity is concentrated in agriculture.

Moderate Paced Planned: Moderate paced urbanization with proper planning for healthcare services, sanitation infrastructure, and appropriate policy. The associate planning involves supporting access to schools and hospitals for the urban population, as well as building infrastructure to support economic activity, travel, water delivery, and waste management. The urban growth is taking place at a manageable pace, similar to the growth experienced in some high-income countries in the past.

Rapid planned: The pace of urban population growth outpaces population growth, with urban agglomeration taking place to form megacities. There is high population density, and massive scale urban development, in some cases engulfing smaller towns or cities and semi urban areas to form large city regions (UNICEF, 2012). With the rapid pace of urban population growth, from rural to urban migration and the urbanization of rural areas, there is sufficient planning taking place to support appropriate infrastructure, health services, economic activity, and access to sanitation. This outcome follows the example of some cities in China, such as Guangzhou, one of the fastest growing cities where urbanization is more compact and dense than the developed world (Tian & Wu, 2015).

Rapid unplanned: There is rapid paced urban population growth, and significant rural to urban migration taking place. This influx of people outpaces city planning responses and sufficient investment in infrastructure and services, resulting in informal settlements also commonly referred to as slums. There are poor living conditions with a lack of sanitation services resulting in open defecation, contaminated water sources, and increases in health threats from the spread of diseases and parasites.

2.2.5 Extreme Poverty

The proportion of the population in lower income countries in extreme poverty is defined as the percentage of the population in low and lower middle economies living on less than $1.90 per day (2011 USD (PPP)). In 2013, 45.5% of the population residing in LICs lived in extreme poverty (UN GA, 2015). The first goal laid out in the Sustainable Development Goals is to end poverty in all forms, with a subsequent goal being to eradicate extreme poverty by 2030. The pathways for extreme poverty are represented below.

High pathway: There is a slow decrease to the proportion of population living on less than $1.90 per day. A substantial portion of the population, in excess of 10%, persists in extreme poverty through 2100. Extreme poverty persists, and the Sustainable Development Goal to eradicate extreme poverty will not be met, nor will the goal to end poverty in all forms..

Medium pathway: Moderate paced reductions to the proportion of population living on less than $1.90 per day. The SDG will be missed for 2030 but no more than 5% of the population persists in extreme poverty by 2100.

Low pathway: Proportion of population living on less than $1.90 per day decreases significantly each year. The country is on track to meet the Sustainable Development Goal to eradicate extreme poverty by 2030 or shortly after. Eradication of extreme poverty will be quantified at less than 2% of the population living on less than $1.90.

2.2.6 Quality of Healthcare

Quality of healthcare in lower income countries could be represented by many variables. Here we chose child mortality (under the age of 5) as a proxy. The under-five mortality rate is defined as the probability per 1,000 that a newborn baby will die before reaching age five. “Mortality among children under 5 years of age remains high in sub-Saharan Africa, with a rate of 84 deaths per 1,000 live births in 2015” (UN ESC, 2017, p. 5). The global rate during the same year was 43 deaths per 1000 live births for children under 5 years of age. According to the World Bank Group (2018) in 2016 the under-five mortality rate for High Income countries (HIC) was 5.3, while that number was 78.4 for sub-Saharan Africa (excluding high income countries in the region). As a proxy for healthcare, it is assumed that decreases to the under-five mortality rate equate to improvements in quality of healthcare, access to services, increases in number of

trained medical professionals, etc. The Sustainable Development Goals for healthcare aim to reduce the under-five mortality rate to 25 per 1000 live births (UN GA, 2015). In comparing that goal to current levels in HICs, that benchmark is 5 times higher. Furthermore, the goals stipulate, "access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all" (UN GA, 2015, p. 16). The pathways for quality healthcare are defined below.

Figure 8: Under-five mortality rate from 1990 to 2015 in sub-Saharan Africa (green), low income countries (blue), and high income countries (purple). Results generated through the World Bank Group Data (2018).

High pathway: Healthcare substantially improves with significant reductions to the under-five mortality rate. Countries are on track to meet the SDG to reduce under-five mortality to 25 or less per 1000 live births by 2030, or shortly after.

Medium pathway: Moderate improvements to healthcare, with steady decreases to the under-five mortality rate. SDG is achieved by the end of the century.

Low pathway: Minimal improvements to healthcare, with slow decreases to the under-five mortality rate. Quality of healthcare does not meet the sustainable development goal.

2.2.7 Water Scarcity

Conditions of water scarcity in lower income countries are defined as the availability of less than 1000 cubic meters of renewable water resources per person per year. Typically defined as an average at the national level, the 1000 cubic meters per person threshold represents an amount available each year for households, growing food, supporting industries, and maintaining the environment. There is limited data available in regard to the renewable internal freshwater resources per capita measured in cubic metres for LICs and LMCs in Africa; as such the pathways are a bit more speculative. With limited data, it is difficult to say whether on average the LICs and LMCs in Africa have high, medium, or low water scarcity. The pathways describe

the portion of the population living in water scarce conditions (less than 1000 cubic meters of renewable water resources per person per year). The pathways are informed by data from UNDP's (2006) Human Development Report.

High pathway: Substantial increase (>25%) in the portion of the population living in water scarcity.

Medium pathway: Moderate increase (15-25%) to the portion of the population living in water scarcity.

Low pathway: Minimal increase (<15%) to the portion of the population living in water scarcity.

2.2.8 Educational Attainment

Educational attainment in lower-income countries is defined by the proportion of the population that has undertaken schooling at a particular level. We measure attainment by the percentage of people who have undertaken schooling beyond the primary level; i.e., at least some secondary or tertiary (college/university) education. In line with the fourth goal of the SDGs - "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (UN GA, 2015, p. 17), we are making an assumption with these pathway percentages that there is inclusive and equitable access to education. When considering primary completion rates, in 2015 high income countries were at 98%, while sub-Saharan Africa had 68%, while lower secondary completion rates, were 42% for SSA compared to 92% for HIC (World Bank Group, 2018). "The completion rate indicated how many persons in a given age group have completed the relevant level of education" (UNESCO, 2013). This stark drop in secondary schooling is concerning for Africa's LICs and LMCs and presents an uphill battle to achieve subgoals of the SDGs including; "that all girls and boys complete free, equitable and quality primary and secondary education" (UN GA, 2015, p. 17) by 2030. The pathways below describe improvement in post-primary schooling as the percentage of the population undertaking schooling beyond the primary level. Furthermore, each pathway describes the status of equal access to education for both girls and boys.

High pathway: Rapid improvement, with the majority (>70%) of the population undertaking post-primary schooling by the end of the century. Significant progress to promote post primary enrolment, and completion of secondary and tertiary schooling, however countries still lag behind HICs. There is gender parity in access to education and quality of education. This would be the upper limit of the high pathway

Medium pathway: Moderate improvement, with over half of the school age population (60-70%) undertaking post-primary schooling by the end of the century. There is still some gender

disparity, with more boys attending school than girls. Significant progress has been made to promote equal access to education.

Low pathway: Slow improvement with less than 60% of the population undertaking post-primary schooling by the end of the century. Gender disparity persists, with limited progress to ensure inclusive and equitable access to education.

2.2.9 Quality of Governance

Quality of governance is defined as a composite of six Worldwide Governance Indicators (WGI), specifically Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. There remains much debate as to how to best define quality of governance. The pathways for quality of governance are defined below based on the WGI.

High pathway: Over time, there is more improvement in governance quality than deterioration. There is an absence of violence, political stability at all levels of government, and significant control of corruption.

Medium pathway: Overall changes in governance quality are moderate. There are improvements to stability and effectiveness, however quality of governance is inconsistent, and progress is moderately paced.

Low pathway: Over time, there is more deterioration in governance quality than improvement. There is rampant corruption, significant violence, a lack of stability, and poor regulatory quality.

2.2.10 Sanitation

Access to sanitation in lower income countries is defined as the proportion of the population with access to sanitation. The current Sustainable Development Goals aim to address sanitation by ending open defecation, achieving universal access to basic sanitation services, and "paying special attention to the needs of women and girls and those in vulnerable situations" (UN GA, 2015, p. 18). Descriptions of the pathways are informed by service level definitions for drinking water, sanitation and hygiene featured in the Sustainable Development Goals. In accordance with the Millennium Development Goals, and the corresponding Sustainable Development Goals, the definition for sanitation encompasses parasite prevalence as "the reliability of drinking water supplies and improved water management in human settlement areas reduce transmission risks of malaria and dengue fever" and "safe drinking water and basic sanitation help prevent water-related diseases, including diarrhoeal diseases, schistosomiasis, filariasis, trachoma and helminths" (WHO & UNICEF, 2004, p. 7). The increased risk of close link between the risk of infectious diseases as a result of a lack of safe water, hygiene and sanitation services disproportionately affects sub-Saharan Africa (UN ESC, 2017). Figure 9 illustrates historical

trends for the percentage of the population with access to improved sanitation services. Improved sanitation services implies unshared, generally onsite sanitation services with proper waste disposal and treatment. Qualitative descriptions of the pathways are as follows.

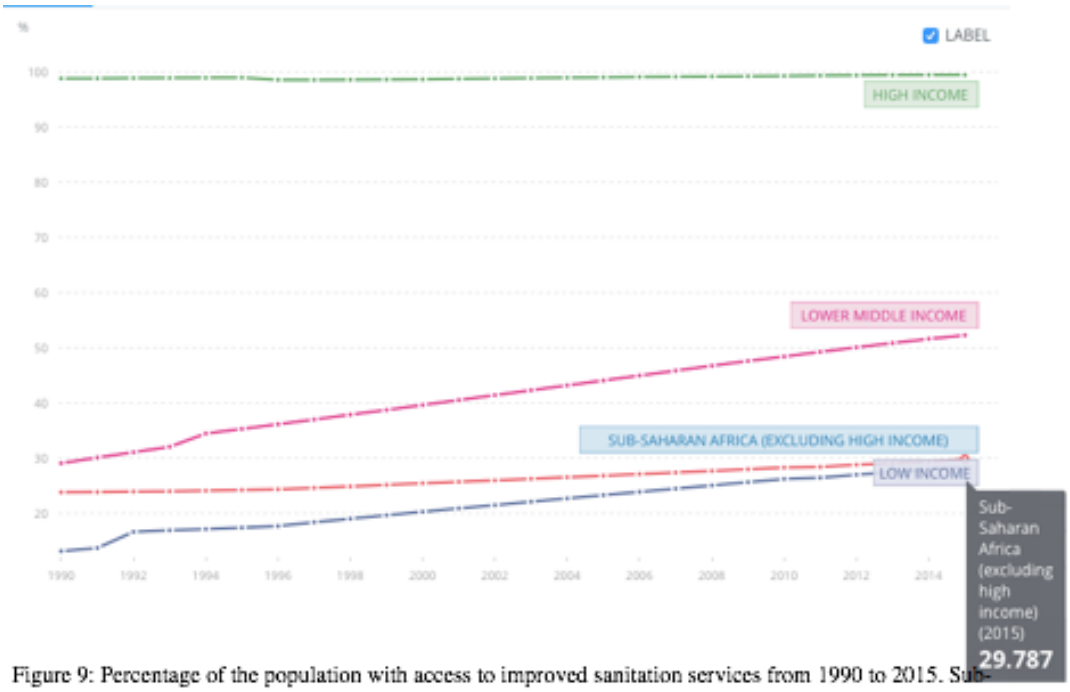


Figure 9: Percentage of the population with access to improved sanitation services from 1990 to 2015. Sub-Saharan Africa (red), low income countries (blue), lower-middle income (pink) and high income countries (green). Results generated through the World Bank Group Data (2018).

High pathway: Rapid improvement, where the majority (>70%) of the population have access to safe and adequate sanitation services. Overall conditions are described as follows: There is a safely managed level of service for drinking water, facilities, and hygiene. On premise, clean and safe water sources are available, with improved and unshared facilities with proper transportation and treatment of waste. In addition there is hand washing and hygiene services available. There is effective disease control, and risk factor for water borne diseases is controlled. In line with the SDG for sustainability, there is an end to open defecation.

Medium pathway: Steady improvement, where half the population has access to safe and adequate sanitation. Overall conditions are described as follows: Drinking water sources are safe and available in closer proximity, less than 30 minutes round trip, resulting in a basic service level There is a transition from limited sanitary facilities such as shared facilities between households, to more basic service with facilities in each household. Portions of the population have limited availability of hygiene services such as soap and water (WHO & UNICEF, 2017). There are still concerns over controlling the risk of infectious diseases, however disease control is improved.

Low pathway: Slow improvement, where only a small portion (30-40%) of the population have access to safe and adequate sanitation. Countries will not meet the Sustainable Development

Goals for sanitation - goal 6. Drinking water sources are from unimproved sources such as unprotected wells, or surface water directly from rivers, lakes or streams. There is continued open defecation in some areas, and overall unimproved services, defined as the "use of pit latrines without a slab or platform, hanging latrines or bucket latrines" (WHO & UNICEF, 2017, p. 8). There is no hand washing facility to support hygiene. As a result of the limited level of sanitation services there is an increased risk for the spread of infectious disease, and poor control for disease vectors.

2.2.11 Technology Transfer

A Special Report from the IPCC on "Methodological and Technological Issues in Technology Transfer" defined technology transfer as "a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions" (Metz et al., 2000, p. 3). The technology being adopted will equip the recipient Lower Income or Lower Middle Income country with tools to address complex problems, through means previously unavailable to them (Rogers, 1983). The IPCC defines the five stages of technology transfer to be 1. Assessment; 2. Agreement; 3. Implementation; 4. Evaluation; 5. Adjustment and Replication (Metz et al., 2000). Literature is in a constant state of flux in determining the effectiveness of technology transfer, and defining indicators to determine the success of transfers in frequency and quality. In order for a new technology to be successful it must be applicable to the recipient country's needs. Africa's LICs and LMCs face challenges in terms of adapting and implementing technologies as a result of their limited infrastructure. In some cases, the recipient countries are receiving technologies they didn't ask for, or don't even need, with developed nations failing to understand the local conditions or evaluate the applicability of the transferred technology. Given this background, qualitative descriptions for pathways of technology transfer for Africa's LICs and LMCs are as follows.

High pathway: There is "rapid and widespread transfer and implementation of technologies" (Metz et al., 2000, p. 3). The transfers are broad and effective in scope, targeting a broad array of development issues, to improve human capacity, improve institutions, frameworks, and networks, and utilizing hardware technologies adapted to local needs (IPCC, 2000). There is sustained use of technology (Rogers, 2010), with multiple technologies being transferred.

Medium pathway: There is steady-paced technology transfer taking place but it is limited in scope. There is a focus on acquiring the technology, and less of an emphasis on the implementation and adaptation of the technology. As such there are cases of discontinued use, limited and isolated adoption of technologies (Rogers, 2010), and not all transfers meet the local needs of the adopting country.

Low pathway: There is slow-paced technology transfer taking place with finite success. Countries are in the early stages of identifying particular areas of need for a technology transfer (Metz et al., 2000). The countries are working through the decision-making process, however there is little collaboration taking place. The few transfers that take place result in rejection, or false starts.

Chapter 3: Research Method

3.1 Research Framework and Design

This research will evaluate the relationships between socioeconomic descriptors using a new scenario analytic technique called cross-impact balances (Weimer-Jehle, 2006), to evaluate the challenges to climate change mitigation and adaptation in Africa's low and lower-middle-income countries. According to the IPCC (2014C); "a comprehensive assessment of climate policies involves going beyond a focus on mitigation and adaptation policies alone to examine development pathways more broadly, along with their determinants" (p. 5). This research builds on recent progress in the climate change research community by augmenting versions of global Socioeconomic Pathways by elaborating them at a more localized level to examine challenges to adaptation and mitigation in a sub-global context. A main goal of this research is to determine and assess different internally consistent combinations of socioeconomic trends for Africa's low and lower-middle-income countries in the context of sustainable development. This knowledge will further our understanding of the challenges and opportunities related to mitigation strategies and adaptation efforts, while shedding light on the conditions that may promote progressive development trajectories. Further research can determine where these scenarios are situated in regard to the degree at which they present challenges to adaptation and mitigation (O'Neill et al. 2013).

The results of this research will contribute to a larger body of research and knowledge regarding climate change scenarios. Through the Cross Impact Balance analysis method, which will be discussed in detail in this section, this research will yield plausible future scenarios for Africa's LICs and LMCs that provide an illustration of the consistent configurations of descriptor states. This research is considering a set of socioeconomic conditions for scenarios that are not always included together, but characterize a society's composition and dictate their human systems' ability to adapt and mitigate climate change. These scenarios will be distinguished based on their development trends to determine the role of key outcomes in promoting development and assess the human dimensions of climate risk. The production of these internally consistent scenarios will enable examination of "trends in social, economic, and environmental development" (O'Neill et al., 2013, p. 388).

3.2 Method: Cross Impact Balance Analysis

Cross-impact balance (CIB) analysis is a relatively new qualitative research method, developed in the early 2000s and based on previous Cross Impact methods (Weimer-Jehle, 2006). Cross Impact Balance Analysis (CIB) is a form of qualitative system research used to derive plausible illustrations of future developments (Weimer-Jehle, 2010). This method has already been applied in numerous research fields including climate change emission scenarios, energy sustainability, obesity prevention, among others (Weimer-Jehle, 2014). CIB is used in multidisciplinary studies characterized by many interacting factors, such is the case with this study, as we aim to understand the interactions between descriptors to determine which combinations lead to

plausible future developments. CIB is particularly useful for the derivation of these plausible future developments, in combining outcomes to create scenarios. CIB is employed to find these possible scenarios, and test the likelihood of their occurrence to "provide a rough and yet consistent illustration of the basic development possibilities for an area" (Weimer-Jehle, 2010, p. 1). This is particularly useful in policy-making and planning for both short and long term development.

CIB has been chosen as the main research method for this study given its unique ability to assess multitudinous interactions taking place between descriptors to determine which combinations are most consistent, and rank them based on this internal consistency or level of plausibility. The CIB analysis provides a quantitative check for the qualitative nature of a number of the socioeconomic determinants (Weimer-Jehle, 2010). CIB will likely only grow in real world application, as the understanding and appreciation of complexity in multidisciplinary systems continues to strengthen.

3.2.1 Brief History:

Cross impact balance analysis was developed by Wolfgang Weimer-Jehle in 2001. CIB is based on Cross-Impact Analysis which was created in the early 1960s, and documented by Gordon and Hayward (1968). Both the method of Cross Impact Balance Analysis and its corresponding software, Scenario Wizard were created in the early 2000s. Further adjustments took place over the course of seven years from 2004 to 2011(Weimer-Jehle, 2014). The timespan saw one of the development institutes involved, ZIRN, the Interdisciplinary Research Unit of Risk Governance and Sustainable Technology Development, merge with ZIRIUS, who now serve as the current keepers of the software and method. Wolfgang Weimer-Jehle remains the leading force behind this method, working on the software and method through his role at ZIRIUS. CIB illustrates multiple plausible future developments, based on internal consistency, previous models on the other hand focused on probability (Weimer-Jehle, 2006). This was the case to reflect the uncertainty of future conditions, and assist decision makers with a wide scope of possibilities. CIB arrives at similar end results but through a more branched structure of possibilities determined by the impact balance (Weimer-Jehle, 2006).

3.2.2 Uses and Applications:

Cross Impact Balance analysis is applied in the construction of scenarios (Weimer-Jehle, 2014). Scenarios are extremely useful tools for long term planning and decision making. They involve careful consideration of a multitude of factors from different fields, as represented in the Figure 10 below of a multidisciplinary system. To date there have been a number of research projects carried out using CIB as the methodology. These applications can be housed in areas of waste, sustainability, climate change, health, energy, societal change, innovation, education and water. Examples of specific projects include drug shortage scenarios, innovation studies, sustainability indicators, emission consequences, among others. Wolfgang Weimer-Jehle the developer of CIB

analysis, and ZIRIUS, the Stuttgart Research Center for Interdisciplinary Risk and Innovation Studies in Germany document research applications on the CIB website (http://www.cross-impact.de/index.htm) which serves as a tool to inform researchers on the method, and support collaboration amongst applicants.

The scenarios generated from CIB analysis aim to be holistic and reflect various combinations obtainable from the system descriptors (Weimer-Jehle, 2014). "It is characterized by an easy-to-understand procedure, transparency, and high flexibility in application and evaluation" (Weimer-Jehle, 2016, p. 8). The analysis can theoretically be retraced by another research, as the process is completely traceable. Through the use of CIB Analysis, the expert panel and research team are able to gain a greater appreciation and deeper understanding of the system being investigated. This enables the researcher to formulate a bigger picture and clearer understanding of the influence patterns, from what was a complex system with numerous interacting descriptors (Weimer-Jehle, 2014). Furthermore, the comprehensive analysis can yield surprising scenario combinations (Weimer-Jehle, 2010), that may have otherwise not been considered through alternative methods such as genius forecasting or intuitive logistics.

The ability of this method to synthesize large amounts of important information and interpret results to illustrate interactions is particularly useful in these multidisciplinary systems list above (Weimer-Jehle, 2014). Despite the recent conception of this method, it has been applied in numerous research fields, and in many projects. The ability for CIB to understand qualitative systems and generate comprehensive illustrations of the system under study is immeasurable (Weimer-Jehle, 2010). Multidisciplinary systems can present many challenges as a result of their complexity and interconnectedness (Weimer-Jehle, 2009). The user friendliness of this method enables researchers without extensive mathematics backgrounds to apply this method and ensures widespread usage across disciplines (Weimer-Jehle, 2010). Through the real-world application process feedback is generated and taken into consideration for future updates and modifications to the CIB software, Scenario Wizard.

3.2.3 Defining Cross Impact Balance Analysis:

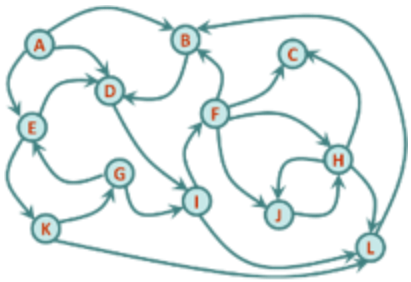


Figure 10: Impact relations diagram. http://www.cross-impact.de/english/CIB_e_Alg.htm

CIB "is characterized by an easy-to-understand procedure, transparency, and high flexibility in application and evaluation." (Weimer-Jehle, 2016, p. 8). As a form of scenario analysis, CIB processes different combinations of system factor states to create potential illustrations of future developments, to determine their plausibility or likelihood (Weimer-Jehle, 2014). CIB depicts the relationships between identified factors in an impact network, as illustrated in the multidisciplinary system of Figure 10 (Weimer-Jehle, 2014).

Figure 10 shows the system nodes represented in a multidisciplinary system. Each factor is given a letter, A to L and the arrows depict the interactions; with the line extending influence from A to E, or K to L, etc. CIB takes this information and analyses the impact network. The interactions can be mutually influential, or one directional (Weimer-Jehle, 2014). These same nodes illustrated in the above Figure 9, are plotted as descriptors in the CIB matrix. Examples of descriptors for an environmental system could be "whether a certain environmental indicator is likely to rise, stagnate, or fall" (Weimer-Jehle, 2010, p. 6), for example atmospheric carbon concentrations. Qualitative judgements are passed on each descriptor and the influence on one another. This information informs potential scenarios, in which CIB software is able to scan "all possible combinatorial scenarios" (Weimer-Jehle, 2010, p. 5) to determine which ones are non-contradictory, that is to say consistent.

"CIB is particularly useful when conducting analysis which, owing to their disciplinary heterogeneity and the relevance of "soft" system knowledge, do not permit the application of quantitative prognosis models and yet remain too complex for intuitive system analysis" (Weimer-Jehle, 2010, p. 1). The qualitative systems being studied through CIB are characterized as involving many interactions. The research process will be explored in further detail, and each step will be defined in the following sections.

Cross Impact Balance Analysis has been chosen as the main research method for this study, due to its ability to support the analysis of interacting influences taking place in a system. The system in question for this research is the LIC and LMCs in Africa, and the system factors are the 11 socioeconomic descriptors identified by experts listed in Section 2.6 Socioeconomic Determinants. The CIB analysis enables the evaluation of the system factor interactions taking place, to determine combinations of factor trends that are probable in future scenarios. These scenarios can inform research on the impacts of future trends in socioeconomic descriptors, and their influence in managing climate change, and in more advanced research; ultimately present opportunities to better understand the threats of climate change to both human and natural systems.

The research area and system under question presents qualitative and quantitative aspects, with many socioeconomic descriptors inherently qualitative. With 11 interacting socioeconomic descriptors however, there is a high degree of complexity preventing simple intuitive analysis (Weimer-Jehle, 2010). The CIB approach will enable these influences to be represented and accounted for. In addition, hypothetical scenarios will be tested to determine if they are consistent or contradictory. Socioeconomic determinants represent important drivers of climate change emulating from our social/societal function. The 11 selected descriptors are most relevant to Africa's low and lower-middle income countries, whose development status is low. Given the complexity amongst these factors, and the qualitative information represented, CIB can serve as a quantitative check to determine the consistency of plausible scenarios (Weimer-Jehle, 2010).

That is to say, determine given varying socioeconomic conditions, what future conditions could resemble, and in future research; our climate policy now and into the future can respond to such future scenarios. “CIB offers an opportunity for qualitative systems analysis without complex mathematics” (Weimer-Jehle, 2009, p. 1).

Figure 11:Descriptor List

1) Population
2) Income per capita
3) Agricultural Productivity
4) Urbanization
5) Extreme Poverty
6) Quality of Healthcare
7) Water Stress
8) Educational Attainment
9) Quality of Governance
10) Access to Sanitation
11) Technology Transfer

3.3 Research Process:

The Cross Impact Balance Analysis process involves a succession of several important steps. Following the identification of the research question and the system under study, the research team assembles a panel of experts well versed on the system being studied. The expert panel should cover the full depth and breadth of knowledge relevant to the particular system under question, and understanding of influences networks on the system. (Weimer-Jehle, 2014). In the case of this research, the study is building off of the global SSP research undertaken by Schweizer and O’Neill (2014). The system was identified as Low Income and Lower Middle Income countries through their study, and was refined to focus in on this country grouping within Africa for this particular research. The necessity for expert knowledge requirements can be supplemented and or fulfilled through extensive literature review (Schweizer & Kriegler, 2012). In the case of this thesis, it is building off the initial expert consultation undertaken by Schweizer and O’Neill (2014), and will be further supplemented through a literature review.

Following the assemblage of an expert panel, the next step in the research process involves the preparation of a list of system descriptors.“The expert panel prepares a list of the most important system factors ("descriptors") and compiles all available information on the expected future evolution of the descriptors” (Weimer-Jehle, 2016, p. 9). Figure 11 lists this study’s descriptors. “Variables that comprise a scenario in CIB analysis are called descriptors. Specific outcomes that descriptors can take are called descriptor states.” (Schweizer & Kriegler, 2012, p. 3). In any multidisciplinary system there are a suite of factors interacting and exerting influence on other factors. These descriptors build the foundation for Cross Impact Balance Analysis and the construct of the Cross Impact Matrix.

Figure 12: Descriptor States

1) Population
   - High
   - Medium
   - Low
2) Income per capita
   - High
   - Medium
   - Low
3) Agricultural Productivity
   - High
   - Medium
   - Low
4) Urbanization
   - Rural
   - Moderate Paced Planned
   - Rapid Paced Planned
   - Rapid Unplanned
5) Extreme Poverty
   - High
   - Medium
   - Low
6) Quality of Healthcare
   - High
   - Medium
   - Low
7) Water Stress
   - High
   - Medium
   - Low
8) Educational Attainment
   - High
   - Medium
   - Low
9) Quality of Governance
   - High
   - Medium
   - Low
10) Access to Sanitation
   - High
   - Medium
   - Low
11) Technology Transfer
   - High
   - Medium
   - Low

For this research, the system and factors were defined through a combination of expert consultation

and extensive literature review. The system factors were identified through expert consultation carried out in the survey process lead by Schweizer and O'Neill (2014). There were a number of adjustments carried out to render the system factors more appropriate to the system, and the descriptor states were determined through extensive literature review and analysis of historical figures from the World Bank database, and supplemental literature.

Each descriptor from the system will have corresponding states, as featured in Figure 12. These states show pathways for the descriptors future evolution based on historical information. Depending on the descriptor in the system, the state could be a numerical measure, or a qualitative state. For 10 of the descriptors the corresponding states are; low, medium, and high. Urbanization features four states; rural, moderate paced planned urbanization, rapid planned urbanization, and rapid unplanned urbanization. Literature was gathered on each of the descriptors. This research informs the analysis on interdependencies between descriptors. Using a qualitative judgment scale, cross impact judgments were expressed on the influence of these interdependencies. The qualitative judgement scale has a corresponding integer scale. The Figure #13 (Weimer-Jehle, 2014) shows the scale from +3 to -3 with varying levels of influence, varying from "strongly promoting influence," to "no influence," to "strongly restricting influence" (Weimer-Jehle, 2014). The literature review was designed to cover extensive knowledge of the descriptors, what they influence, and how they are influenced. Based on the information gathered in this review, cross-impact judgements were applied. For each of the descriptor states, in relation to each of the other descriptor states, a judgement and corresponding number from this scale was applied. The rule of standardization was executed which implies that the sum of each judgement group (refer to Figure 17) equals 0. "This convention expresses that promoting influences towards one state restricts respective opposites" (Weimer-Jehle, 2016, p. 120).

Figure 13: Judgement Scale
-3: strongly restricting influence
-2: moderately restricting influence
-1: weakly restricting influence
0: no influence
+1: weakly promoting influence
+2: moderately promoting influence
+3: strongly promoting influence

These judgements are all imputed/input into the cross impact matrix to calculate the significance of the interaction, and the internal consistency of scenarios. Together all of these judgements create an impact network.

The influence map (Figure 14) shows the influence patterns in the system. The row exerts influence on the column. For example, the column of population receives influence from six descriptors, as represented by the point on the diagram. The column for population receives influence from Income, urbanization, poverty, health, education, and governance. Reading across the row for population, this descriptor exerts influence on three descriptors; income, poverty, and water scarcity.

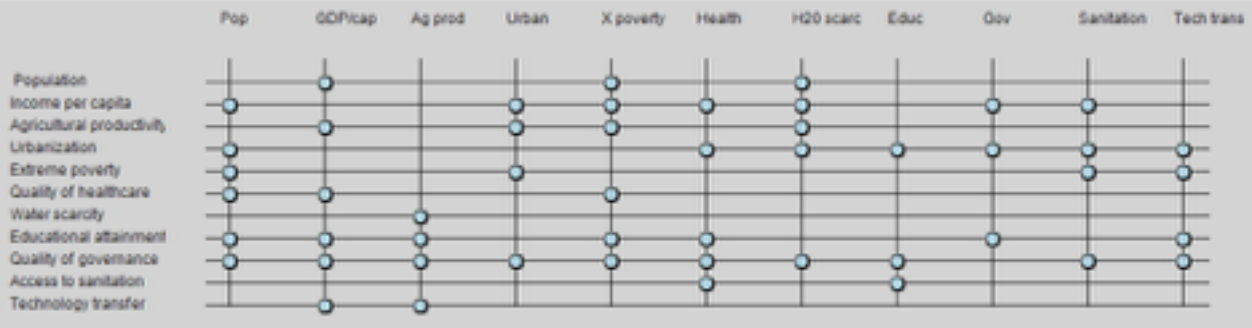


Figure 14: Influence Map. The dots plotted in this diagram indicate a direct influence. The row exerts the influence to the column.

3.4 Translating Literature into Numerical Judgements

Impacts on: Population		Income per capita		Agricultural Productivity		Urbanization	
Income per capita	X	Population	X	Population		Population	
Agricultural productivity		Agricultural productivity	X	Income per capita		Income per capita	X
Urbanization	X	Urbanization		Urbanization		Agricultural productivity	X
Extreme poverty	X	Extreme poverty		Extreme poverty		Extreme poverty	X
Quality of healthcare	X	Quality of healthcare	X	Quality of healthcare		Quality of healthcare	
Water scarcity		Water scarcity		Water scarcity	X	Water scarcity	
Educational attainment	X	Educational attainment	X	Educational attainment	X	Educational attainment	
Quality of governance	X	Quality of governance	X	Quality of governance	X	Quality of governance	X
Access to sanitation		Access to sanitation		Access to sanitation		Access to sanitation	
Technology transfer		Technology transfer	X	Technology transfer	X	Technology transfer	

Impacts on: Extreme Poverty		Quality of Healthcare		Water Scarcity		Educational Attainment	
Population	X	Population		Population	X	Population	
Income per capita	X	Income per capita	X	Income per capita	X	Income per capita	
Agricultural productivity	X	Agricultural productivity		Agricultural productivity	X	Agricultural productivity	
Urbanization		Urbanization	X	Urbanization	X	Urbanization	X
Quality of healthcare	X	Extreme poverty		Extreme poverty		Extreme poverty	
Water scarcity		Water scarcity		Quality of healthcare		Quality of healthcare	
Educational attainment	X	Educational attainment	X	Educational attainment		Water scarcity	
Quality of governance	X	Quality of governance	X	Quality of governance	X	Quality of governance	X
Access to sanitation		Access to sanitation	X	Access to sanitation		Access to sanitation	X
Technology transfer		Technology transfer		Technology transfer		Technology transfer	

Impacts on: Quality of Governance		Access to Sanitation		Technology Transfer	
Population		Population		Population	
Income per capita	X	Income per capita	X	Income per capita	
Agricultural productivity		Agricultural productivity		Agricultural productivity	
Urbanization	X	Urbanization	X	Urbanization	X
Extreme poverty		Extreme poverty	X	Extreme poverty	X
Quality of healthcare		Quality of healthcare		Quality of healthcare	
Water scarcity		Water scarcity		Water scarcity	
Educational attainment	X	Educational attainment		Educational attainment	X
Access to sanitation		Quality of governance	X	Quality of governance	X
Technology transfer		Technology transfer		Access to sanitation	

Figure 15: Influence Map List. The X represents a direct influence on the descriptor column.

An extensive literature review was undertaken to understand the direct influences from one descriptor to another. The literature review began with an analysis of the IPCC Fifth Assessment Working Group Two section on Impacts, Adaptation and Vulnerability, regional chapter on Africa. Referenced literature from this report along with reports from UNICEF, the United Nations, the World Bank, and the World Health Organization were then studied to extract key statements attesting to direct relationships between descriptors. Some descriptors exert a weak influence onto another descriptor, while others exert a strong influence. The literature review extracted only direct influences, as the indirect influences are accounted for through the CIB analysis processes. The numerical judgement was determined based on the information obtained in a literature excerpt, and in overall literature consensus from more than one author. Quality of governance exerts a direct influence on all the descriptors in the network, while technology transfer and water scarcity influence only a small number of descriptors. A full overview of literature excerpts corresponding to each direct influence represented in Figure 15 can be found in the Appendix.

	Pop		
	L	M	H
Educational attainment			
Low	-2	-1	3
Medium	-1	1	0
High	1	1	-2

Figure 16: Cross Impact Balance Matrix Judgement Section

The following is an example of the translation of literature into numerical judgements. There is substantial evidence in literature to support the direct influence between educational attainment and population. The United Nations Department of Economic and Social Affairs (2003) report on Population, Education and Development cites education "as a strategy to curb population growth" (UN DESA, 2003, p. 9), and continues to say "evidence confirms that education has a major impact on the level of fertility, especially in developing countries" (UN DESA, 2003, p. 34). With this particular relationship there was an abundance of literature attesting to the direct relationship. In interpreting the following quote "the spread of education throughout a population has been shown to be of central importance for the long-term demographic transition from high to low levels of fertility" (UN DESA, 2003, p. 1), a +3 for strongly promoting influence was applied for low education to high population, and a -2 to represent the moderately restricting influence from high education to

high population. Additional quotes support -2 moderate restricting, and -1 weakly restricting to balance out the low educational attainment judgement group. This quote further supports the relationship; "educational differentials in the mean ideal number of children are greatest in sub-Saharan Africa, where women with no education desire to have 2 children more than women with a secondary or higher education, on average." (UN DESA, 2003, p. 33). This high educational attainment judgement group features weaker influences to population than the low state, as literature pointed to a stronger impact from low education influencing high population. This particular descriptor relationship featured a high degree of consensus in literature, and was largely informed from UN Population, Education, and Development Report (2003).

The key quotes extract from literature for all direct descriptor relationships were analyzed, interpreted, and translated into numerical judgements corresponding to the CIB judgement scale (+3 to -3). These judgements populate the Cross Impact Matrix.

3.5 Cross Impact Matrix

The cross impact matrix acts as a database housing all cross impact judgements between descriptor states. The matrix itself represents the system; Africa's LICs and LMCs. The 11 socioeconomic descriptors are listed, on the x axis as columns and the y axis as rows. Each descriptor will also feature columns and rows for the associated states (Low, Medium, High). With the descriptors and corresponding states defined, the judgements can be imputed/input into the matrix. The numerical judgements that are inputed/input represent direct influences determined through the extensive literature review. The values are solely direct influences, as indirect influences are captured through the cross impact analysis. In the matrix, the row indicates the source of the impact, and the column represents the descriptor receiving the influence (Weimer-Jehle, 2016).

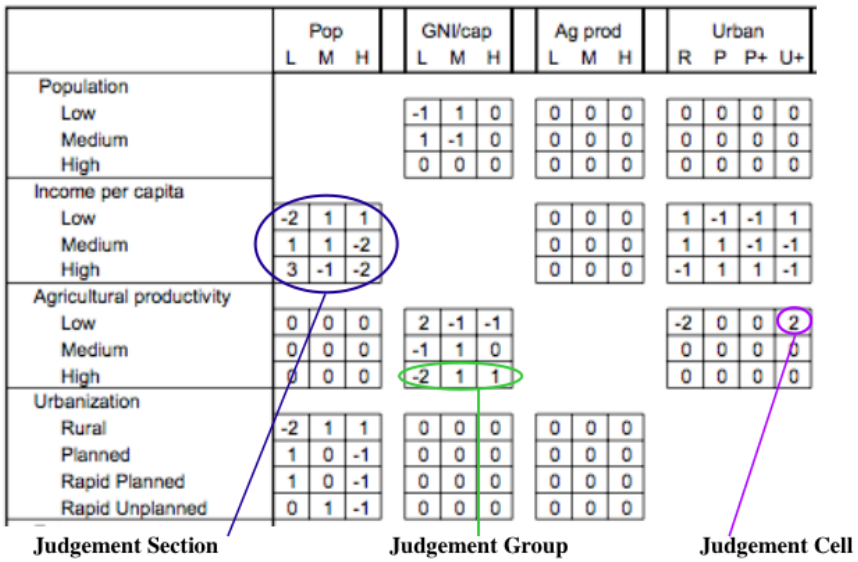


Figure 17: Labelled Cross Impact Balance Matrix featuring four of the eleven descriptors.

Ultimately, the analysis of the cross-impact network will generate numerous possible scenarios based on the socioeconomic descriptors of the system. Using the number of descriptors and descriptor states the total number of possible combinations equals: 3x3x3x4x3x3x3x3x3x3x3= 236,196. This comprehensive analysis can yield surprising scenario combinations (Weimer-Jehle, 2010) that may have otherwise not been considered through genius forecasting or intuitive logics. One of the most relevant advantages comes from the check for internally consistent scenarios. Of the possible 236,196 possible combinations of descriptor states, CIB scores them based on their consistency (Schweizer & O'Neill, 2014), that is to say their plausibility for future development. This information supports a foundation for the development of suitable strategies and responses to a particular system. In terms of the input of bias in the scenario analysis, "the assertion of prejudices, the pursuit of hidden agendas, and the proposal of tactical judgements that aim to produce specific result is made more difficult" (Weimer-Jehle, 2010, p. 8). Lastly, the ability for CIB to understand qualitative systems, and generate comprehensive illustrations of the system under study is immeasurable (Weimer-Jehle, 2010). The CIB analysis enables the researcher to view the influence pattern of one determinant on another (Schweizer & O'Neill, 2014). In a particularly complex system, this information is vital for scenario generation and understanding the role of descriptors in influencing outcomes.

The following page features the completed cross impact matrix with all judgements.

	Pop L	Pop M	Pop H	GNI/cap L	GNI/cap M	GNI/cap H	Ag prod L	Ag prod M	Ag prod H	Urban R	Urban P	Urban P+	Urban U+	X poverty L	X poverty M	X poverty H
Population																
Low				-1	1	0	0	0	0	0	0	0	0	1	0	-1
Medium				1	-1	0	0	0	0	0	0	0	0	-1	0	1
High				0	0	0	0	0	0	0	0	0	0	-2	1	1
Income per capita																
Low	-2	1	1				0	0	0	1	-1	-1	1	-2	-1	3
Medium	1	1	-2				0	0	0	1	1	-1	-1	0	1	-1
High	3	-1	-2				0	0	0	-1	1	1	-1	2	1	-3
Agricultural productivity																
Low	0	0	0	2	-1	-1				-2	0	0	2	-3	1	2
Medium	0	0	0	-1	1	0				0	0	0	0	0	1	-1
High	0	0	0	-2	1	1				0	0	0	0	2	0	-2
Urbanization																
Rural	-2	1	1	0	0	0	0	0	0					0	0	0
Planned	1	0	-1	0	0	0	0	0	0					0	0	0
Rapid Planned	1	0	-1	0	0	0	0	0	0					0	0	0
Rapid Unplanned	0	1	-1	0	0	0	0	0	0					0	0	0
Extreme poverty																
Low	1	0	-1	0	0	0	0	0	0	0	0	0	0			
Medium	-1	0	1	0	0	0	0	0	0	0	0	0	0			
High	-3	1	2	0	0	0	0	0	0	0	-1	-1	2			
Quality of healthcare																
Low	-1	1	0	3	-1	-2	0	0	0	0	0	0	0	-1	0	1
Medium	1	-1	0	1	0	-1	0	0	0	0	0	0	0	0	0	0
High	2	-1	-1	-3	1	2	0	0	0	0	0	0	0	1	0	-1
Water scarcity																
Low	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	1	1	-2	0	0	0	0	0	0	0
High	0	0	0	0	0	0	2	1	-3	0	0	0	0	0	0	0
Educational attainment																
Low	-2	-1	3	3	-1	-2	1	0	-1	0	0	0	0	-2	1	1
Medium	-1	1	0	-2	1	1	0	1	-1	0	0	0	0	1	0	-1
High	1	1	-2	-3	1	2	-2	0	2	0	0	0	0	1	1	-2
Quality of governance																
Low	0	0	0	2	-1	-1	1	0	-1	2	-2	-2	2	-3	1	2
Medium	0	0	0	-2	1	1	1	-1	0	1	1	1	-3	1	0	-1
High	2	-1	-1	-3	1	2	-2	1	1	1	1	1	-3	2	0	-2
Access to sanitation																
Low	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technology transfer																
Low	0	0	0	2	-1	-1	2	-1	-1	0	0	0	0	0	0	0
Medium	0	0	0	-1	1	0	-1	1	0	0	0	0	0	0	0	0
High	0	0	0	-1	0	1	-1	-1	2	0	0	0	0	0	0	0
			v	v			v						v			v
Balance:	-8	3	5	12	-5	-7	6	0	-6	1	-4	-4	7	-13	3	10

	Health L	Health M	Health H	H20 scarc L	H20 scarc M	H20 scarc H	Educ L	Educ M	Educ H	Gov L	Gov M	Gov H	Sanitation L	Sanitation M	Sanitation H	Tech trans L	Tech trans M	Tech trans H
Population																		
Low	0	0	0	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	-1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Income per capita																		
Low	1	0	-1	1	0	-1	0	0	0	0	0	0	2	-1	-1	0	0	0
Medium	-1	0	1	-1	1	0	0	0	0	-1	1	0	-1	0	1	0	0	0
High	-2	1	1	-1	0	1	0	0	0	-2	1	1	-3	1	2	0	0	0
Agricultural productivity																		
Low	0	0	0	1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	-1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	-2	-1	3	0	0	0	0	0	0	0	0	0	0	0	0
Urbanization																		
Rural	0	0	0	1	0	-1	1	0	-1	0	0	0	1	0	-1	1	0	-1
Planned	-2	1	1	-1	1	0	-1	0	1	-1	0	1	-2	1	1	-2	1	1
Rapid Planned	-1	0	1	-2	1	1	-1	0	1	-1	0	1	-2	1	1	-3	1	2
Rapid Unplanned	0	0	0	0	1	-1	0	0	0	0	0	0	3	-1	-2	0	1	-1
Extreme poverty																		
Low	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	1	1
Medium	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	0	-1	1	0
High	0	0	0	0	0	0	0	0	0	0	0	0	2	-1	-1	1	-1	0
Quality of healthcare																		
Low				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
High				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water scarcity																		
Low	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0
Educational attainment																		
Low	3	-1	-2	0	0	0				3	-1	-2	0	0	0	3	-1	-2
Medium	-2	1	1	0	0	0				-1	1	0	0	0	0	-1	1	0
High	-3	1	2	0	0	0				-2	1	1	0	0	0	-3	1	2
Quality of governance																		
Low	2	-1	-1	-1	0	1	2	-1	-1				2	0	-2	2	0	-2
Medium	-1	1	0	1	0	-1	1	0	-1				-1	1	0	-1	1	0
High	-2	0	2	2	-1	-1	-2	0	2				-3	1	2	-2	-1	3
Access to sanitation																		
Low	3	-1	-2	0	0	0	2	-1	-1	0	0	0				0	0	0
Medium	0	1	-1	0	0	0	0	1	-1	0	0	0				0	0	0
High	-3	1	2	0	0	0	-2	1	1	0	0	0				0	0	0
Technology transfer																		
Low	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Medium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
High	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	v					v	v			v			v			v		
Balance:	9	-3	-6	0	0	0	4	-2	-2	3	-1	-2	9	-3	-6	6	-1	-5

Figure 18: Scenario 3 complete Cross Impact Matrix. The highlighted rows indicate the descriptor state featured in this self-consistent scenario.

3.6 Internal Consistency:

"The benefit of the Cross-Impact matrix is that it helps to check all system states by enumeration if they are self-consistent (i.e. not contradictory) in the sense of the established understanding of the system. The check of a system state ("scenario") takes place in two steps which investigate the double role of the descriptors as source and target of influences. Scenarios that do not contain contradictions between both perspectives are then accepted as valid." (Weimer-Jehle, 2006, p. 340). If a scenario proves to be inconsistent it is rejected. "The CIB principle of consistency formalises the terms plausibility and consistency to the extent that they can be automated using a computer program," (Weimer-Jehle, 2010, p. 5).

The impact balance at the bottom of the matrix calculates the balances based on the qualitative judgements contained within the matrix, for the scenario under question. The rows highlighted in the matrix below are the scenario being tested. The CIB algorithm contained with the Scenario Wizard software is able to test every possible scenario combination, and calculate the impact score, to determine which scenarios are most consistent (Weimer-Jehle, 2014). The impact score at the bottom, contains arrows at the top representing the scenario assumption, this is the same as the combination of factors highlighted in the matrix. The bottom arrows point to the highest impact score. If all the arrows match up, that is to say the scenario assumption corresponds with the highest impact score, the scenario is internally consistent. The impact score numbers are calculated only from the judgements from the descriptors within the scenario assumption being tested, and not the entire matrix.

Table 5: Bias Statistics

Descriptor	Low	Medium	High
Population	45.6%	42.3%	25%
Income per capita	35.5%	41.4%	43.1%
Agricultural Productivity	50.6%	40.7%	23.5%
Extreme Poverty	27.7%	60.4%	24.6%
Quality of Healthcare	28.1%	42%	50.6%
Water Scarcity	31.2%	35.8%	55.2%
Educational Attainment	47.2%	27.8%	41.7%
Quality of Governance	33.3%	58.3%	55.6%
Access to Sanitation	47.2%	28.7%	47.2%
Technology Transfer	22.2%	50%	40.7%

Table 6: Urbanization Bias Statistics

	Rural	Planned	Rapid Planned	Rapid Unplanned
Urbanization	51.9%	44.4%	27.2%	35.8%

3.7 Bias Statistics:

The cross impact balance analysis features bias statistics as a tool to show the probability of a descriptor state. "A descriptor is biased if the maximum impact score of a randomly chosen scenario is assigned more frequently to some descriptor variants than to others" (Weimer-Jehle, 2016, p. 78). A biased descriptor is determined by the cross-impact judgements in the column of the particular descriptor and corresponding state. "The bias statistics indicate how often a descriptor variant reaches the maximum score when all possible scenarios are applied to the descriptor," (Weimer-Jehle, 2016, p. 78). Ideally the frequencies are as close to equal

as possible across the descriptor states. Across the descriptor states however, the percentage likelihood of a particular state occurring can vary. Across descriptor states, the bias statistics can exceed a total of 100%. Equal percentages across descriptor states are not always possible, as the descriptor state interactions make some states more likely than others. The frequencies are illustrated in Table 5. The highest percentage belongs to medium extreme poverty at 60.4%, and the lowest percentage stands at 22.2% for low technology transfer.

According to Weimer-Jehle the creator of Cross Impact Balance analysis, "moderate bias statistics is nearly inevitable and tolerable" (Weimer-Jehle, 2016, p. 78), however "strong bias and forbidden variants should motivate to reconsider the respective descriptor judgements" Weimer-Jehle, 2016, p. 78). In reviewing early bias statistics some adjustments were made to the matrix in response to low bias statistics for rapid planned urbanization, low and high extreme poverty, and medium educational attainment. Special attention was paid specifically to descriptor states below 20%. "In extreme cases an unfavourable choice of judgments may completely disable a descriptor variant ("forbidden variant"), no matter how the cross-impact in the other descriptor columns are chosen" (78). There were no forbidden states that feature a 0% statistic.

Traditional CIB studies involve the expert panel in the final stage of the research process reviewing and evaluating the results. In the case of this research project, the results will be reviewed by the research team. The findings of this study and the internally consistent scenarios will be discussed in detail in the following chapter.

Chapter 4: Analysis and Findings

4.1 Discussion of Internally Consistent Scenarios:

Cross Impact Balance (CIB) analysis examines this study's impact network by evaluating the relationships between factors to construct consistent images of plausible descriptor combinations (Weimer-Jehle, 2016). These plausible scenarios are "the consistent configurations of the impact network" (Weimer-Jehle, 2016, p. 9) generated through the CIB algorithm. These consistent scenarios "reflect the systemic balance of influences of the network including all indirect effects and provide a set of plausible future system states" (Weimer-Jehle, 2016, p. 9). In being consistent and plausible, the scenarios are free of internal inconsistencies. The consistent states are determined by the maximum impact score, which captures the total sum of all influences promoting this state, caused by other descriptors. These combinations of descriptor states are plausible and free of inconsistencies that would render them unlikely or not possible. The CIB analysis is able to analyze and quantify the influence network to evaluate the direct influences of one descriptor to another, and the indirect influences at play to determine combinations that are logical. A more technical discussion of the CIB calculations can be found in Weimer-Jehle 2006 and 2009. In this system under study, there are eleven total descriptors, with 10 of the 11 featuring 3 descriptor states, and one descriptor (Urbanization) featuring four descriptor states. Of the 236,196 possible configurations, the nine consistent scenarios will be examined in detail in this section.

4.2 Preliminary Analysis of consistent scenarios

The initial analysis began with categorizing the 9 consistent scenarios according to population pathways. Across the nine consistent scenarios there are three high population scenarios, one medium population, and five low population. Starting with the high population scenarios, these three scenarios are named the Status Quo - Demographic Trap scenarios, where development status remains low. These three scenarios are characterized by the demographic trap whereby key development indicators such as healthcare, sanitation, and educational attainment remain low, with subsequent high extreme poverty, preventing improvements to agricultural productivity and income per capita. The low status of these socioeconomic descriptors contributes to high population and rapid unplanned urbanization, which in turn reinforces the low development conditions. These scenarios highlight the demographic trap. The three high population scenarios share similarities in all descriptor states, with the exception of water scarcity. The results show that Africa's LICs and LMCs status quo - low development pathways remains internally consistent under low, medium and high water scarcity pathways. This result is somewhat surprising, but is in line with scholarly findings referencing the socioeconomic dimensions of water scarcity. Literature suggests that Africa's overall water scarcity can be low when development is stifled, as countries do not have proper water infrastructure to support safe access to water for all citizens, leading to relatively low scarcity. Additional factors however, can lead

to increased levels of water scarcity as referenced in scenario 2 and 3 at the medium and high states.

Scenario 6 is the only medium population scenario. This scenario is classified as a Rural Development scenario. There are medium projections for descriptors such as governance, educational attainment, and income per capita. Under this rural state there is high quality of healthcare and high access to sanitation. This shift in progress for the descriptors in these scenarios could indicate the role of sanitation and quality of healthcare in acting as a stepping stones for development. This scenario features medium population as a result of the rural lifestyle that tends to promote larger family sizes to help with the primarily agrarian lifestyle.

There are a total of five low population scenarios. The low population scenarios 4, 5, and 7 illustrate a steady development progression, with scenarios 8 and 9 representing high income outcomes. Starting with scenario 4, there is low population under planned urbanization with medium states for all other descriptors with the exception of extreme poverty which is low. As the scenarios progress, scenario 5 and 7 illustrates a shift in a number of descriptors from medium to high states. Both these scenarios feature planned urbanization and low extreme poverty, with scenario 5 featuring high quality of healthcare and high sanitation, and then educational attainment shifting from medium in scenario 5 to high in scenario 7. This progress across these key descriptors is indicative of their role in promoting sustained development, and acting as a stepping stone for medium pathways to move to high pathways for the remaining descriptors in scenarios 8 and 9.

Scenarios 8 and 9 represent high income scenarios where there is low population, low extreme poverty, and high levels for the remaining descriptor states. This scenario is the ideal situation, where there is low population, and development status has been achieved across the descriptors, with conditions resembling those of high income developed nations. These scenarios have varying urbanization states, with scenario 8 along the planned urbanization pathway, and scenario 9 featuring rapid planned urbanization.

This section breaks down the outcomes for each internally consistent scenario.

4.3 High Population Scenarios:

Scenario No. 1,2,3 Status Quo - Demographic Trap

Total impact score: 69 (Scenario 1), 70 (Scenario 2), 71 (Scenario 3)

Scenario 1: Status Quo - Demographic Trap illustrates a scenario with the LICs and LMCs in Africa further lagging behind the rest of the world. They are caught in a demographic trap of extreme poverty, low educational attainment, and low quality of governance, promoting high population, and no improvements to developmental conditions. There is low agricultural productivity, as a result of limited technology transfer, encouraging low income per capita, and stagnate development. This trap is most strongly influenced by low educational attainment and low quality of governance, exerting a total influence on system descriptors of +17 and +14 respectively. These particular descriptors promote the stability of the network, with quality of governance exerting influence on every descriptor in this scenario except for the high population pathway, so it comes as no surprise that it exerts the strongest total influence.

Table 7: Scenarios 1,2,3 Status Quo - Demographic Trap

Population	High
Income per capita	Low
Agricultural productivity	Low
Urbanization	Rapid Unplanned
Extreme poverty	High
Quality of healthcare	Low
Water scarcity	Low, Medium, High outcomes
Educational attainment	Low
Quality of governance	Low
Access to sanitation	Low
Technology transfer	Low

This low pathway for quality of governance is characterized by corruption, violence, poor regulatory quality, and a lack of stability. This poor quality of governance hinders progress across the board especially in key areas such as income per capita, educational attainment, health, and sanitation, among others. With a lower percentage of the population having undertaken post primary schooling, it prevent reductions in population growth, stifling potential growth in income, and severely hindering improvements to healthcare, among impacts on other descriptors including agriculture, technology transfer, and quality of governance. The low level for educational attainment encourages low income per capita, and low agricultural productivity, key pieces to economic growth. The influence of low education strongly encourages high population growth (+3), low quality of governance (+3), and low technology transfer (+3). Low educational attainment also stifles development progress in key areas, as it encourages low quality of healthcare, and extreme poverty directly. Low income per capita (+9), low agricultural productivity (+7), high extreme poverty (+7) additionally contribute high influences across the network and prevent countries from exiting the demographic trap and achieving progress in healthcare, sanitation, and technology transfer. It is clear through the direct influences, and indirect influences captured in the matrix that there is a strong mutually reinforcing relationship taking place, that each descriptor is promoting the low state of the next, and so forth, further stalling development, and encouraging the demographic trap.

The outcome of low educational attainment, which appears to be a key anchoring descriptor, is made possible by a trend of low quality of governance and low access to sanitation. Poor access

to sanitation, clean drinking water, and hygiene limits a child's access to education, and ability to succeed as a result of increase in exposure to waterborne diseases. Literature references "for children living without access to sanitation or clean drinking water they are more likely to fall ill with a parasite or waterborne disease, which in turn prevent them from being able to attend school" (Ortiz-Correa et al., 2016). Furthermore, for girls in particular, they are often required to travel great distances to acquire water for the family, which prevents them from attending school and succeeding in education. "Estimates suggest that access to water and sanitation services has a positive and significant effect on schooling when measured by the completed number of school years" (Ortiz-Correa, 2016, p. 31).

Quality of governance exerts influence across the matrix, as is observed in the literature review and society. The low quality of governance with corruption and violence, prevents important development progress and encourages low agricultural productivity directly, while also promoting low technology transfer, and with minimal improvements in technology, agricultural productivity is further slowed. Low quality of governance also promotes low sanitation, an important indicator of development. Low sanitation is also promoted strongly by rapid unplanned urbanization, which is characterized by people living in informal settlements also commonly referred to as slums. There are poor living conditions with a lack of sanitation services resulting in open defection, contaminated water sources, and increases in health threats from the spread of diseases and parasites. These conditions feature poor sanitation services, and contaminated water sources. Low sanitation has far reaching impacts in development, encouraging low quality of healthcare, and as previously mentioned; low educational attainment, as children can fall ill from waterborne diseases, and unsafe drinking water. For the impact of low sanitation to healthcare literature suggests; "Poor sanitation is responsible for one of the heaviest existing disease burdens worldwide" (Van Minh & Nguyen-Viet, 2011, p. 64). Furthermore, looking specifically at the under-five mortality rate that is used to define quality of healthcare, literature finds; "the water and sanitation-related health burden for children under five in Africa, for instance, is up to 240 times higher than it is in high-income countries" (Cheru, 2005, p. 4-5).

This demographic trap scenario, involves development conditions remaining stagnant, with high population, encouraging extreme poverty, rapid unplanned urbanization, and low access to sanitation, further reinforcing the low educational attainment that promotes high population to persist. It should become apparent in later scenarios that higher pathways and thus progress in the above key descriptors will likely kickstart improvements in other descriptors and shift development from this demographic trap to more sustained development.

Scenario No. 2 Status Quo Demographic Trap - Medium Water Scarcity

In Scenario 2, the influences are the same as those outlined in Scenario 1 however water scarcity is under the medium pathway. Under this medium pathway, low agricultural productivity (-1) somewhat restricts, while rapid unplanned urbanization (+1) somewhat promotes medium water scarcity, resulting in a zero for the total impact score of this pathway. Both the low and the high pathway have the same impact score which is why they are both plausible pathways given this combination of descriptor states.

Scenario No. 3 Status Quo Demographic Trap - High Water Scarcity

For Scenario 3, all descriptor states remain the same as those in scenarios 1 and 2, but there is now high water scarcity. The promoting influences for this state are high population (+1) as slightly promoting the pathway, and low quality of governance (+1). Low income per capita (-1) and rapid unplanned urbanization (-1) are somewhat restricting the high pathway. We end up with 0 as our total impact score.

4.4 Medium Population Scenario

The shift from high population scenarios 1,2,3, to the only medium population scenario, features a change from the low pathway to the medium pathways for most descriptors. Urbanization shifts from rapid unplanned to rural urbanization, with this being the only rural scenario. Literature suggests that urbanization patterns across the world are trending toward urban living, however Africa at this point in time Africa remains a primarily rural continent, with only 40% of the population residing in urban centres (UN DESA, 2014). Under this rural scenario there are two high pathways with both quality of healthcare and access to sanitation at high states. This finding could indicate that sanitation infrastructure and quality healthcare may be essential to achieve and maintain development progress in Africa's LICs and LMCs under rural conditions.

Table 8: Scenario 6 Rural Development

Population	Medium
Income per capita	Medium
Agricultural productivity	Medium
Urbanization	Rural
Extreme poverty	Medium
Quality of healthcare	High
Water scarcity	Medium
Educational attainment	Medium
Quality of governance	Medium
Access to sanitation	High
Technology transfer	Medium

Scenario No. 6 Rural Development

Total impact score: 24

This medium population pathway is promoted by the rural conditions which tend to encourage larger family sizes as a result of the agrarian lifestyle often associated with rural living. Furthermore, rural populations tend to be less aware of contraception (Arouri et al., 2014, p. 6) and as such birth rates trend higher in rural settings. Medium income per capita in turn is promoted by the influence of improved agricultural productivity along the medium pathway, furthermore the

influence of improved technology transfer also boosts income per capita and promotes agricultural productivity.

There are two high pathways, first the high sanitation pathway influenced by medium income per capita and restricted by the rural pathway, resulting in a 0 impact score. The high sanitation pathway influences high quality of healthcare (+2) as people have access to hygiene services and clean water which improves overall health and helps to stop the spread of diseases. "In cities and neighborhoods well served by piped water and sanitation, child mortality rate are generally around 10 per 1,000 live births. On the other hand, in cities and neighborhoods with inadequate provision of water and sanitation, mortality rates are commonly 10 to 20 times higher" (Shi, 2000; Woldemichael, 2000:207-227). Furthermore, there is proper waste management with sanitation services, ensuring that waste does not come in contact with people or water, which additionally helps to control waterborne diseases. This improved access to hygiene and sanitation, as well as closer proximity to clean drinking water promotes medium educational attainment (+1). "Estimates suggest that access to water and sanitation services has a positive and significant effect on schooling when measured by the completed number of school years" (Ortiz-Correa, 2016, p. 31). As well with clean water available on site or close to homes, females are able to attend school more regularly. "Women and girls are responsible for water collection in 8 out of 10 households with water off premises, so reducing the population with limited drinking water services will have a strong gender impact." (WHO & UNICEF, 2017, p. 11) In addition to being influenced by sanitation, quality of healthcare receives further influence from medium income per capita, and medium educational attainment. For education, literature suggests; "of the socio-economic variables that have been found to be associated with differentials in health and mortality, education is among the strongest and the most consistent. Wherever the relationship has been examined, better-educated people and their family members appear to stay healthier and to live longer lives." (UN DESA, 2003, p. 52).

This scenario illustrates a plausible future in which the population remains predominantly rural, with medium population growth, and strong improvements to key development descriptors including high pathways for healthcare and sanitation. With medium conditions across the other descriptors, with strong influence coming from quality of governance, educational attainment, and income per capita, this scenario emerges as a Rural Development future.

4.5 Low Population Scenarios: 4, 5 and 7

Scenario No. 4 Eradication of Extreme Poverty

Total impact score: 30

Table 9: Scenario 4 Eradication of Extreme Poverty

Population	Low
Income per capita	Medium
Agricultural productivity	Medium
Urbanization	Planned
Extreme poverty	Low
Quality of healthcare	Medium
Water scarcity	Medium
Educational attainment	Medium
Quality of governance	Medium
Access to sanitation	Medium
Technology transfer	Medium

Scenario 4 features consistent development progress for each of the descriptors with medium pathways for all except population (low), extreme poverty (low) and urbanization (planned). Compared to the Status Quo - Development Trap scenario, this scenario of low extreme poverty and low population growth features steady improvements to all descriptor states, shifting away from the low development, to a path of progress and growth. The notable development progress in this scenario features a mutually reinforcing relationship driven by improvements in key socioeconomic descriptors such as educational attainment and income per capita, leading to low population.

Low population is a key indicator for development progress. Literature suggests "high fertility reinforces poverty and makes an escape from poverty more difficult" (Sinding, 2009, p. 3025). Therefore, with lower fertility rates, reductions in poverty are more likely. In addition to the influence from low population, extreme poverty is influenced by medium educational attainment, and medium quality of governance. These three influencing descriptors are very important in development progress. With low population, there are fewer children for a family to care for which can increase prospects for escaping poverty (Sinding, 2009). Improved stability in government enables proper poverty reduction strategies, and increased rates of post-primary schooling for the population along the medium education pathway supports better job prospects.

Increases in agricultural productivity and progress in technology transfer, both along medium pathways promote growth in income per capita. Medium quality of governance, and medium educational attainment provide additional influence to income growth. There is also a mutually reinforcing relationship for low population to medium income per capita. Low population improves income growth, just as the growth in income along the medium pathway encourage reductions in fertility rates. Medium water scarcity, and medium technology transfer, encourage the medium state for agricultural productivity. Technology has an important role in promoting agricultural productivity. "Although farmers usually have rich knowledge of local conditions and valuable practical knowledge or experience of how best to successfully exploit their environment, they require innovation information generated from research and development to boost their productivity (Apata, 2010)" (Okpachu, 2014, p. 26). Improved educational attainment along the medium pathway also promote accelerated agricultural productivity, which is stated in

literature as education supports literacy and productive capabilities in adapting to changing conditions in agriculture and adopting new innovative agricultural practices.

The planned urbanization pathway is promoted by medium income per capita and medium quality of governance, as "policies that favor city dwellers - can push rural residents to cities" (Bloom, Canning & Fink, 2008). The importance of quality of governance is continuously present across scenarios, and in this situation in the promotion of planned urbanization. As referenced in literature, "weak local government creates and exacerbates problems including the lack of appropriate regulatory structures and mandates; poor or no planning" (Niang et al., 2014, p. 1225), furthermore large-scale cities require complex management systems and active government participation (Arouri et al., 2014).

Water scarcity is not a key piece in this scenario, the medium pathway is promoted by increased income per capita along the medium pathway, and planned urbanization which is characterized by an increased concentration of people in urban areas which "challenge(s) the sustainability of resources by decreasing water supply or increasing demand" (Jimenez-Cisneros et al., 2014, p. 234).

Educational attainment is an important influence across this impact network. Medium educational attainment contributes a total impact score of +5 across descriptors in this scenario, and -1 in restricting medium population. Medium educational attainment however is only influenced by medium sanitation in this particular scenario. In terms of direct influence, the role of increased access to sanitation services in integral to encouraging higher rates of post-primary schooling. Medium quality of governance represents a strong descriptor influence, like educational attainment, and is promoted by educational attainment and income per capita. Dryden-Peterson et al., (2014) find that higher levels of educational attainment contribute to three important elements of good governance: "voice and accountability, control of corruption, and political instability and violence." There is a clear relationship at play between educational attainment, quality of governance and income per capita descriptors, and they exert significant influence across scenarios promoting positive development outcomes. This role will be discussed further in Chapter 5.

Scenario No. 5 Standard of Living Development

Total impact score: 34

Scenario 5 is a low population scenario where considerable progress is experienced on the path towards development. Population, extreme poverty, and planned urbanization remain the same as scenario 4, but in this scenario there is advancement in descriptor states from medium to high for access to sanitation and quality of healthcare. The low population pathway remains low as a result of consistent income per capita, along the medium pathway, as well as planned urbanization, low extreme poverty, and it is now more strongly promoted by the influence of

high quality of healthcare. This influence of healthcare to low population is a result of specifically female reproductive health as referenced in this quote from corresponding literature; "in the fields of reproductive health and female education, will have strong direct and indirect effects on future population trends, mostly in the direction of lower population growth" (Abel et al., 2016, p. 14294)Enhanced quality of healthcare along the high pathway further contributes to promoting medium income per capita, and maintaining low extreme poverty. With higher healthcare outcomes there is less extreme poverty, as referenced in literature; "health improvements are disproportionately beneficial for the poor, as they depend on their labor power more than any other segment of the population" (Bloom & Canning 2000, p. 1207). The onset of high access to sanitation promotes high quality of healthcare (+2), and medium educational attainment. The influence of sanitation on education will be discussed in greater detail in the following scenario. The development progression at play in this scenario suggests there may be value in prioritizing the elimination of extreme poverty, improving access to and quality of healthcare, in addition to ensuring access to sanitation. These three descriptors play an important role in ensuring development in the LICs and LMCs in Africa. The result of low extreme poverty, high access to sanitation, and high quality of healthcare suggests this scenario depicts the achievement of poverty eradication. Medium income per capita and low extreme poverty indicates the overall population is able to support themselves in achieving their basic needs. The high pathways for sanitation and healthcare ensure the population has safe access to clean water, quality healthcare, and low parasite prevalence. The next scenario highlights the important influence of educational attainment in this influence network.

Table 10: Scenario 5 Standard of Living Development

Population	Low
Income per capita	Medium
Agricultural productivity	Medium
Urbanization	Planned
Extreme poverty	Low
Quality of healthcare	High
Water scarcity	Medium
Educational attainment	Medium
Quality of governance	Medium
Access to sanitation	High
Technology transfer	Medium

Scenario No. 7 Promoting Human Capital

Total impact score: 36

Scenario 7 is very similar to scenario 5, the only difference here is that educational attainment has shifted from a medium to a high state. With scenario 5 and 7 the total impact score for educational attainment is the same, with both being 1, influenced from access to sanitation. This tie for impact score indicates that high and medium educational attainment are both possible when all else remains equal across the influence network. Sanitation is very important in its influence on education. With improved access to sanitation, clean drinking water, and hygiene services, there is effective disease control ensuring less days missed from school. Furthermore for females in particular they don't need to travel as far for clean water, as the high pathway

Table 11: Scenario 7 Promoting Human Capital

Population	Low
Income per capita	Medium
Agricultural productivity	Medium
Urbanization	Planned
Extreme poverty	Low
Quality of healthcare	High
Water scarcity	Medium
Educational attainment	High
Quality of governance	Medium
Access to sanitation	High
Technology transfer	Medium

represents clean water within 30 minutes round trip. This task is traditionally borne on women, and thus improved services will enhance female participation in school. Across the scenarios and in literature the influence of educational attainment is clear, especially in population, healthcare, governance, income, and poverty, among others. Educational attainment is one of the strongest influences in this system. This scenario result that suggests the importance of educational attainment is encouraging development. There is evidence in literature attesting to the strong influence of this descriptor, and within this network education exerts influence on 6 descriptors.

This scenario is characterized as promoting human capital, as there is a well-educated, healthy, and prosperous population with access to essential services. With gender parity along the high educational attainment outcome, there is greater empowerment amongst the population, and women are given equal access to education, and thus improved prospects. As referenced in the descriptor background section literature indicates; "no society can consider itself truly developed without its citizens' being educated." (UN DESA, 2003, p. 48).

4.5.1 Low Population Scenarios: High-Income Development

Scenarios 8 and 9 represent a high-income development outcome. These scenarios are plausible future pathways for sustained development. Each of these scenarios follow a similar trajectory with a low population pathway, low extreme poverty and high pathways for the remaining socioeconomic descriptors. They are differentiated by their urbanization outcome, with scenario 8 under planned urbanization, and scenario 9 with rapid planned urbanization. The conditions of these scenarios resemble those of current high income developed countries.

Scenarios 8 and 9 feature a well-educated, healthy, and prosperous population, with low fertility rates, transparent government, and promising technological advancements fueling high agricultural productivity. Contrary to scenarios 1,2,3 where Africa's LICs and LMCs were stuck in a demographic trap, where population growth is high, educational attainment is low, income is limited, there is government corruption, and much of the population lives in extreme poverty without access to sanitation or quality healthcare. The high-income outcome illustrated in scenarios 8 and 9 represents a plausible future that is the ideal future for the countries in Africa currently stuck in a demographic trap.

The only difference between scenario 8 and 9 is the urbanization state. Scenario 8 reflects the progress experience by many of today's high-income countries, where moderate paced planned urbanization ensured services and policy could keep pace, and infrastructure could be upgraded to reflect the needs of the people and the area. Scenario 8 remains plausible especially when considering that at this point in time much of Africa remains predominantly rural. However, literature suggests that perhaps scenario 9 along the rapid planned urbanization pathway may be more likely given the strong consensus in literature that urbanization is expected at rapid rates in Africa, with a number of countries expected to double their urban populations by 2050. The results send a cautionary note to Africa's LICs and LMCs that urbanization is expected to be rapid, therefore it is important to follow a planned pathway, and avoid falling into an unplanned trajectory can cause significant development problems.

Scenario No. 8 Sustainable Development - Planned Urbanization

Total impact score: 60

High pathways across the key socioeconomic descriptors of income per capita, quality of governance, quality of healthcare and educational attainment contribute to the sustained low population outcome, and aid in achieving development across the scenario. Income per capita (+3) most strongly influences low population, and quality of governance and quality of healthcare additionally contributing +2 influence each to population. The improved quality of healthcare means that a greater number of infants are surviving, and thus families are able to better plan, and achieve desirable family sizes. Furthermore, quality governance along a high pathway could imply that the government has implemented national programs and strategies to support family planning services and influence smaller family sizes. The impact of high quality of governance is strong throughout scenario 8 and 9, with +2 influence on low population, high income per capita, low extreme poverty, quality of healthcare, educational attainment, and access to sanitation. Furthermore, quality of governance most strongly influences technology transfer (+3), and planned urbanization, agricultural productivity, while slightly restricting high water scarcity (-1) outcome. High income per capita is another highly influential descriptor. With higher levels of income, there is greater access to sanitation as families are able to afford non-shared facilities. Greater income also contributes to improved healthcare, as individuals and families are able to afford medicines and treatments. Lastly, high income

Table 12: Scenario 8 Sustainable Development - Planned Urbanization

Population	Low
Income per capita	High
Agricultural productivity	High
Urbanization	Planned
Extreme poverty	Low
Quality of healthcare	High
Water scarcity	High
Educational attainment	High
Quality of governance	High
Access to sanitation	High
Technology transfer	High

encourages low extreme poverty, given the eradication of extreme poverty in earlier scenarios, there are likely reductions to overall poverty levels with this scenario and the lower population growth.

Scenario No. 9 Sustainable Development - Rapid Planned Urbanization

Total impact score: 62

In this case there is rapid planned urbanization, which is in line with the projections found in the literature suggesting rapid urbanization taking place, but under this assumption there is associated planning involved, and sufficient infrastructure to support the influx of people and the high concentration in city centers. The outcome of rapid planned urbanization is a result of the influence from high income per capita and high quality of governance. This level of urbanization in turn supports high pathways for technology transfer, access to sanitation, quality of governance, educational attainment, quality of healthcare, and low population. The concentration of people in urban areas helps promote improved diffusion of technologies, and increased engagement and participation in governance. Furthermore, there is greater access to education, thus increasing the portion of the population undertaking post-primary schooling. The concentration of people, improves proximity to services such as healthcare, and the associated urban planning ensures safe sanitation services for the majority of the population.

Table 13: Scenario 9 Sustainable Development - Rapid Planned Urbanization

Population	Low
Income per capita	High
Agricultural productivity	High
Urbanization	Rapid Planned
Extreme poverty	Low
Quality of healthcare	High
Water scarcity	High
Educational attainment	High
Quality of governance	High
Access to sanitation	High
Technology transfer	High

The conditions of this scenario resemble those of current high income developed countries with low population, high income, high quality of governance and an educated population. With good access and quality healthcare, and proper access to sanitation there is sustained development. With higher agricultural productivity and high technology transfer, and high income per capita the economy is well set up to adapt to changing circumstances and compete locally and internationally. These development conditions enable the LICs and LMCs of Africa to better cope with climate change impacts, as well as adapt to and prepare for changing conditions.

Chapter 5: Interpretation and Discussion

5.1 Introduction

This study was undertaken with the goal of assessing the human dimensions of climate risk in Africa's Low and Lower-Middle Income Countries. Climate change is a complex issue that will affect natural and human systems alike. Climate change impacts are determined as a result of the intersection between the level of the hazard, and the socioeconomic conditions that characterize the vulnerability of the locale under question. For low income countries, they face a heightened risk to climate change impacts, as a result of their low development status that limits their ability to adapt to changing conditions. Socioeconomic conditions such as high population growth, low income, and low educational attainment stifle a country's ability to progress and ensure the delivery of basic needs to their citizens. The network of socioeconomic conditions that characterize these countries also hold insight into what outcomes should be prioritized to move countries up from the low income status. Analyzing the socioeconomic piece of the human dimensions of climate risk, this research used a set of 11 socioeconomic conditions, specific to the low and lower-middle income countries in Africa, and Cross Impact Balance analysis generated 9 self-consistent scenarios. These self-consistent scenarios indicate possible future conditions for development in Africa's LIC and LMCs. These results shed light on the socioeconomic conditions of plausible future outcomes and provide insight on potential areas for prioritization to promote development and improve countries' ability to cope with changing climatic conditions. This section will further examine the results from chapter 4, drawing connections between the 9 consistent scenarios, and the implications of these results.

5.2 Revisiting the Research Question 1:

The primary objective of this research was to answer the following question:

1. What are plausible combinations of socioeconomic conditions that illustrate possible future scenarios for Africa's Low and Lower-Middle Income countries development?

The following section will revisit the 9 self-consistent scenarios in the context of Africa's LICs and LMCs potential development trajectories, specifically focusing on key variables that emerged through analysis that could be the driving force for an exit out of the demographic trap. Lastly, each scenario will be considered in regard to the degree in which they potentially make adapting to climate change, easier or harder.

5.2.1 Demographic Trap

Africa's LICs and LMCs currently find themselves in conditions similar to the status quo demographic trap situations of scenarios 1,2,3. These self-consistent scenarios feature high population growth, high extreme poverty, rapid unplanned urbanization, and low pathways for the remaining socioeconomic descriptors. This societal composition features high challenges to

climate change adaptation. Rapid unplanned urbanization leads to urban slums and informal settlements that lack proper structure, safety, and access to sanitation services and clean water. Extreme poverty, low income, reduced agricultural productivity, and corruption in low governance promotes these unstable and densely populated settlements, which render populations incredibly vulnerable to the impacts of climate change, including the increased frequency and severity of storms. "Often these slums are located on dangerous sites, highly vulnerable to flooding and other natural disasters" (Cohen, 2009, p. 10). Under these scenarios, the gap between LICs and LMCs to HICs likely continues to widen (O'Neill et al., 2017). These nations face challenges in meeting the needs of their citizens, including the provision of clean drinking water, safe sanitation facilities, quality healthcare, and access to education. The increased vulnerability of people in these countries limits their capacity to adapt to changing conditions, especially extreme conditions that are expected with a changing climate including prolonged periods of drought, heavy precipitation events, and more frequent and dangerous weather events. The perpetuation of these demographic trap scenarios will likely result in very few sustainable development goals being met, particularly those pertaining to sanitation, healthcare, poverty, and education.

From the status quo demographic trap scenarios that characterize average current conditions across Africa's LICs and LMCs, there remains the question of where to go next. Globally there is debate as to how to approach development, or where to target change to move countries out of the demographic trap along a path to sustained development. The question of where to begin varies across literature and amongst global decision-making bodies. The current conditions of the demographic trap can be compared to a tangled web, with each socioeconomic piece represented by a branch; they are interwoven, tangled, and the web is not easily untangled or solved. If you push or pull on one piece, you may be hindering the progress of another. If you fail to account for all the branches of the web, you won't make as much progress, because some components are maintaining the status quo, and others can act as catalysts, but the interconnectedness needs to be considered. If you forget to pour resources into all parts of an interlinked problem, you will not make as much progress as expected on the one you're focusing on because there are other things in the system that keep the status quo in place. Additionally, there may be two components that need to be pursued in tandem, which appears to be the case in this study with sanitation and gender equality in schooling.

The sustainable development goals lay out objectives and timelines, along with strategies to meet these markers, however development is an interdisciplinary system with one facet impacting another, and changes in one area may railroad growth in another or accelerate progress in unexpected areas. These initial low development demographic traps scenarios give insight into what is reinforcing some of these trap trends, such as the role of low quality of governance in holding back progress across the system, and low educational attainment preventing income growth, smaller family sizes, and progress in healthcare and poverty. Just as the status quo low-

development scenarios give insight into some key descriptors that prevent progress, the low population scenarios and higher income results reveal detail about this complex system, and what hidden variables drive progress across the system, and encourage the transition from the demographic trap to sustained development.

5.2.2 Middle Income Development

The low and lower-middle income countries in Africa are looking to transition away from the demographic trap scenarios (1,2,3) to a pathway of growth. The goal for many lower income countries is to progress to become high income prosperous nations, as represented in scenarios 8 and 9. They have an exceedingly long way to go though. A more likely progression across the continuum of country classification according to income, could be to move from the low and lower middle countries, to the middle income or upper-middle income mark. By all means it is possible to leapfrog from LIC or LMC to upper or high income, and some nations have done so. Based on the results of the scenarios, I am led to believe that there may be a sequence that needs to be followed, progressing to middle income, addressing scarcity in resources, and achieving living standards.

From the scenario results, there are four plausible self-consistent scenario combinations that enable progress to middle income nations. Along this continuum of development and income growth, there are possible futures for Africa's LICs and LMCs to progress to middle income nations along both a rural trajectory characterized by medium population growth, and that of a more urban lifestyle with smaller family sizes.

Middle Income Country Scenarios

Scenario 6	Scenario 4	Scenario 5	Scenario 7
Medium Population	Low Population		
Medium Income per Capita			
Medium Agricultural Productivity			
Rural	Moderate Paced Planned Urbanization		
Medium Extreme Poverty	Low Extreme Poverty		
High Quality of Healthcare	Medium Quality of Healthcare	High Quality of Healthcare	
Medium Water Scarcity			
Medium Educational Attainment			High Educational Attainment
Medium Quality of Governance			
High Access to Sanitation	Medium Access to Sanitation	High Access to Sanitation	

Table 14: Tableau of Middle Income Country Scenarios

Scenario 6 - Rural Development illustrates this income growth projection from low income to middle income, with a predominantly rural lifestyle. This scenario features slightly larger family sizes than much of the world. This is likely a result of the focus on agriculture, which is a medium pathway suggesting perhaps there is not necessarily large scale commercial farming, but

steady increases in productivity in family farm holdings and cooperative entities. This scenario indicates a finding that if Africa chooses a path where for cultural or economic reasons, most of their settlements are rural, it is possible to have a stable outcome around these conditions. According to this scenario, progress is made across descriptor states from low to medium, but overall, they follow moderate paced historical patterns of growth. Two descriptors stand out with high states; quality of healthcare and access to sanitation. Improved quality of healthcare, with better maternal health, reductions in under-five mortality, along with access to clean drinking water, and use of safe sanitation services with appropriate waste management highlights key development in this scenario. There are still slightly larger families residing in rural areas but quality living standards are being met with access to sanitation, and the population is of good health overall. This type of scenario is a potential plausible future outcome that sees Africa's growing population slow slightly but with limited urban to rural migration, suggesting development standards can be achieved in a rural setting.

These development standards in healthcare are made possible through influence from medium income per capita, medium educational attainment, and a strong influence from access to sanitation. Higher education levels improve knowledge surrounding healthy practices, "in developing countries, education, especially that of mothers, has been found to significantly differentiate levels of child mortality. In practically all countries, children of uneducated mothers have higher relative risks of dying in early childhood than the children of mothers with primary education" (UN DESA, 2003, p. 37). Todaro & Smith (2012) find the same direct relationship stating that "under-5 mortality rates improve as mothers' education levels rise," (p. 60). This advancement to high healthcare is also influenced through sanitation. "The water and sanitation-related health burden for children under five in Africa, for instance, is up to 240 times higher than it is in high-income countries" (Cheru, 2005, p. 4-5). In terms of the global picture "about 1.7 million people die every year from diarrhoeal diseases, and 90% are children under 5 years, mostly in developing countries. Eighty-eight percent of cases of diarrhoeal diseases worldwide are attributable to unsafe water, inadequate sanitation, and poor hygiene." (Van Minh & Nguyen-Viet, 2011, p. 64). This high sanitation outcome is driven by medium income per capita, and slightly restricted by rural living which tends to be more remote and less densely populated. This outcome of high sanitation under rural living is surprising but possible through increased income. Higher levels of income per capita increase access to sanitation, as individuals are able to afford better facilities such as toilets and water infrastructure (Cheru, 2005). It could be that there is privatized service provision available with increased income, or "point-use technologies, which can be very relevant in rural areas" (Ortiz-Correa et al., 2016, p. 42). This result appears counterintuitive to scholarly findings on the trends in urbanization. This scenario is showing though that according to this influence network, there can be a predominantly rural lifestyle in a middle-income country with high levels of sanitation and healthcare, as long as there is income growth, greater stability in government, and improved education.

With the medium state of quality of governance, there are more improvements to governance than deterioration. With improved stability and better control of corruption, the ability to adapt to climate change is improved from the demographic trap scenarios. Improvements to quality of healthcare, reduced extreme poverty, and better access to sanitation, driven by medium income per capita slightly reduces the human dimension of climate risk, especially in comparison to the demographic trap scenario. This results in moderate challenges to adaptation. The predominantly rural lifestyle will not be immune to climate change impacts, however the challenges to adapting to some impacts may be lessened by rural settlements. Urban areas tend to face higher challenges when dealing with extreme temperatures, as well as major rain events. The rural landscape better promotes increased evaporation and absorption of heavy precipitation, and experiences natural cooling processes much better than urban areas that grapple with the heat island effect. A Zeleňáková et al. (2015) study showed that "climate change increases the number of warm nights in urban areas substantially more than in rural areas" (p. 1172). This improved adaptive capacity regarding some climate change impacts is worth noting, however this study can't speculate the degree in which the challenge level to adaptation changes compared to urban areas, but only on the human dimensions of climate risk characterized by their socioeconomic conditions. We are making an assumption that the rural lifestyle may slightly alleviate some challenges to adaptation.

Scenario 4, 5 and 7 are the additional middle-income scenarios, but with urban living and low population. These outcomes illustrate plausible future scenarios where there is moderate paced urbanization, similar to the growth seen in some of todays developed high income nations, where cities grew at a controllable rate.

Scenario 4 - Eradication of Extreme Poverty takes Africa's LICs and LMCs to the middle-income characterization, but unlike the rural outcome with somewhat larger family sizes, this scenario features low population growth and subsequent smaller family sizes, living in more urban areas. Scenarios 4 is the starting point for three possible planned urbanization outcomes in a middle-income situation. This scenario involves the eradication of extreme poverty. Low extreme poverty is influenced by low population, medium quality of governance and medium educational attainment. There is low extreme poverty, which is influenced by medium quality of governance and medium educational attainment. "With fewer children to care for and raise, families can improve their prospects for escaping the poverty trap." (Sinding, 2009, p. 3030). Small improvements to stability and effectiveness of government, despite inconsistencies and moderate pace, which characterize the medium pathway, have an important influence in curbing poverty and meeting the SDG of eradicating extreme poverty, likely by the 2030 date, or shortly thereafter. This eradication of extreme poverty under these conditions is also influenced by improvements to quality of education along the medium state, where significant progress has been made to promote equal access, and in excess of 60% of children are undertaking post-primary schooling. "Primary education is a potent means of reducing poverty and inequality,

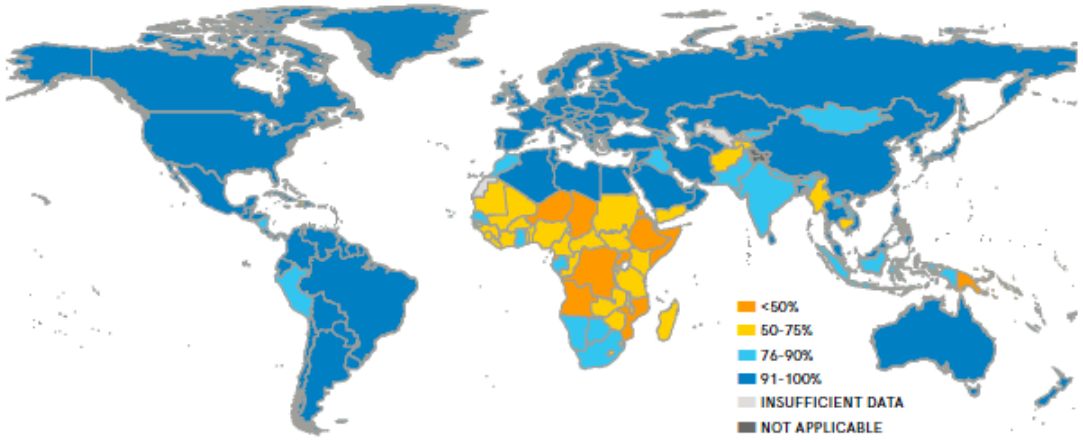
with particularly marked benefits for the poorest segments of society" (UN DESA, 2003, p. 6). The important role of governance and education, may indicate the importance in emphasizing progress in education and governance in order to achieve a subsection of the first sustainable development goal for No Poverty where we "end poverty in all its forms everywhere" (UN GA, 2015, p. 14), specifically goal 1.1 to eradicate extreme poverty. With this middle income scenario overall income per capita is medium, that is to say there is likely still poverty across the board, however with the low extreme poverty outcome, this could be flagging that the tolerance for people with low quality of life has gone down. There is recognized success in having less families living on under $1.90 a day.

This eradication of extreme poverty aids in reducing the challenges to adaptation, but overall development outcomes have not been achieved quite yet in healthcare, education, and sanitation, as they remain at medium states, leaving overall challenges to adaptation as moderate. As referenced in the discussion surrounding the rural lifestyle middle income scenario 6, there are varying challenges to adaptation in the context of rural vs urban. Urbanization does present a challenge to adaptation (Schweizer & O'Neill, 2014), so this may elevate the challenge level.

Scenario 5 - Standard of Living is another scenario that progresses Africa's LICs and LMCs to middle income countries. This progression to middle income countries involves the same low population and eradication of extreme poverty as achieved in Scenario 4, with additional progress across two key descriptors; healthcare and sanitation. This plausible outcome features high pathways for quality of healthcare, and high access to sanitation. High quality of healthcare implies the SDG is met, and the under-five mortality rate continues to decline, along with other health outcomes more closely aligned with those of developed countries. This high healthcare influences continued eradication of extreme poverty, as "health improvements are disproportionately beneficial for the poor, as they depend on their labor power more than any other segment of the population" (Bloom & Canning 200: 1207). The rapid improvement in sanitation ensures the majority of the population has access to sanitation, clean drinking water, and hygiene services. This descriptor is an important piece in the development agenda as it exerts a direct influence on educational attainment, as well as reinforcing high healthcare outcomes. "In cities and neighborhoods well served by piped water and sanitation, child mortality rate are generally around 10 per 1,000 live births" (Cheru, 2005, p. 4-5). As "women and girls are responsible for water collection in 8 out of 10 households with water off premises" (WHO & UNICEF, 2017, p. 11) improving access to sanitation will have a strong impact on promoting schooling and addressing gender equality. This development pathway highlights an emphasis on meeting important living standards in safe access to sanitation and water, along with good healthcare, and well as overall low population growth, in a planned urban setting. This scenario result suggests the potential prioritization of the SDG 3 for Good Health and Well-Being to "Ensure health living and promote well-being for all at all-ages" (UN GA, 2015, p. 14), and SDG 6 for Clean Water and Sanitation to "Ensure availability and sustainable management of water

and sanitation for all" (UN GA, 2015, p. 14). This progress in healthcare and sanitation could indicate their important role in driving development and kick starting progress across this network, particularly in influencing education.

Figure 19: "Proportion of national population using at least basic drinking water services, 2015" (WHO & UNICEF, 2017;3).



In the tangled web of Africa's demographic trap, the results of this scenario could indicate the importance of addressing healthcare and sanitation. Sanitation is a piece of the development puzzle that can often be overlooked. For developed nations, sanitation services have been available to the majority of the population for generations. The technology already exists. This scenario outcome, and the influence sanitation has on education and healthcare, could indicate its value in this system.

Education has long been regarded as a valuable tool for human and societal development and is considered to be one of the most important tools for development. These results are showing that sanitation is behind the scenes supporting the success in education, particularly in the achievement of gender equality. Promoting gender parity in education is important given that "globally, sub-Saharan Africa has the largest gender disparities in education" (UNFPA, 2016, p. 37). The use of CIB analysis enables a full overview of the system (Africa's LICs and LMCs), revealing details about the complexity, and tracing indirect influences. The network influences across the system indicate that education is a powerful influencer on other descriptors, and education is driven by progress in sanitation. Often donor countries can have models for development plans based on their experiences, but what CIB reveals for this particular system are results showing that the value of sanitation cannot be discounted. "The World Health Organization estimates that every $1 invested in better access to water and sanitation can re-present returns ranging from $4 to $12. In addition to the economic returns of these investments, the access to such services is essential for the realization of human rights for all" (Ortiz-Correa et al., 2016, p. 31). The inequality in access to clean water and sanitation leads to inequality in

health and education in two ways, first children in particular become more prone to contracting waterborne diseases, impacting their health and ability to attend school, as well as health concerns associated with dehydration. Second, "children may end up spending more time collecting, hauling, and taking care of water and sewerage storage than attending school or preparing homework" (Ortiz-Correa, 2016, p. 32). On the health front, "better hygiene and safer excreta disposal have a bigger impact on health than improved drinking water alone" (Ortiz-Correa at al., 2016, p. 33). In fact, child mortality is one of the socioeconomic conditions most strongly affected by improved access to sanitation and water. The evidence in literature is reinforced in this scenario, and throughout the scenarios that show development improves. In comparing the system to a complex tangled web, the results are suggesting you can't necessarily unravel the situation without ensuring focus on sanitation.

The progression of sanitation and healthcare to high pathways also plays an important role in reducing the vulnerability of the population to adverse effects of climate change. A healthy population is better able to adapt and cope with fluctuations in climate and weather, helping to reduce the challenge to climate change adaptation. Climate change is expected to impact disease control, therefore by limiting the spread of water-borne diseases in this scenario and encouraging proper hygiene there is a reduced vulnerability to future increases in disease vectors. Improving the standards of living for people and promoting their human capital improves their ability to prepare for impacts, cope and respond. Healthier adults are more productive, ad take better care of their children, and contribute to healthier societies which are proven to foster more dynamic economies (Ortiz-Correa et al., 2016). Looking at the system as a whole there are still challenges to adaptation, but this scenario is shifting from moderate challenges to a lower challenge level.

Scenario 7 - Promoting Human Capital is the final plausible middle-income development outcome. It builds on the progress seen in Scenarios 4 and 5 with additional development advancements in education up to the high pathway. This suggests reason to emphasize the 4th SDG for Quality Education to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (UN GA, 2015, p. 14), along with the aforementioned prioritization areas from the above scenarios, with special consideration for sanitation as it drives education in this network. Education is an important descriptor in this system as it impacts seven descriptors across the network. What emerges in this scenario as was the case for Scenario 5 is the importance to what is driving the changing variable (education). There is ample literature attesting to the influence of education to other descriptors such as, population, income, agriculture, poverty, the success of technology transfer, and healthcare practices, and governance. For population, "educational differentials in the mean ideal number of children are greatest in sub-Saharan Africa, where women with no education desire to have 2 children more than women with a secondary or higher education, on average" (UN, 2003, p. 33). Furthermore, sub-Saharan Africa also has the greatest differentials in contraceptive use by education. For education's influence on income; "learning builds up dynamic capabilities which are key drivers

of catching up and economic development" (Salazar-Xirinachs, Nübler and Kozul-Wright, 2014, p. 2). A 2002 study by Psacharopoulos and Patrinos found through extensive literature review on countries of all development stages, that the average private return from education to be around 27%. A Okpachu et al. (2014) study on the impact of education on agricultural productivity, with examples from Nigeria cited that "one of the major problems facing Agricultural productivity in Nigeria is illiteracy. This has over the years posed great challenges to Agricultural development as well as productivity" (Okpachu et al., 2014, p. 26). The benefits of education to reducing poverty, in addition "education is associated with lower mortality and better health in virtually all contexts, regardless of educational philosophy and orientation" (UN DESA, 2003, p. 50). Dryden-Peterson et al., (2014) find that higher levels of educational attainment contribute to three important elements of good governance: "voice and accountability, control of corruption, and political instability and violence." Lastly, "education is linked with the greater diffusion of information" (UN DESA, 2003, p. 6) which is critical to the success of technology transfer.

The reverse relationship, however, in regard to what is driving education is less clear in literature. For this particular scenario, there are only three descriptors that influence educational attainment; sanitation, quality of governance, and planned urbanization. This scenario is suggesting the Quality Education SDG should be a priority, however this should not be done without giving equal consideration to the driving forces behind education; sanitation, governance, urbanization, and income. With sanitation as a key piece not to be overlooked. Sanitation can often be a bit more of a hidden variable to development, but through the progression in these scenarios and its particular influence on education discussed in greater detail in scenario 5, it appears that throughout this network, not just in this scenario that sanitation is an anchoring piece to the development of the LICs and LMCs of Africa.

The emphasis on promoting human capital in this scenario with low extreme poverty, low population and high pathways for healthcare, sanitation and education are incredibly important for development. Human capital "encompasses the notion that there are investments in people (e.g., education, training, health) and that these investments increase an individual's productivity" (Goldin, 2014, p. 1). Increasing the productivity, skills, and resources of the population could be a very favourable future development trajectory for Africa's LICs and LMCs as a Middle Income country. The overall challenge level to climate change adaptation is similar to Scenario 5, with continued reductions in the challenges to adaptation with a greater percentage of the population being educated, with equal access and gender parity. An educated population reduces vulnerability and improves adaptive capacity, as they are better equipped with knowledge, tools, and skills to cope with changing conditions and understand individual level adaptive strategies, or emergency responses.

5.2.3 High-Income Scenarios

Progressing along the development continuum from the current demographic trap scenarios that characterize Africa's LICs and LMCs, to development progress as middle income nations, the remaining two scenarios are illustrations of high income developed countries. The high outcome for technology transfer suggests both improved adaptation and mitigation prospects, but high agricultural productivity may suggest higher emissions and thus greater challenges to mitigation. On the adaptation front however, the high quality of governance, with an absence of violence, overall political stability, and significant control for corruption aids in the adaptive capacity of the system, and the reduced level of challenges to adaptation. High water scarcity that literature suggests is likely to be a growing concern, and a current predicament for a number of nations in Africa already, does present a higher challenge to adaptation. The significant progress in income, technology, governance, along with low poverty, and the high states for education, health, and sanitation, better equip the system to deal with climate change impacts reducing the challenge to adaptation. The level of urbanization, in particular the rapid planned urbanization for Scenario 11, will heighten risk and impact the capacity to adapt though.

These scenarios represent high income development outcomes where standards of living have been achieved, there is political stability, economic growth, an educated population, and continued technology transfer. This is a stable outcome, and a plausible future scenario for our system, however these scenarios would involve considerable progress in all facets of the network to take the majority of our study site's individual countries to reach this type of outcome.

5.3 Revisiting Research Question 2

2. What are the socioeconomic conditions that can pull Africa out of the demographic trap?

The analysis of the 9 self-consistent scenarios showcase the importance of a number of key socioeconomic conditions. The prominent role of sanitation across the scenarios underlines its role in promoting improvements to education and healthcare, and its anchoring role in shifting the system from the low-income status. Healthcare is another important socioeconomic descriptor underpinning potential middle-income scenario outcomes. The value of a healthy population cannot be understated in terms of economic value, and development. Lastly, quality of governance and quality of education are two highly influential descriptors in that they exert strong influence on a number of other system descriptors, particularly in reducing extreme poverty. The prominent role of these descriptors suggests potential areas of prioritization for the Sustainable Development Goals.

5.4 Research Implications

The 9 self-consistent scenarios provide an illustration into plausible future conditions, and in comparing the progress from demographic trap scenarios that mirror current conditions of continued stagnation, to high income scenarios with different styles of urbanization, we can map

the influence patterns taking place, and learn about hidden variables in international development. The results generated in this research have indicated potential areas for prioritization. It is not a foregone conclusion that by following these steps, these countries will become high income nations, but if Africa's LICs and LMCs want to transition away from low income status, these could be steps or areas to prioritize.

When considering the 17 sustainable development goals of the United Nations, the scenario outcomes for scenarios 4, 5 and 7 suggest potential prioritization to accelerate progress towards sustained development. It is evident that these socioeconomic descriptors, along with the sustainable development goals, do not exist in isolation. There is an interconnected network with many interacting factors exerting direct and indirect influence on descriptors across the system. In the development progress across scenarios, particularly the middle income scenarios, the achievement of a low extreme poverty pathway suggests the need to prioritize poverty reduction measures. Specifically, in this network, educational attainment and quality of governance are driving forces behind this result. For SDGs related to poverty, these results suggest ensuring equal access to quality education is part of these reduction strategies (UN DESA, 2003), along with building government stability and preventing corruption, and reducing population. "High fertility makes poverty reduction more difficult and less likely" (Sinding, 2009, p. 3025). Pushing on poverty and pouring funds and resources into poverty strategies without proper consideration for the driving forces behind it, can limit the effectiveness.

The additional areas for prioritization in line with the SDGs, is the focus on the third goal for Good Health and Well-Being to "Ensure healthy living and promote well-being for all at all ages" (UN GA, 2015, p. 14), and the 6th goal for Clean Water and Sanitation to "Ensure availability and sustainable management of water and sanitation for all" (UN GA, 2015, p. 14). The scenario results suggest that the focus on improving human capital and achieving desirable living standards are two key areas in this influence network, both in their direct and indirect roles across the system. Furthermore, the 4th SDG for Quality Education to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (UN GA, 2015, p. 14) is another target area for promoting development across the system. This area for prioritization cannot be targeted in isolation, as it requires progress in sanitation in order to be effective, as well as stability and quality in government. Sanitation is integral in ensuring gender parity in the education goals.

This research enables better understanding of the complexity of our system and the branches in the tangled web of underdevelopment. In approaching development progress, these results suggest focusing time, resources, and funds to a number of key priority areas. A better understanding of the unique development dynamics in Africa's LICs and LMCs, which account for a large portion of the world's developing nations, can aid in delivering appropriate policy,

specific to Africa's needs in socioeconomic development. This study could additionally be replicated at a country specific scale to gain greater insight at a more local level.

5.5 Limitations and Caveats

5.5.1 Descriptor Relevance

The complexity of the system under study unsurprisingly faces limitations. The descriptors chosen for this study were initially determined through Schweizer and O'Neill (2014) and were determined in the context of the World's Low Income and Lower-Middle Income countries. In the process of refining the descriptor definitions to best reflect conditions in Africa, and pathways forward, it was difficult to account for all the features of some descriptors. Gender is not explicitly captured, but rather housed with educational attainment. Arguably it could be part of a number of descriptors including health, poverty and income to ensure gender parity is being considered. Gender could have also been considered as its own unique descriptor.

Parasite prevalence was another important piece not explicitly captured but paired with sanitation given the relationship between clean and safe sanitation and drinking water to disease control. This particular element could have also been housed in healthcare but in accordance with the SDGs it was determined to be more closely related to sanitation. With both gender and parasite prevalence being housed under the banner of other descriptors they do not necessarily receive adequate consideration in the system and the resulting scenarios.

5.5.2 Literature and Data Availability

In reviewing literature for key quotes to translate into judgements, this study was limited by the availability and applicability of literature and data. There is ample research into a number of descriptors particularly education, income and population (UN DESA, 2015, Todaro & Smith, 2012, UN DESA, 2003), but significantly less for others, or research that was not applicable given its focus on higher income countries. For example, most literature referring to urbanization based many relationships on historical trends from today's high income countries. There is consensus overall as to the rate of urbanization increasing across the developing world, with Africa boasting some of the highest expected rates, but there was little consensus into the influences on urbanization (i.e. income), and the influence urbanization outcomes exert on other system descriptors, particularly education and healthcare (Bloom, Canning & Fink, 2008, Arouri et al., 2014).

For other descriptors such as agriculture, poverty and water scarcity that involve a quantitative component in their definition, the availability of data was constricting. For poverty; "as of 2012, only 27 of 38 countries (in sub-Saharan Africa) had conducted at least two comparable surveys since 1990 to track poverty" (Beegle et al., 2016, p. 4). This trend has been addressed as the number of household surveys conducted since 1990 exceeded the developing world average of 22 (Beegle et al., 2016). This improvement however, has not included consumption data

essential to measuring poverty and inequality. There are a number of fragile states in Africa's LICs and LMCs such as Chad, the Democratic Republic of Congo, Sierra Leone, and Togo, these fragile states are often where data is lacking most. Even countries with multiple surveys such as Guinea and Mali lack the proper data to compare poverty over time. An absence of comparable data at the country level results in inaccurate poverty estimates. This challenge is exacerbated in a country like Nigeria, which is the populous country in this study site.

Similar data hurdles were faced for agriculture and water scarcity, with little data from the past to define historical trends, and thus not enough to go on to extrapolate future projections. Furthermore, for income per capita there are informal markets that are not captured in World Bank datasets. For water scarcity, it only applied subtle differences to descriptor outcomes, and was not a significant factor in the findings, however it will likely be a growing concern for the countries of this study site. Overall the lack of data made it difficult to give the descriptor adequate consideration.

5.5.3 Time horizon

Nine self-consistent long term scenarios were identified, spanning to the end of the century, in keeping with IPCC scenario research that looks to 2100 as a benchmark. The scenarios also considered the SDGs with goals for 2030. With long-term projections we are assuming the influences captured through the literature findings stay the same over the course of the century. Given the dynamic nature of socioeconomic characteristics, future research may want to consider breaking down the research process to generate scenarios for shorter time periods of approximately 25-30 years.

5.5.4 Linguistic Imprecision

Lastly this study can be sensitive to linguistic imprecision (Morgan & Henrion, 1990). Key quotes are referenced from literature and translated into Cross Impact Judgements represented by numbers from -3 to +3. These interpretations are based on the literature, and in some cases imprecise language limits the clarity and specificity of the point and opens up the possibility of misinterpretation of the literature. This was managed by using more than one source for most of the direct influence findings, and wherever possible studying multiple sources to ensure scholarly consensus on the matter.

5.5.5 Caveat: Paradigms in Development Economics

The Rural Development scenario 6 illustrates a development pathway where there is predominantly rural living. In reviewing relevant urbanization literature, there is an overall consensus that urbanization rates are increasing. Currently much of Africa's population remains rural, but literature predicts rapid increases in urbanization over the course of the century. In the field of international development, there is ample literature attesting to the dominant paradigm that economies should strive to be like present-day high-income nations, with low fertility and

populations residing in urban areas to concentrate economic activities. The direct influences for the matrix were imputed based on this literature that supported the model of increasing urbanization, yet the results still produced a stable rural outcome. Even with this literature on the model for urban populations, this rural development scenario stands as a contrast to the dominant vision of what literature says economies should be. This scenario for Rural Development challenges the common narrative for urbanization and illustrates a scenario of medium income, medium population and rural living. This outcome suggests that, if low- and lower-middle-income African countries so choose, there can be future development where people live in rural areas, with medium agricultural productivity, perhaps taking place in the form of cooperatives, family farming, and farming for local markets etc. This pathway sacrifices income growth with a medium income pathway, but prioritizes higher living standards with high access to sanitation and high healthcare. Despite the overwhelming literature on urbanization, this research produced a consistent scenario outcome with predominantly rural living, challenging the common narrative and pointing to a future where a high-income urban future is not a foregone conclusion, but there can be stability in rural living with medium income.

5.6 Future Research:

In revisiting the research questions, each scenario or set of common scenarios were analyzed in the context of conditions that may exacerbate the human dimensions of climate risk, and lead to higher challenges to adaptation, as well as some general insight into potential impacts on mitigation challenges. Future research can take these scenarios, that were generated with no climate data inputs, and combine them with Representative Concentration Pathways that include varying levels of climate change to assess Africa's LICs and LMCs climate change risk. By combining this data, researchers can gain full understanding of Africa's LICs and LMCs capacity to address climate given established climate change impact projections, specific to the region. Furthermore, this study can be expanded to focus on more localized levels. Descriptor states can be specific to one of the countries within the study site, which would allow for geographically specific scenarios with socioeconomic conditions that best represent the area. The results from this study, and future more localized studies, can be incorporated with Shared Socioeconomic Pathways, to further examine varying challenges to climate change adaptation and mitigation.

5.7 Conclusion:

The world's low income countries face increased risk to climate change impacts as a result of their international development status. For the LICs and LMCs in Africa, they are caught in a demographic trap that spurs continued high population growth, which can reinforce poor development conditions. This thesis offers key insight into the socioeconomic pieces that can kick-start development progress and aid in reducing the challenges to coping with and adapting to climate change.

The network of 11 socioeconomic descriptors that describe the socioeconomic landscape in Africa's LICs and LMCs used Cross Impact Balance Analysis to generate a total of 9 self-consistent scenarios. These scenarios illustrate plausible future illustrations of development in Africa. Through the analysis of scenario progression from status quo demographic trap to the sustainable development outcome of the latter scenarios, this research mapped out the influence patterns that dictate development progress and gave insight to areas for prioritization. The results showed that hidden variables such as sanitation and healthcare should be given strong consideration in addressing development. Access to improved sanitation services plays a crucial role in supporting access to quality education, particularly for females. As well, discussion surrounding the driving forces behind key socioeconomic characteristics lent weight to the necessity to consider the complexity of the system, and not just target development outcomes from one angle, or by pouring resources into a single socioeconomic determinant.

Africa's LICs and LMCs, like much of the world's developing nations, are looking to exit the demographic trap and transition to high income nations. The four middle income scenarios suggest that perhaps a plausible outcome for these nations is to strive for improved economic growth in line with today's middle-income nations, and to prioritize the promotion of higher living standards and human capital. Supporting measures that improve living standards such as health and sanitation, along with building human capital through education, can set the path forward for these nations to achieve higher development and future growth.

There is room for further growth in this research to better understand these scenarios at more localized levels. In addition, combining these results with climate change projections can aid future policy discourse to ensure these nations are adequately prepared for current and future climate change, and in turn reduce their challenges to adaptation and mitigation.

In conclusion, Africa's LICs and LMCs still have a considerable task ahead of them to achieve sustained development across socioeconomic characteristics. By analyzing the entire system and tracing out the patterns of influence from one element to another, these nations can better understand their unique development needs, and in turn better prepare climate change adaptation and mitigation strategies.

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Appendix 1: Descriptor Influence Guide

A1.1 Direct Influences on Population:

When looking at global population growth for this century, the United Nations Department of Economic and Social Affairs (2015) projects according to their medium projection variant, that the world's population will reach 11.213 billion people by 2100. Even if fertility rates were to decline at a higher rate than currently predicted, there would still be inevitable population growth through to 2050. The UN estimates there to be "an 80 per cent probability that the population of world will be between 8.4 and 8.6 billion in 2030, between 9.4 and 10 billion in 2050 and between 10 and 12.5 billion in 2100" (UN DESA, 2015, p. 8).

In the current century, population growth rates are largely influenced by fertility levels. In the past population fluctuations were governed by more than fertility levels, but also by a host of other factors promoting higher mortality levels such as famine, war and conflict, and diseases such as the plague. With many of these variables under control, death rates have fallen sharply with life expectancy continuing to rise. In low income countries the falling death rates, paired with continually high birth rates has promoted high population growth (Todaro & Smith, 2012). Under the UN DESA's (2015) medium variant projection, which equates to 11.2 billion people by 2100, there is assumed to be a reduction in fertility levels from 2.5 children per women, to 2.25 by mid-century, to 2.0 by the end of the century. Over time even the slightest changes to number of children per women can have immense impacts on population growth. For example, under a higher projection "if fertility were to be consistently half a child above those levels, world population would reach 10.8 billion by 2050 and 16.6 billion by 2100" (UN DESA, 2015, p. 8). A lower projection of half a child under the medium level results in a world population of 8.7 billion by 2050, and only 7.3 billion by 2100 (UN DESA, 2015). Current trends suggest fertility levels are on the decline across the world. The average number of children per woman in Africa has shifted from 4.9 to 4.7 from 2005-2015 (UN DESA, 2015). Despite these declines in fertility rates, and projections for further declines in the average number of children per woman, there will still be substantial population growth across the world, with least developed countries growing at 2.4% per annum. Growth rates take time to slow, as the population dynamics shift from high levels of youth, to an ageing population. Currently "Africa has the youngest age distribution of any major area. Nevertheless, it is also projected to age rapidly over the next 35 years, with the percentage of its population aged 60 or over rising from 5 per cent in 2015 to 9 per cent by 2050." (UN DESA, 2015, p. 9).

Today, China and India represent the two largest countries, with sixty percent of the world's population residing in Asia. Africa currently accounts for 16% of the global population however in the coming decades, taking us to 2050, over 50% of the world's population growth is set to take place in Africa. From 2010-2015 Africa's population grew 2.55% per year, representing the highest growth rate of any region (UN DESA, 2015). Globally it is estimated by 2050 the world will be dealing with 2.4 billion more people, with 1.3 billion being housed in Africa alone. "A rapid population increase in Africa is anticipated even if there is a substantial reduction of fertility levels in the near future" (UN DESA, 2015, p. 3). Furthermore, beyond 2050 "Africa is expected to be the only major area still experiencing substantial population growth" (UN DESA, 2015, p. 3). As a result of Africa's continued growth, and overall low to minimal population growth in other major areas around the world, Africa's portion of the global population will

increase for its current state of 16% to 25% by 2050, before reaching 39% by the end of the century. There will always be a level of uncertainty in quantifying future population growth rates and totals, however literature suggests a high level of confidence in high population growth in Africa as "the larger number of young people currently on the continent who will reach adulthood in the coming years and have children of their own, ensures that the region will play a central role in shaping the size and distribution of the world's population over the coming decades" (UN DESA, 2015, p. 3-4). In fact, 41% of Africa's population are under the age of 15, and 19% are aged 15-24.

Ten African countries designated as LICs and LMCs are excepted to experience population increases by at least five-fold from 2015-2100, these countries include; "Angola, Burundi, Democratic Republic of Congo, Malawi, Mali, Niger, Somalia, Uganda, United Republic of Tanzania and Zambia" (UN DESA, 2015, p. 4). Furthermore, by the midpoint of the century, populations are expected to double in 28 African countries (UN DESA, 2015). Nigeria, is expected to experience the greatest population increases of Africa's LICs and LMCs, in fact by 2050 they will jump the ranks from the seventh largest country in the world to the third, growing at a more accelerated rate than any other nation. These high population growth projections in some of the poorest countries in the world has serious consequences for the development progress of the above listed countries, and the additional least developed low and lower-middle income countries in Africa. The UN DESA (2015, p. 4) cites that this highly concentrated growth "will make it harder for those governments to eradicate poverty and inequality, combat hunger and malnutrition, expand education enrolment and health systems, improve the provision of basic services."

"To realize the substantial reductions in fertility projected in the medium variant, it is essential to invest in reproductive health and family planning, particularly in the least developed countries, so that women and couples can achieve their desired family size" (UN DESA, 2015, p. 5). Africa only has one country classified as a low-fertility nation. A low-fertility country is defined as a nation where women on average have less than 2.1. children. The majority of Africa's countries on the other hand are classified as high-fertility countries, where women have on averaged more than 5 children. Globally 19 of the 21-listed high-fertility nations are housed in Africa, with Africa accounting for the top four largest (UN DESA, 2015). From 2010-2015, there were only two countries outside of Africa that had total fertility levels in excess of 5 children on average per woman. Looking forward long term there is hope of stabilization by the end of the century. "In all major areas of the world, fertility levels are projected to converge to a level at or just below the replacement level by 2095-2100." (UN DESA, 2015, p. 10). Overall the most substantial declines in fertility levels will take place in Africa. These declines however, and their corresponding effects on demographic transition will take time before population growth slows considerably.

Another factor that our study does not focus heavily on is migration. Literature suggests that migration plays an important role in population growth, but overall migration movements are from low income nations, to countries of higher development status. Todaro and Smith (2012) suggest that "population increases in developing countries therefore depend almost entirely on the difference between their crude birth rates (or simply birth rates) and death rates." (Todaro and Smith, 2012: 275), and that migration does not play a significant role.

Direct Influences on Population

"Economists and demographers for the most part agree that important ingredients of improved living standards, such as urbanization, industrialization and rising opportunities for non-agrarian employment, improved educational levels, and better health all lead to changed parental perceptions of the costs and benefits of children, leading in turn to lower fertility." (Sinding, 2009, p. 3023).

- Income per capita
- Urbanization
- Extreme Poverty
- Quality of Healthcare
- Educational Attainment
- Quality of Governance

Descriptor Relationship: Income per capita influence on Population

There is no specific passage in the IPCC Africa report supporting this direct influence however, it has been widely documented in literature that there is a relationship between rising incomes and reductions in fertility rates. In the Barro (1997) study cited in the IPCC Special Report on Emissions Scenarios, "a statistically significant correlation between per capita GDP growth and the variables life expectancy and fertility in his analysis of post-1960 growth performance of 100 countries. Other things being equal, growth rates correlate positively (higher) with increasing life expectancy and negatively (lower) with high fertility, which confirms the view that the affluent live longer and have fewer children." (Nakicenovic et al, 2000, p. 112). Based on this documented research, it can be assumed that the same influence is applicable between GNI/capita and population in Africa.

"A broad consensus has developed over time that as incomes rise, fertility tends to fall. There is little debate about the causal relationship between rising prosperity and declining fertility" (Sinding, 2009, p. 3023).

Descriptor Relationship: Urbanization to Population

With increases in urbanization there is a slight decline in population as "urban populations are more aware of contraception and more likely to have fewer children" (Arouri et al., 2014, p. 6). Furthermore, "birth rates are usually lower in urban than rural settings" (Bloom, Canning & Fink, 2008). The agrarian lifestyle associated with rural living slightly promotes higher population as families seek to have more children to assist with agricultural activities and labour. "Urbanization has been found to have positive impacts on fertility, mortality and other demographic trends." (Cheru, 2005, p. 5)

Descriptor Relationship: Extreme Poverty to Population

The relationship between extreme poverty and population is mutually reinforcing. Overall the scope of literature supporting the descriptor relationship between extreme poverty and population, specifically fertility rates is quite limited (Schoumaker, 2004). This however, does not mean that the relationship does not exist. Extreme poverty may not exert as strong of a force on population as other descriptors such as educational attainment. According to a 2004 study by

Bruno Schoumaker, "the links between poverty and fertility behaviour have important implications for the demographic future of Sub-Saharan Africa"(2). In Sub-Saharan Africa, there are estimates that close to 50% of the population survives on less than $1 a day, and those living on less than $2 a day cumulatively account for 75% of the population (Schoumaker, 2004). With these staggering poverty numbers, "there will be no sustained fertility decline in Africa unless poverty is dramatically reduced or/and unless considerable fertility declines occur among the poor" (Schoumaker, 2004, p. 2). Furthermore, "poverty is a key explanatory factor of high fertility" (Schoumaker, 2004, p. 2). A number of countries in South Asia and Latin America have experienced fertility declines in the face of extreme poverty, with these results largely attributed to the innovation diffusion approach, that is to say the "spread of ideas, values and technology to the entire population, regardless of their economic status" (Schoumaker, 2004, p. 3). With some African countries experiencing similar declines, the relationship between extreme poverty and population is weak, with values of +1 and -1. This relationship has been studied by Schoumaker (2004 & 1999), specifically focused on countries within Sub-Saharan Africa, with results suggesting a relationship between poverty and fertility varying across nations. Overall though results show that fertility rates remain high among poor populations.

Descriptor Relationship: Quality of Healthcare to Population

At first glance, a positive descriptor relationship may be drawn from quality of healthcare to population, where improvements to healthcare lead to population growth. However, literature suggests that as healthcare improves, it impacts a country's demographic transition, promoting negative population growth. An Abel et al. (2016) article referenced "in the fields of reproductive health and female education, will have strong direct and indirect effects on future population trends, mostly in the direction of lower population growth" (14294). They continue to expand further in saying "health and education targets have direct and indirect consequences on future mortality and fertility trends" (Abel et al., 2016, p. 14294). This article specifically looks at lowering world population growth through the achievement of the Sustainable Development Goals. These goals do not include population targets, but instead Abel et al., (2016) interpret that "goals related to child mortality, maternal mortality, causes of death, and reproductive health can be translated more or less directly into future mortality and fertility pathways" (14295).

Descriptor Relationship: Educational Attainment Influences Population

There is substantial evidence in literature to support the direct influence between educational attainment and population. The United Nations (2003) report on Population, Education and Development cites education "as a strategy to curb population growth" (UN, 2003, p. 9), and continues to say, "evidence confirms that **education has a major impact on the level of fertility, especially in developing countries**" (UN, 2003, p. 34).

The following quotes from literature support the direct influence of educational attainment on population; "In the field of population studies, it has long been recognized that education is strongly related to a broad range of demographic behaviours. **The spread of education throughout a population has been shown to be of central importance for the long-term demographic transition from high to low levels of fertility**." (UN, 2003, p. 1). There is continued evidence in literature of the strong relationship between education levels and both fertility and mortality rates. A study in 1980 by Caldwell indicated that once the majority of a

society's children attended school that high fertility could not continue. Present day, this theory appears to be holding true.

The United Nations Population, Education and Development Report (2003) states that as educational attainment increases for women, fertility decreases. There is further evidence in contraception usage among educated women. "Africa, the proportion using contraception among women with a secondary or higher education is more than 3 times as high as that among women with no education." (UN, 2003, p. 51). The difference in desired family fertility versus actual numbers is most pronounced between women with no education or primary education, in a comparison with higher levels of education. Studies show that the desired family size is smaller for women with higher education levels. "Educational differentials in the mean ideal number of children are greatest in sub-Saharan Africa, where women with no education desire to have 2 children more than women with a secondary or higher education, on average." (UN, 2003, p. 33). Furthermore Sub Saharan Africa also has the greatest differentials in contraceptive use by education. Overall this region has the lowest levels of contraceptive usage, however education increases usage tremendously. "The percentage using contraception among married women with a secondary or higher education is more than three times as high as that among married women with no education." (UN, 2003, p. 34). Overall in low income countries, as educational attainment increases, fertility decreases, "with very few exceptions, current fertility levels (TFRs) decrease from one educational level to the next" (UN, 2003, p. 31).

Given the evidence stated above we have reason enough to believe there is a strong direct influence between increases in educational attainment leading to decreases in population, through reductions in fertility levels, as such the strong influence is represented with +3 and -3.

Descriptor Relationship: Quality of Governance to Population

A number of countries in Africa including; South Africa, Botswana, Zimbabwe, Kenya, and Rwanda, have all experienced successful population planning where "the interest and commitment of the political leadership translated into national policies and programmes designed both to influence family size norms and to provide family planning services to those who wanted them. The response on the part of the public in every case was positive and substantial. All of these countries saw large increases in contraceptive use and falls of between 15 and 25 per cent in their birth rates." (Sinding, 2009, p. 3029). According to Sinding's (2009) assessment of these and other population planning programs "population policies and reproductive health programmes can work in Africa." (3030).

A1.2 Direct Influences on Income per capita:

- Population
- Agricultural Productivity
- Extreme Poverty
- Quality of Healthcare
- Educational Attainment
- Quality of Governance
- Technology Transfer

Descriptor Relationship: Population to Income per capita
There is "long-established negative correlation between fertility rates and per capita income" (Nakicenovic et al, 2000, p. 112)."The future of economic development in Africa depends in part on bringing down the extraordinarily high fertility of most Sub-Saharan states." (Sinding, 2009, p. 3029) This relationship is not as strong as the influence from income per capita to population, as "fertility reduction is by no means an economic development panacea and is certainly not a sufficient condition for economic growth, but it may well be a necessary condition, establishing conditions in which governments can invest more per capita in education and health, thus creating the human capital for sustained economic growth." (Sinding, 2009, p. 3030). This relationship is represented with weak variables, +1 and -1.

Descriptor Relationship: Agricultural Productivity to Income per capita
"Evident from its high share in GDP, the prospects of the agricultural sector heavily influence economic development in most countries in Sub-Saharan Africa." (OECD/FAO, 2016, p. 61).

The impact of agricultural productivity on income per capita vary across Africa. North Africa comprised of two large upper-middle income countries; Algeria and Libya, as well as Morocco and Tunisia, both lower-middle income countries, accounts for 35% of the continent's total GDP. This area has a much more diversified economy. To the South, the country of South Africa, contributes on its own an additional 30% of Africa's GDP, while representing only approximately 5% of the population (NEPAD, 2013). For the Low Income and Lower-Middle Income countries that comprise the bulk of the rest of Africa, they represent a small portion of the continent's GDP. For these countries, agriculture represents a large portion of their economic activity.

"**Agriculture, which is the main economic activity in terms of employment share**" (Niang et al., 2014, p. 1212). A large portion of the population is highly reliant on agriculture for income, in fact "agriculture creates most of the jobs in Africa," (NEPAD, 2013). Overall 48% of the population in all of Africa rely on agriculture, with levels reaching upwards of 70% in the East Africa area (NEPAD, 2013). The role of Agriculture in upper-middle income countries is significantly lower than low income countries. "In Central Africa Republic, the agriculture value-added as percentage of GDP is 55%; in South Africa it is 3%" (World Bank Group, 2013).

Furthermore: "the Comprehensive Africa Agriculture Development Program (CAADP), which works under the umbrella of NEPAD, was established in 2003 to help **African countries reach**

a higher path of economic growth through agriculture led development." (Niang et al., 2014, p. 1213).

"Improvement of a human capacity for agricultural productivity is a pre-requisite for social and economic development for rural areas. This is because agriculture forms the bedrock of economic activities in the rural area" (Okpachu et al., 2014, p. 27)

Descriptor Relationship: Quality of Healthcare to Income per capita

"The positive correlation between health and income per capita is one of the best-known relations in international development" (Bloom & Canning, 2000, p. 1207). Productivity is said to be higher amongst healthy populations. In a Bloom & Canning (2000) study based on life expectancy as a marker for quality of healthcare, real income per capita in the healthier country grew "0.3% to 0.5% per year faster than in its less healthy counterpart" (1207). Furthermore, they reference that poor health is a fundamental cause of low income.

The following quotes from additional literature sources further illustrate the consensus amongst scholars that improvements to healthcare yield growths in income per capita. "Investments in health and education are powerful vehicles for promoting economic growth and human well-being (Bloom and Luca, 2015; Bloom et al., 2015)" (UNFPA, 2016, p. 48). In addition, "health capital can influence economic activity directly through its impact on labor productivity" (Arouri et al., 2014, p. 3). Poor health tends to lead to lower productivity and lost wages which negatively impacts income per capita.

"Today's economists are increasingly of the view that a well-educated and healthy population are essential ingredients in sustained economic growth." (Sinding, 2009:3028).

"Health capital can influence economic activity directly through its impact on labor productivity." (Arouri et al., 2014, p. 3)

Descriptor Relationship: Educational Attainment to Income per capita

There is significant evidence in literature attesting to the positive influence between education and economic growth. Support for this relationship is well documented dating back decades. In 2000, primary education was recognized as "critical for achieving social and demographic progress, sustained economic development and gender equality" (UN DESA, 2003). Furthermore, "learning builds up dynamic capabilities which are key drivers of catching up and economic development" (Salazar-Xirinachs, Nübler and Kozul-Wright, 2014:2). The UN DESA (2003) Concise Report on Population, Education and Development states that at "the household level, research has established that education boosts individual incomes in a wide variety of settings" (5). A 2002 study by Psacharopoulos and Patrinos found through extensive literature review on countries of all development stages, that the average private return from education to be around 27%. "Increased schooling promotes greater productivity and, in turn, higher income" (Bloom & Canning, 2000, p. 1207), "contributing to societies' economic growth and to the economic fortunes of individuals" (UN, 2003, p. 48).

In our study the educational attainment descriptor is looking at the percentage of the population undertaking schooling beyond the primary level. Having children attend school is the best means

of building up human capital for a strong adult labour force, yielding positive benefits to health and economic growth (Lutz, Cuaresma & Sanderson, 2008). Ultimately economic growth and development will not be be sustained without fully developed human resource pool, because "educated individuals are far more able to contribute to the well-being and advancement of their societies" (UN, 2003, p. 53). "Complementing primary education with secondary education in broad segments of the population is likely to give a strong boost economic growth" (Lutz, Cuaresma & Sanderson, 2008, p. 1047). In a Lutz, Cuaresma & Sanderson (2008) study using economic and education data, results showed "statistically significant education effects on economic growth for some age and education groups" (1048).

In the transition from the Millennium Development Goals that advocated for universal primary education, to the new Sustainable Development Goals including universal access to both primary and secondary education, it was determined that secondary education would be necessary to move low income countries out of poverty (Abel et al., 2016). In the Lutz, Cuaresma & Sanderson (2008) study they considered a scenario where 50% of population received primary education, that was otherwise uneducated, and the results showed GDP growth, higher than average. An additional scenario that included this 50% of the population receiving secondary education, displayed economic results that were far greater than the initial primary education scenario. This study concluded that the goal of universal primary education does not go far enough, that portions of the population need to be receiving secondary education (Lutz, Cuaresma & Sanderson, 2008). "Only this is likely to give initially poor countries the human capital boost that is necessary to bring large segments of the population out of poverty" (Lutz, Cuaresma & Sanderson, 2008, p. 1048). They further conclude that "better education does not only lead to higher individual income but also is a necessary (although not always sufficient) precondition for long-term economic growth" (Lutz, Cuaresma & Sanderson, 2008, p. 1047).

Descriptor Relationship: Quality of Governance to Income per capita

"Increasingly, economists and policy makers are recognizing the importance of good governance and institutions for economic growth and development" (Fayissa & Nsiah, 2010, p. 1). The results of a Fayissa & Nsiah (2010) study concluded "that good governance or lack thereof contributes to the gaps in income per capita between richer and poorer African countries" (1). There is a plethora of literature supporting the relationship between dimensions of good governance and economic growth. Chauvet and Collier (2004) concluded that GDP growth was negatively impacted per year in countries hindered by poor governance in comparison to their counterpart developed nations (Fayissa & Nsiah, 2010).

In the Fayissa & Nsiah (2010) study on the impact of quality of governance on per capita income in Africa, they found "that good governance has a positive and significant impact on growth" (Fayissa & Nsiah, 2010, p. 14). The value of good governance on economic growth is most important for the lowest income per capita nations.

"Good governance is indispensable in enhancing the effectiveness of government operations and in stimulating private investment, and therefore, growth" (Sikod & Teke, 2012, p. 4). Furthermore, through an extensive literature review Sikod & Teke (2012) concluded that Kaufman et al (2005), World Bank (1994a), Knack (2002), and Edison (2003) "established that

the quality of governance has a strong and unequivocal impact on economic performance" (Sikod & Teke, 2012, p. 5).

A Saachs (2005) article "Can Extreme Poverty Be Eliminated?" finds that "governance makes a difference but is not the sole determinant of economic growth" (58).

"Corruption and inefficient bureaucracy create difficulties and uncertainties in establishing enterprise or gaining and maintaining employment." and "Poor rule of law discourages investment" (Bloom et al., 2007, p. 4).

Gyimah-Brempong (2002) conclude"corruption decreases economic growth directly and indirectly" (183) in addition to finding "that increased corruption is positively correlated with income inequality" (**Gyimah-Brempong, 2002, p. 183).**

A Kauffmann et al., (2005) study showed results that a "reduction in corruption from the very high level prevalent in Indonesia to the lower level in Korea leads to between a two- and fourfold increase in per capita incomes" (12). Furthermore Kaufmann et al., (2005) studied the relationship between rule of law and increases in income per capita, the "causal effects suggest that good governance should be given a high priority on the development and poverty-reduction agendas" (12).

Descriptor Relationship: Technology Transfer to Income per capita

A Amavilah (2007) study on the "Intensity of technology use and per capita real GDP across some African countries" results showed "that a feeble technology undercuts per capita real GDP across African countries" (1). The study suggests that policies should seek to invest in "new technologies for which productivity is high and the adoption and diffusion costs seem low." (Amavilah, 2007, p. 1). The study further finds that a country's technical capabilities influence their economy's production possibilities (Amavilah, 2007). The author hypothesized based on the economic transition of current developed nations that African countries economic growth has been constrained by a lack of adequate and progressive technological change and a feeble technological foundation (Amavilah, 2007). Early literature even supported this connection; "of all gaps that separate Africa from the rest of the world the science and technology is probably the most critical, and the most profound" (Segal, 1985, p. 110).

Discussion: Descriptor Relationship: Lack of Consensus in Literature for Urbanization to Income per capita

"Throughout history, urbanization has been a key force in human and economic development" (Arouri, et al., 2014, p. 2). A quick scan of the high-income countries of the world, and it is clear that urban areas are the main economic sectors, however for many of these nations, urbanization occurred at a controllable rate and progressed along a pathway from town, to small city, to large scale urban area, allowing for policy and infrastructure to somewhat keep up (Bloom, Canning & Fink, 2008). With Africa's high population growth, and evidence pointing towards rapid urbanization rates, infrastructure and city services have not been able to keep up with the influx of people. In the case of LICs and LMCs particularly taking into account the conditions of these nations in Africa, urbanization at rapid rates results in large informal settlements with a lack of basic services, clean water, and access to sanitation.

There is a fairly large pool of literature providing evidence of the positive impacts of urbanization on economic growth, the concentration of highly skilled workers, increasing labour forces, etc, all of which support claims of urbanization promoting higher income per capita. However when it comes to low income countries in the twenty first century, with the lack of basic provisions urbanization is shown to have an overall weak, and in some cases nonexistent relationship with income per capita growth. Past literature has pointed to a weak relationship in the history of Africa's urbanization and associated economic growth, unlike other regions of the world (Arouri, et al., 2014). According to a Arouri et al., (2014) study "rapid urbanization and investment in human capital seems to be modifying the pattern of economic growth in Africa in the recent period, even if there are no academic studies confirming that observation" (2). A Bloom, Canning & Fink (2008) study on the other hand found "no evidence that the level of urbanization affects the rate of economic growth" (2).

Arouri et al., (2014) concluded that after extensive review of urbanization literature that "the majority of studies suggest that urbanization should have a positive impact on economic growth" (2). When urbanization occurs at a rapid pace, infrastructure systems often can't meet demand, and are strained and overused. Overall literature suggests a positive relationship between urbanization and income per capita, but there is no focus on low income countries, and in the case of Africa's low and lower-middle income countries, rapid urbanization and poor infrastructure systems will likely impede this economic growth.

Bloom, Canning & Fink (2008), represent the argument that the growth of urban areas does not imply they will become economic success stories. They believe the lack of relationship from urbanization to income per capita is a result of different types of urbanization at play. The reason for the movement from rural area to city plays an important role in whether urbanization will directly impact income per capita. Asia has experienced rapid urbanization with subsequent economic growth. This is likely due to the movement of people to urban centres in the interest of job opportunities and industrialization. Africa on the other hand has seen urbanization without strong growth. In this case, urban movement of people is driven by other factors such as politics, and the environment. Ultimately, "development is a multifaceted process and economic growth, or the absence thereof, is not a strong indicator of progress in other dimensions of development" (Bloom, Canning & Fink, 2008, p. 10-11). Bloom, Canning & Fink (2008) argue that the "share of the total population living in urban areas seems to have little effect on economic growth, it may be that other measures of urban composition to matter" (11). Their findings suggest "policies specifically aimed at accelerating, or retarding, urbanization are unlikely to speed up economic development" (Bloom, Canning & Fink, 2008, p. 11).

Arouri et al., (2014) observed that the push and pull effects of urbanization vary in Africa as compared to other parts of the world. Barrios, Bertinelli and Strobl (2006) indicated that climatic changes, such as shifts in rainfall are driving people from rural to urban settings, "while in other parts of the world, migration from rural areas to urban areas is explained by the positive externalities of urbanization and shifts in the economy from agriculture to manufacturing and services" (Arouri et al., 2014, p. 11). Furthermore, "Annez, Buckley and Kalarickal (2010) extend this analysis and find similar results, demonstrating "the strong links that exist between

geographical factors and urbanization trends in Africa, while finding that the linkage between policy and urbanization trends is weak." (Arouri et al., 2014, p. 11).

Given the inconclusive nature of the literature, no judgements were expressed for the influence of urbanization on income.

A1.3 Direct Influences on Agricultural Productivity:

- Water scarcity
- Educational Attainment
- Quality of Governance
- Technology Transfer

Descriptor Relationship: Water Scarcity to Agricultural Productivity
There is strong evidence demonstrating the direct relationship between water availability and agricultural productivity. "Agriculture, which is the main economic activity in terms of employment share, is **98% rainfed in the sub-Saharan region** (FAO (b), 2002)" (Niang et al., 2014, p. 1212). The availability of water directly promotes agricultural productivity. "Africa's food production systems are among the world's most vulnerable because of extensive reliance on rainfed crop production." (Niang et al., 2014, p. 1218). Rainfed agriculture is prominent in Northern Africa as well. "Changes in water resources are particularly relevant in areas where water availability is a limiting factor for economic development. This is the case in the Mediterranean basin, where both higher income and low income countries have a common dependence on water availability to meet the needs of increasing populations and living standards, **development of irrigated agriculture** (Cudennec et al., 2007)" (García-Ruiz et al., 2011, p. 2-3). "Rainfed agriculture in northern Africa is highly dependent on winter precipitation and would be negatively impacted if total precipitation and the frequency of wet days decline across North Africa, as has been indicated in recent studies (Born et al., 2008; Driouech et al., 2010; Abouabdillah et al., 2010; Garcia-Ruiz et al., 2011)." (Niang et al., 2014, p. 1217). There is also evidence of this direct relationship, in its impact on livestock production. "Water stress also limits livestock systems." (Porter et al., 2014, p. 502). There is also a indirect influence "Livestock production will be indirectly affected by **water scarcity** through its **impact on crop production** and subsequently the availability of crop residues for livestock feeding." (Niang et al., 2014, p. 1220)."The interaction between water resources and agriculture is expected to become increasingly important as climate changes." (Porter et al., 2014, p. 504).

As water scarcity increases, agricultural productivity will be severely hindered, leading to lower total factor productivity. This relationship is strong and is depicted with the high water scarcity pathway strongly restricting the high agricultural pathway (-3). Low water scarcity does not ensure high agricultural productivity, as such it slightly promotes a high agricultural productivity pathway.

Descriptor Relationship: Educational Attainment to Agricultural Productivity
There is a plethora of literature attesting to the positive benefits of increased access to education and improved agricultural productivity. Education is extremely beneficial to Africa's development, and given the current importance of agriculture to Africa's economy, it is expected that educational attainment will have a positive impact on agricultural productivity. A Okpachu et al. (2014) study on the impact of education on agricultural productivity, with examples from Nigeria cited that "one of the major problems facing Agricultural productivity in Nigeria is illiteracy. This has over the years posed great challenges to Agricultural development as well as productivity" (Okpachu et al., 2014, p. 26). For farmers to be able to use new technologies, or take advantage of improved agricultural practices, they require education. Okpachu et al. (2014)

observed that "numerous studies have shown that farmer education has important effects on agricultural production" (27). Alene & Manyong (2007) found that farmers that are educated are able to better adapt than their less educated counterparts. This adaptation to new technology or changing conditions is crucial in agricultural productivity. Furthermore, "education is expected to accelerate agricultural productivity by enhancing the productive capabilities of all producers by exposing them to a more systematic and dynamic production systems and by enhancing their ability to choose the optimal levels of inputs and outputs (Welch, 1970)" (Alene & Manyong, 2007, p. 142). There is a fairly strong consensus across the literature that education promotes higher agricultural productivity, especially in the context of low income countries. Reimers & Klasen (2011) showed that "education indeed has a highly significant, positive effect on agricultural productivity" (1)

The impact of educational attainment on agricultural productivity is of even greater importance as it relates to empowering the rural female farmer population. "Education is the basis for full promotion and improvement of the agricultural productivity of the rural women. It is the basic tool that should be given to rural women in order to increase productivity and income from agriculture" (Okpachu et al., 2014, p. 27).

Descriptor Relationship: Quality of Governance to Agricultural Productivity

Government has a very important role to play in promoting agricultural productivity. There are a number of studies showcasing positive success stories in other low income countries, particularly South East Asia and India, where strong deliberate planning and funding from government lead to sustained agricultural growth and corresponding economic improvements. Africa on the other hand has experienced idle food grain yields dating back to the sixties. Success stories in agricultural productivity have been few and far between with pockets of success dotting the continent. "There are 48 countries in Africa and only one (South Africa) of these is producing genetically modified (GM) crops commercially. Why? The answer is that most government and university research systems in Africa are producing only a trickle of new technology and improved farm practices. Consequently, African nations are severely challenged to invest in generating new knowledge for increasing agricultural productivity." (Eicher, 2006, p. i).

"Africa's commitment of an average 2.4 percent of its government's budget to agriculture is distressing in a continent where more than 60 percent of the people depend on the rural sector for their jobs, food and income (Fan and RAO 2003). Africa's current expenditure on agriculture is dismal when compared with Asia's public expenditure in the 1970s and 1980s. India spent 10 to 20 percent of its government budget on agriculture in the 1970s, while Malaysia spent an average of 20 percent of government investment on agriculture from 1960 to 1983 (Jenkins and Lai 1992)." (Eicher, 2006, p. 32). "African nations invested an average of 4.1 percent in 2001 (Fan and Rao 2003)." (Eicher, 2006, p. 17).

"Success in future agricultural productivity is not foreordained, but will require research and inputs. Much will depend on political leadership, vision, policies, strategies, incentives, innovations and hard work over a period of 30 to 40 years (Macedo et al 2003)." (Eicher, 2006, p. 26).

Descriptor Relationship: Technology Transfer to Agricultural Productivity

As referenced in the relationship between governance and agriculture, the lack of investment in technology is resulting in flat yields. “University research systems in Africa are producing only a trickle of new technology and improved farm practices. Consequently, African nations are severely challenged to invest in generating new knowledge for increasing agricultural productivity.” (Eicher, 2006, p. i). Researchers and government alike argue that adopting genetically modified crops could hinder their European market, however with stagnant yields for over half a century, agricultural productivity is in serious need of technological innovation to promote total factor productivity growth. “South Africa is currently the only one of 53 countries in all of Africa that is growing GM crops (Table 3). This is an important issue because of the widening technology gap between Africa, Asia and Latin America.” (Eicher, 2006, p. 34). When it comes to the minimal investment in technology for agriculture “the overall track record of donor investments in AET within Africa is riddled with “false starts.”” (Eicher 2006, p. 5-6)

“Although farmers usually have rich knowledge of local conditions and valuable practical knowledge or experience of how best to successfully exploit their environment, they require innovation information generated from research and development to boost their productivity (Apata, 2010)” (Okpachu, 2014, p. 26). The use of new technologies enables farmers to better adapt to changing environmental conditions. Technology use can allow for disease and drought resistant crop varieties to be planted, along with higher yielding crops, in addition to the use of chemical fertilizers and pesticides to promote more efficient agricultural practices and higher overall productivity (Alene & Manyong, 2007).

“African scientists argue that the future of agricultural research in Africa is not foreordained. Much will depend on political leadership, vision, policies, strategies, incentives, innovations and hard work over a period of 30 to 40 years (Macedo et al 2003.” (Eicher, 2006, p. 26).

A1.4 Direct Influences on Urbanization:

Urbanization has been increasing for decades, with 30% (746 million) of the world's population residing in urban areas in 1950, to levels of 54% (3.9 billion) in 2014. It is estimated that that number will increase to 66% by 2050 (UN DESA, 2014). Africa is still a predominantly rural continent, with 40 percent of the population residing in urban centres. Currently 90% of the world's rural population resides in Africa and Asia, with only 40% of the population in Africa living in urban areas. Africa along with Asia are on track to urbanize at rapid levels, with Africa reaching 54% by 2050 (UN DESA, 2014). The UN projects that through 2050 a large portion of world population growth will occur in the urban centres of low and middle-income countries (Revi et al., 2014). This growth will be in areas of Africa, Asia, and Latin America, in urban centres that currently have less than a million inhabitants (Revi et al., 2014). "Continuing population growth and urbanization are projected to add 2.5 billion people to the world's urban population by 2050, with nearly 90 per cent of the increase concentrated in Asia and Africa" (UN DESA, 2014, p. 1). Nigeria alone is expected to add 212 million people to the world's urban population growth.

In 2014, six large countries in Africa with populations in excess of 10 million people, had urbanization levels under 20%. It is predicted that these same countries; Uganda, Ethipopia, Malawi, Niger, South Sudan, and Burundi, will double their urbanization levels by 2050 (UN DESA, 2014). "Africa and Asia are urbanizing more rapidly than other regions of the world" (UN DESA, 2014, p. 8). It is estimated that Africa's percentage of the population living in urban areas is increasing by 1.5% per year (UN DESA, 2014). Given that higher income countries are already largely urbanized with places like Belgium, Japan, Argentina, and the Netherlands sporting urbanization percentages of 90% or greater, their rate of urbanization will be slower than the rapidly growing low and lower-middle income nations of Africa. In as few as three years, Africa is projected to be the "fastest urbanizing region" (UN DESA, 2014, p. 9), and will hold steady till 2050.

There are 28 cities in the world that house in excess of 10 million residents, these mega-cities only hold about 1 in 8 urban people. Small urban settlements on the other hand, with less than 500,000 people house close to 50% of the world's urban peoples. "Several decades ago most of the world's largest urban agglomerations were found in the more developed regions, but today's large cities are concentrated in the global South. The fastest-growing urban agglomerations are medium-sized cities and cities with less than 1 million inhabitants located in Asia and Africa" (UN DESA, 2014, p. 1).

Urbanization is often association with economic growth, and other valuable societal transformations in line with the development process; lower fertility rates and a longer life expectancy, shifting demographics to an ageing population, in addition to increases in educational attainment, improved social services, and participation in government (UN DESA, 2014). Globally and in many nations the majority of GDP is produced in urban areas. This concentration of important services; government, commerce, and transportation, along with high economic activity supports decreases in poverty both in urban areas and in rural areas, while servicing linkages between different regions locally and internationally. When looking at the world's developed high-income countries, the majority are largely urbanized.

For nations in the low and middle-income classifications their rapid urbanization has been linked with strong economic growth (Revi et al., 2014). However, the process of urbanization does not guarantee every nation a successful development trajectory. Rapid and unplanned urbanization leads to poor infrastructure, and inadequate living conditions, in addition to a host of other urban sprawl issues, with grave consequences for sustainable development. Quality of governance is an important factor in ensuring equitable and sustainable urban development.

The UN's Report on World Urbanization Prospects: The 2014 Revision states "there is no common global definition of what constitutes an urban settlement." (UN DESA, 2014, p. 4). There are a number of criteria that can be employed to to determine if an area is urban. The UN report lists them in the following order "a minimum population threshold; population density; proportion employed in non-agricultural sectors; the presence of infrastructure such as paved roads, electricity, piped water or sewers; and the presence of education or health services." (UN DESA, 2014, p. 4). A number of these criterion will support progress for this study's descriptors, most notably health, and sanitation. Despite urbanization rates, the association of urbanization with economic growth, is not nearly as strong in low income nations as it once was in today's high-income countries.

Direct Influences on Urbanization

- Income per capita
- Agricultural productivity
- Extreme poverty
- Quality of Governance

Descriptor Relationship: Income per capita on Urbanization

Rapid urbanization is taking place in Sub-Saharan Africa due to economic stagnation (Cheru, 2005). This influence of low income and stagnation influences rapid unplanned urbanization outcomes. Henderson, Roberts & Storeygard (2013) note that Africa's urbanization is outpacing increases in income or GDP. "As cities have generated higher incomes, they have also become the preferred destinations of migrants. Studies of migration have demonstrated that rural to urban migrants move largely in pursuit of higher wages and not the other features of urban life." Cohen 2009, p. 9). This quote further reflects the migration of low income individuals to the city in search of higher income and economic opportunity. For rates of higher income per capita there is more of a desire to pursue planned urbanization, as they are more interested in urban amenities given that they already have higher incomes.

"In 1970 about half of urban growth in developing countries could be attributed to migration, the other half to natural increase. By 1990, that ratio had shifted towards 70 percent from natural increase and 30 percent from migration. The areas where migration was still important included Africa, South Asia, and China." (Cohen 2009, p. 9).

"Studies in the 1970s demonstrated that people at the top and bottom of the rural income distribution are most likely to migrate away from the countryside. People at the top migrate, because they see that with their surplus savings, they can move towards higher earnings and a higher quality of life. People at the bottom, often landless people in rural India or rural Africa,

leave the rural areas because they have no chance at securing a sustainable livelihood." (Cohen, 2009, p. 14). This relationship is represented with the low pathway for income per capita influencing rapid unplanned urbanization which is associated with slums and poor infrastructure. On the high pathway for income, those with higher incomes are promoting the planned moderate paced urbanization outcome, as well as the rapid planned state.

Descriptor Relationship: Agricultural productivity to Urbanization

Low agricultural productivity will restrict the rural outcome and promote the rapid unplanned urbanization state. "Barrios, Bertinelli and Strobl (2006) use rainfall data to show that low rainfall (low agricultural productivity) is associated with higher contemporary urbanization in Africa" (Arouri et al., 2014, p. 6). Furthermore "a decrease in the share of agricultural value-added leads to a significant increase in urbanization for a panel of 41 African countries during 1960-2007. Poelhekke (2011) explains African urbanization mainly by rural-urban migration as an insurance mechanism for agricultural risk - due to higher aggregate agriculture risk, which induces rural-urban migration." (Arouri et al., 2014, p. 6).

The following quotes focus on low agricultural outcomes and the push towards urban living.

- "Low agricultural productivity in turn leads to poor conditions of life in rural areas, further compelling people to migrate to the cities." (Cheru, 2005, p. 7)

- "Slow-growing, rapidly urbanizing countries in Africa may thus be experiencing "push" rather than "pull" urbanization, resulting from agricultural stress (Annex & Buckley, 2009, p. 7-8)

- "the pressures of agricultural production forcing rural inhabitants off the land." (Cohen 2009, p. 10

Descriptor Relationship: Quality of Governance on Urbanization

"Weak local government creates and exacerbates problems including the lack of appropriate regulatory structures and mandates; poor or no planning; lack of or poor data; lack of disaster risk reduction strategies; poor servicing and infrastructure (particularly waste management and drainage)" (Niang et al., 2014, p. 1225). According to this information it can be assumed that low quality of governance promotes rapid unplanned urbanization.

Large scale cities require complex management systems and active government participation (Arouri et al., 2014) "the data and analysis necessary to inform policy at country and city scales are inadequate or just do not exist. Urbanization management needs to produce open data helping researchers and policymakers to do the right analysis and take the right decisions. Unfortunately, urban statistics for Africa may be "highly suspect," and many can be shown to be "downright wrong." (Arouri et al., 2014: 18).

"Researchers, governments, international organizations and donors now seem to agree that it is urgent to develop consistent policy actions in urban planning and governance in Africa in the next decades, as African cities are expected to become home of more than half of Africa's population by 2030" (Arouri et al., 2014, p. 2). With improved quality of governance there is

greater understanding and awareness of the need for this policy as referenced above. As such high and medium governance is associated with promoting planned urbanization.

Higher quality of governance tends to push for planned urbanization outcomes, or further enables people to stay in rural areas because government is accounting for their needs and is free of corruption. "Policies that favor city dwellers - can push rural residents to cities" (Bloom, Canning & Fink, 2008).

"Governments have often tried to influence the pace or location of urbanization" (Arouri et al., 2014, p. 2). With higher quality levels, we are assuming that government has a better understanding of the needs of their country and how to best promote their influence for pace and location.

"The provision of urban infrastructure is key for boosting the urbanization dividend." (Arouri et al., 2014, p. 18). The planned pathway outcomes are the states that support the benefits of urbanization, as such the influence of higher quality of governance is associated with improved provision of infrastructure as well as policies.

When it comes to the influence of governance, mismanagement associated with the poor quality of governance promotes the lack of planning associated with rapid unplanned; "municipal governments tend to be poor and unable to provide basic services, including operation and maintenance of basic infrastructure such as roads or drainage" (Cohen 2009, p. 31).

Descriptor Relationship: Extreme Poverty on Urbanization

"Increasing numbers of the world's urban population live in slums" (Cohen 2009,10). These informal settlements are where impoverished individuals live. The number of people residing in urban slums, "was estimated at 924 million in 2003 by the Millennium Development Project, with the expectation that most of the projected 2 billion additional urban residents would live in poor housing conditions, lacking clean water supply and sanitation as well as other needed infrastructure services such as drainage, solid waste collection, and electricity" (Cohen 2009,10). This direct influence between extreme poverty and urbanization is only described along the high pathway for extreme poverty. High levels of extreme poverty are associated with rapid unplanned urbanization. As the number of people living in extreme poverty increases, the number of individuals residing in urban slums increases. "Each of these dimensions of urban life has become a source of vulnerability, for individuals, families, and urban communities. The dimensions lie on top of each, as layers of vulnerability, creating cumulative disadvantages and risks" (Cohen, 2009, p. 13).

A1.5 Direct Influences on Extreme Poverty:
The Millennium Development Goal related to poverty, took aim at reducing the number of people living on less than US$1.25 per day by 50% (UN ESA, 2009). "In absolute terms, extreme income poverty has fallen substantially, with the number of people living on less than $1.25 a day having declined from a high of 1.9 billion in 1981 to a low of 1.4 billion in 2005. In relative terms, the proportion of people living in extreme poverty dropped from 52.0 to 25.7 per cent during this period (Chen and Ravallion, 2008)." (UN ESA, 2009, p. 13-14).

"Although the income-based (per capita) conventional poverty measure is sensitive to population growth, careful analysis does not provide any support for the Malthusian claim that poverty can be attributed to population growth in excess of output growth, especially food production. Instead, the demographic transitions experienced by a wide variety of societies suggest that family sizes tend to decline with higher in- comes and greater economic security. Conversely, poor families tend to have more children in the hope of increasing contributions to household income as well as of ensuring continued economic security as parents age (Leibenstein, 1957; Mamdani, 1972; Robbins, 1999)." (UN ESA, 2009, p. 15).

While there have been some notable declines in extreme poverty in East Asia, other regions such as sub-Saharan Africa and South Asia are still plagued by high extreme poverty levels.

Direct Influences on Extreme Poverty:

- Population
- Income per capita
- Agricultural Productivity
- Quality of Healthcare
- Educational Attainment
- Quality of Governance

Descriptor Relationship: Population on Extreme Poverty
Higher fertility levels, which describe the high state, are associated with higher levels of extreme poverty, and make escaping extreme poverty more difficult. The following key quotes from literature support this influence pattern.

- "high fertility reinforces poverty and makes an escape from poverty more difficult." (Sinding, 2009, p. 3025).
- "High fertility exacerbates poverty or, better put, that high fertility makes poverty reduction more difficult and less likely" (Sinding, 2009, p. 3025).
- "with fewer children to care for and raise, families can improve their prospects for escaping the poverty trap." (Sinding, 2009, p. 3030).

Descriptor Relationship: Income per capita to Extreme poverty:
"Economic growth is an exceedingly powerful way to reduce poverty" (Bloom & Canning, 2000, p. 1207). As such the direct influence from income per capita will be reflected as follows, with high income restricting high extreme poverty, and low income promoting high levels.

"Poverty trends are arithmetically related to trends of economic growth per capita (mean income) and income distribution" (UN DESA, 2009, p. 42). According to the UN Division of Economic

and Social Affairs, their simple arithmetic identity shows "poverty reduction will be faster when the growth of per capita income is higher and/or when income distribution is improving." (UN DESA, 2009, p. 43). Furthermore, literature suggests that in low income countries changes to income levels has a greater initial impact than in more developed nations with already well-established economies with greater equality. "The global economic crisis is adding additional constraints on economic development efforts, leading to increased loss of livelihood and widespread poverty" (Niang et al., 2014, p. 1211).

Saachs (2005) finds that economic growth is the most powerful mechanism for reducing extreme poverty but not the only factor. Using the metaphor of a rising tide not lifting every boat he says "average income can rise, but if the income is distributed unevenly the poor may benefit little, and pockets of extreme poverty may persist" (Saachs, 2005, p. 59).

Descriptor Relationship: Agricultural Productivity to Extreme Poverty

This influence is similar to the relationship between agriculture to income per capita, but more pronounced. Agricultural productivity increases can directly pull individuals out of extreme poverty, past the threshold point of $1.90 a day which defines the low extreme poverty pathways. "Increases in agricultural productivity are central to growth, income distribution, improved food security and alleviation of poverty in rural Africa (FAO(a) ,2002)" (Okpachu et al., 2014, p. 27). Okpachu et al., (2014) adds that "development, food security and poverty alleviation will not be truly achieved without rapid agricultural growth" (27).

Descriptor Relationship: Quality of Healthcare to Extreme Poverty

The following quotes from literature support the direct relationship between health and poverty, with improvements to health, reducing poverty.

- "health improvements are disproportionately beneficial for the poor, as they depend on their labor power more than any other segment of the population" (Bloom & Canning 2000: 1207).
- "Ill-health limits people's ability to earn higher incomes, and contributes to poverty" (WHO, 2003, p. 26).
- In reference to the Millennium Development Goals that preceded the updated SDGs "in many countries, it will be impossible to achieve a 50% reduction in income poverty (Goal 1, Target 1) without taking steps to ensure a healthier population" (WHO, 2003, p. 27).
- "reducing health risks among the poor is a powerful tool for poverty reduction" (WHO 2003, p. 100).
- "the burden of malnutrition has been directly linked to poverty" (Bail et al., 2013, p. 4).

Descriptor Relationship: Educational Attainment to Extreme Poverty

The UN Department of Economic and Social Affairs (2003) Concise Report on Population, Education and Development found in their review of relevant literature "that primary education is a potent means of reducing poverty and inequality, with particularly marked benefits for the poorest segments of society" (UN DESA, 2003, p. 6). Other benefits were identified including the relationship between primary education and higher rates of technology transfer and innovation.

Descriptor Relationship: Quality of Governance to Extreme Poverty

Saachs (2005) article "Can Extreme Poverty Be Eliminated?" argues that "extreme poverty persists because governments fail to open up their markets, provide public services and clamp down on bribe taking" (Saachs 2005, p. 58). The article further references that if governance were to clean up mismanagement and cut back on corruption, development and poverty could be better address. Furthermore, "government spending, directed at investment in critical areas, is itself a vital spur to growth, especially if its effects are to reach the poorest of the poor" (Saachs 2005, p. 59). Direct investment in key areas is a feature that we can assume is more closely aligned with higher quality of governance, greater stability, and less corruption. "Corruption in the public sector -- the misuse of public office for private gain -- is often viewed as exacerbating conditions of poverty" (Chetwynd, Chetwynd, & Spector 2003, p. 3).

A1.6 Direct Influences on Quality of Healthcare

Quality of healthcare is represented by the under-five mortality rate. The under-five mortality rate is defined as the probability per 1,000 births that a newborn will die before reaching age five. The United Nations Department of Economic and Social Affairs Report on Population (2015) cites the under-five mortality rate as "an important indicator of development and the well-being of children" (UN DESA, 2015, p. 6).

Globally as well as in LICs the under-five mortality rate has been falling. Globally, the number of deaths per 1000 live births fell from 71 from 2000-2005, to 50 in 2010-2015 (UN DESA, 2016). While the global level reached 50, in 2010 the under-five mortality rate for lower-income countries was just over 100. There is significant progress being made, "between 2000-2005 and 2010-2015, under-five mortality has decreased by more than 20 per cent in 156 countries, with widespread reductions of 20 per cent or more recorded in Africa (42 out of 57 countries)," (UN DESA, 2015, p. 11). The reduction of under-five mortality, which has received intense global attention as the target of Millennium Development Goal 4, has proceeded swiftly in many countries in the past decade. "Absolute declines were particularly large in Sub-Saharan Africa (142 to 99 per 1,000) and in the least developed countries (125 to 86 per 1,000). In the majority of countries in Sub-Saharan Africa and the group of LDCs, the annual pace of decline in under-five mortality accelerated after 2000." (UN DESA, 2015, p. 6). This rate varies across Africa but in some countries infant mortality rates are substantially higher than the global average and the LIC average. In Chad for example "209 out of 1,000 children die before the age of one" and in the "Democratic Republic of Congo 126 children per 1,000 die before the age of five" (World Bank Group, 2013). While some LIC countries in Africa have seen promising declines such as Madagascar, with the largest decline, at 60% (World Bank Group, 2013), other countries have seen increases, for example "infant mortality increased by 21% in Congo Republic during 1990-2009, the largest increase in Sub-Saharan Africa" (World Bank Group, 2013). Overall, Africa has one of the highest under-five mortality rates in the world (Liu et al., 2012). In sub-Saharan Africa, where the majority of Africa's lower income countries are located, there is limited data to inform the causes of under-five mortality, and this region has particularly high mortality rates (Liu et al., 2012).

Many nations face a number of challenges contributing directly to high under-five mortality rates. "In Burundi, 39% of children under the age of five are underweight." (World Bank Group, 2013). "A striking 73.2% (2.600 million) of deaths in children younger than 5 years were due to infectious causes in Africa, which included 95.7% (0.540 million, UR 0.406–0.679 million) of global child deaths due to malaria and 89.5% (0.142 million, UR 0.115–0.166 million) of global child deaths due to AIDS." (Liu et al., 2012, p. 2156).

Direct Influences on Quality of Healthcare:

- Income per capita
- Urbanization
- Educational attainment
- Quality of governance
- Sanitation

Descriptor Relationship: Income per capita to Quality of Healthcare

"Economic capabilities affect health, as low income constrains access to healthcare and health-promoting opportunities." (WHO, 2003, p. 26). The WHO World Health Report (2003) references a study where "data collected by 106 demographic and health surveys in more than 60 countries show that children from poor households have a significantly higher risk of dying before the age of 5 years than the children of richer households" (WHO, 2003, p. 8). The poor in this study is looking at the lowest 20% of income. Though this result may include those in extreme poverty, the influence being discussed remains relevant for income to healthcare. The WHO report continues to reference that the main causes of death among children are closely associated with low income.

Descriptor Relationship: Urbanization to Quality of Healthcare

"Fink and Hill (2013) demonstrate that urbanization significantly reduces under-five mortality in developing countries, from 92 to 56 deaths per 1,000 live births on average between 2001 & 2010." (Arouri et al., 2014, p. 8). Urban populations have more chance to reach hospitals, care centres and sanitation. Health care systems are also more developed, which may lead to better health performance than those in rural areas. We are assuming that these benefits of urban conditions are associated with the planned states for urbanization. They provide improved proximity and access to healthcare facilities, hospitals and public health information that there is improved health in urban areas.

For rapid unplanned urbanization, there is not the same positive relationship. There is limited data and information as to infant mortality rates in slums, but it can be assumed that the violence, volatility, and unsafe structures would severely impact health. "slum residents live in an environment that poses a daily health threat" (UNDP, 2006, p. 37).

Descriptor Relationship: Educational Attainment to Quality of Healthcare

There is a long-established connection between the role of education in quality of healthcare and specifically to the health of children under the age of five. The United Nations Report on Population and Education (2003) states that "of the socio-economic variables that have been found to be associated with differentials in health and mortality, education is among the strongest and the most consistent. Wherever the relationship has been examined, better-educated people and their family members appear to stay healthier and to live longer lives." (UN DESA, 2003, p. 52). Furthermore, there is evidence of significant variations in child mortality levels in LIC and LMCs when looking at the education levels of mothers. "In practically all countries, children of uneducated mothers have higher relative risks of dying in early childhood than the children of mothers with primary education" (UN DESA, 2003, p. 37). Education impacts access and usage of key health interventions such as immunizations, and healthcare during pregnancy and child delivery. Usage of these healthcare services drops with lower or no education levels. "In close to one quarter or more of the births among uneducated women in Burundi (1987), Nigeria (1990), Rwanda (1992) and Uganda (1988 and 2001-2002), women went through the delivery process alone." (UN, 2003, p. 37). "Since education is associated with lower mortality and better health in virtually all contexts, regardless of educational philosophy and orientation, expanded access to education is likely to lead to gains in health and survival. In brief, for both children and adults, better education is associated with significant improvements in health, reduction of mortality, and longer life" (UN DESA, 2003, p. 50). "In developing countries, education, especially that of mothers, has been found to significantly differentiate levels of child mortality. In practically all

countries, children of uneducated mothers have higher relative risks of dying in early childhood than the children of mothers with primary education" (UN DESA, 2003, p. 37).

"under-5 mortality rates improve as mothers' education levels rise," (Todaro & Smith, 2012, p. 60)

"eliminating gender disparities and increasing enrolment rates for primary education are prerequisites for success in improving health outcomes" (WHO, 2003, p. 27).

Descriptor Relationship: Quality of Governance to Quality of Healthcare
According to Niang et al., 2014 drivers of climate related health outcomes include poor governance. "Improving government policy, increasing political will and application of community adapted strategies" in tackling malnutrition. (Bain et al., 2013, p. 6). Gupta & Abed (2002) find that countries that tend to have corruption in government experience higher rates of child mortality. In fact, "infant mortality rates in countries with high corruption, for example, could be almost twice as high as in countries with low corruption" (Gupta & Abed 2002:265). Their results found that "countries with low corruption and high quality of health care provision tend to have fifty-nine fewer child mortality per 1,000 liver births than countries with high corruption and low quality of health care provision" (Gupta & Abed, 2002, p. 253). Furthermore their "results show that better health care and education indicators are positively and significantly correlated with lower corruption" (Gupta & Abed, 2002, p. 258).

Gupta & Abed's (2002) book "Governance, Corruption, and Economic Performance" "discuss the dominant role played by government in the provision of health care" (272). They find that "countries with less corruption and higher predictability of corruption tend to have better quality of health care and more efficient provision of public services" (Gupta and Abed, 2002, p. 251).

Descriptor Relationship: Sanitation to Quality of Healthcare
The following quotes from literature support the positive relationship between sanitation and healthcare:
"Although progress has been made on improving safe water and sanitation coverage, sub-Saharan Africa still has the lowest coverage, highlighting high vulnerability to the health risks of climate change (UNICEF and WHO, 2008, 2012)" (Niang et al., 2014, p. 1222).

"Poor sanitation is responsible for one of the heaviest existing disease burdens worldwide. The diseases associated with poor sanitation and unsafe water account for about 10% of the global burden of disease. Diseases associated with poor sanitation are diarrhoeal diseases, acute respiratory infections, undernutrition and other tropical diseases such as helminth and schistosomiasis infections. Diarrhoeal diseases are the most common sanitation related diseases. **Globally, about 1.7 million people die every year from diarrhoeal diseases, and 90% are children under 5 years, mostly in developing countries.** Eighty-eight percent of cases of diarrhoeal diseases worldwide are attributable to unsafe water, inadequate sanitation, and poor hygiene." (Van Minh & Nguyen-Viet, 2011, p. 64).

"In cities and neighborhoods well served by piped water and sanitation, child mortality rate are generally around 10 per 1,000 live births. On the other hand, in cities and neighborhoods with

inadequate provision of water and sanitation, mortality rates are commonly 10 to 20 times higher (Shi, 2000; Woldemicael, 2000:207-227). The water and sanitation-related health burden for children under five in Africa, for instance, is up to 240 times higher than it is in high-income countries." (Cheru, 2005, p. 4-5)

"Poor sanitary conditions create health problems which reduce physical strength and the number of days earning wages" (Cohen 2009, 10).

A1.7 Direct Influences on Water Scarcity

Africa is a continent characterized by "a large and rapidly growing population, enormous expanses of dry land, extensive poverty, lack of investment in water infrastructure, and chronic health problems" (Vörösmarty et al., 2005, p. 230). Water stress is currently a challenge globally and is expected to worsen significantly as temperatures increase. Given the importance of water to human life, shortages will have a ripple effect through society, affecting development, health, food security, among other things (Vörösmarty et al., 2005). Vörösmarty et al., (2005) analyzed water stress in Africa to find over fifty percent of Africans rely on a highly variable water source. Given the low development status of LICs and LMCs in Africa, their water use is actually rather low, this is largely attributed to the minimal water infrastructure reducing overall use. As development continues forward though, increased uses in water will boost economic growth, but also impact water stress. Furthermore, given the importance of agriculture, water stress is expected to become an even more pressing issue. "A significant fraction of cropland resides in Africa's direst regions, with 39% of the irrigation non-sustainable" (Vörösmarty et al., 2005, p. 230). An additional constraint to water stress, is the limited data on water resources in Africa. "Since 1990, there has been a 90% reduction in routine reporting of African river discharge (an important source of water supply data) to relevant international agencies" (Vörösmarty et al., 2005, p. 230). The continent as a whole has been plagued by persistent droughts, and with continued developmental challenges, water scarcity will be a critical issue in coming years. The surprisingly modest levels of people affected my water stress is not an indicator of a lack of water shortages, but rather development challenges linked to extreme poverty, lack of access to sanitation services, and clean water infrastructure, as Africa as a continent has the lowest water access coverage in the world (Vörösmarty et al., 2005).

"Most of Africa's continental area, 82%, is arid and semiarid, with evaporative demands exceeding rainfall over the bulk of the landmass" (Vörösmarty et al., 2005, p. 231). It almost goes without saying, but the majority of the continent of Africa is dry and water-scarce. "Approximately 75% of all Africans live in the aid and semiarid regions of the continent," (Vörösmarty et al., 2005, p. 233) and roughly 20% "live in areas that experience high interannual climatic variability," (Vörösmarty et al., 2005, p. 233). "With regard to water resources, more than 60% of Africans live with mean locally generated runoff of approximately 300 mm y1 or less, and about 40% live with less than 100 mm y1." (Vörösmarty et al., 2005, p. 233).

Direct Influences on Water Scarcity:

- Population
- Income per capita
- Agricultural productivity
- Urbanization
- Governance

Descriptor Relationship: Population to Water Scarcity

Water scarcity is expected to be influenced by a number of socioeconomic factors. The IPCC WGII regional Chapter on Africa specifically references the impacts on the Zambezi River Basin, where it is expected that non-climate drivers will have a greater influence on water availability than climate change. The IPCC further reports that they expect climate change impacts on water scarcity in Africa to be minimal in comparison to "**population growth**,

urbanization, agricultural growth" (Niang et al., 2014, p. 1217). This statement is supported by a high level of confidence. Furthermore, in this regard the IPCC anticipated climate change impacts on groundwater to also be modest in comparison to the aforementioned socioeconomic determinants (Niang et al., 2014). Specifically, in areas of North Africa by 2050 Droogers at al. (2012) estimates "78% of increased future water shortages (to) be attributed to socioeconomic factors" (Niang et al., 2014, p. 1217). Overall, population growth is expected to have a far greater impact on resources than climate change warming of around 2 degrees Celsius (Jiménez Cisneros, et al., 2014).

The following quotes from literature further support the influence of population to water scarcity:
There is evidence that even in areas with low water stress, such as Lake Victoria, "there is evidence of population and development pressure on water supplies" (Vörösmarty et al., 2005, p. 234)

Population is categorized as an important non-climatic driver to water availability (Jimenez-Cisneros et al., 2014). Increases in the frequency and severity of droughts along with expected increases to population will put water supplies at increased stress (Jimenez-Cisneros et al., 2014).

"Under a scenario of moderate population growth (UN, 2011), the global number of exposed people is projected to increase by a factor of 7 to 25, depending on the RCP, with strong increases in Asia and Africa due to high population growth." (Jimenez-Cisneros et al., 2014, p. 248).

"over the next few decades and for increases in global mean temperature of less than around 2°C above preindustrial, changes in population will generally have a greater effect on changes in resource availability than will climate change." (Jimenez-Cisneros et al., 2014, p. 250).

Descriptor Relationship: Income per capita to Water Scarcity
Increases in economic development promote increases in water use and demand (Jimenez Cisneros et al., 2014). GDP is listed as a socioeconomic non-climate driver of water stress, affecting hydrological changes (Jimenez-Cisneros et al., 2014). The UNDP (2006) Human Development Report lists income growth as a factor that increases water demand. As income increases, water use tends to also increase. "Population growth, rising incomes, changing dietary patterns, urbanization and industrial development will increase demand for what is essentially a fixed supply of water." (UNDP 2006, p. 173). The influence is weak overall, so it is represented by 1 and -1.

Descriptor Relationship: Agricultural Productivity to Water Scarcity
Agriculture, a driving force in low and lower-middle income economies, however agriculture has a strong direct influence on water availability. A number of deltas and watersheds in Africa are estimating future water shortages at the hands of climate change and changes to precipitation patterns but also as a direct result of increased withdrawals for the purpose of agricultural irrigation (Niang et al., 2014).

"Water shortages are also estimated for the Okavango Delta, from both climate change and **increased water withdrawals for irrigation** (Murray-Hudson et al., 2006; Milzow et al., 2010; Wolski et al., 2012), and the Breede River in South Africa (Steynor et al., 2009). (Niang et al., 2014, p. 1217).

"Reduced flows in the Blue Nile are estimated by late century due to a combination of climate change (higher temperatures and declining precipitation) and **upstream water development for irrigation and hydropower** (Elshamy et al., 2009; McCartney and Menker Girma, 2012)." (Niang et al., 2014, p. 1217)

"future agricultural land use, especially irrigation, which accounts for about 90% of global water consumption and severely impacts freshwater availability for humans and ecosystems (Döll, 2009)." (Jiménez Cisneros, et al., 2014)

A large portion of agricultural activities in our study site, take place in dry regions, these regions obviously require greater irrigation than more humid areas. Irrigation is essential in arid and semiarid zones (Vörösmarty et al., 2005). "In the direst cropped areas, 97% of agricultural area is irrigated. Across these areas, irrigation withdrawals (43 km3 y1) exceed locally generated runoff (5 km3 y1) by almost an order of magnitude, necessitating use of river corridor flows or aquifer mining. (Vörösmarty et al., 2005, p. 233). Irrigation in dry regions "may seriously compromise the integrity of an important renewable resource on which both human society and aquatic ecosystems depend" (Vörösmarty et al., 2005, p. 233).

Descriptor Relationship: Urbanization to Water Scarcity

The concentration of people in urban areas "challenge(s) the sustainability of resources by decreasing water supply or increasing demand" (Jimenez-Cisneros et al., 2014, p. 234). In the IPCC Working Group 2 Chapter on Freshwater Resources, Jimenez-Cisneros et al., (2014) list urbanization as an important non-climatic driver impacting the quantity and quality of water resources. Furthermore, increasing urbanization affects streamflow, and decreases groundwater recharge. The UNDP (2006) Human Development Report projects water use in urban areas and industry to double by the year 2050. "As urbanization and the growth of manufacturing continue to gather pace, demand for water from industry and municipalities will continue to grow" (UNDP 2006, p. 137). "Urbanization and industrial development will increase demand for what is essentially a fixed supply of water" (UNDP 2006, p. 173). Given that we describe planned urbanization pathways to have infrastructure including water services, we are assuming these states will be associated with increases in water use. Given that rural areas and informal settlements tend to have reduced piping for water, we are assuming they have less of an impact on promoting increased water scarcity.

Descriptor Relationship: Governance to Water Scarcity

"Governments in water-stressed regions have started to acknowledge the need to tackle unsustained hydrological debt" (UNDP 2006, p. 141). "In all countries the relationship between water security and water availability is mediated through the infrastructure and institutions that govern water" (UNDP 2006, p. 155). The UNDP Human Development role references the need for demand management and the use of restrictions, and institutional frameworks for balancing use and needs. The report references geographical examples of frameworks that involve

extraction rates, as well as legislation in South Africa for water use permits. These examples of government actions "demonstrate how governments are now being forced to respond to the consequences of past public policy mistakes" (UNDP 2006, p. 141), however the future approaches will need to be much more radical in nature. "Efforts to realign supply and demand through administrative reallocation under conditions of water stress present major governance challenges" (UNDP 2006, p. 143). The ability of government to handle these water challenges will depend on their quality of governance. High governance with greater stability and lacking corruption will be better aligned to face these challenges, than a low pathway where there is a lack of regulatory control, rampant corruption and instability. "The core challenge in water governance is to realign water use with demand at levels that maintain the integrity of the environment" (UNDP 2006, p. 147).

Additional examples from literature:
"A core aim of integrated water resources management is to adjust water use patterns to water availability, taking into account the needs of the environment. Achieving this goal requires a high level of information about water resources. It also requires a capacity on the part of national and local governments to implement pricing and allocation policies that constrain demand within the bounds of sustainability. Effective national planning has to make provisions for the environment as a water user" (UNDP 2006, p. 147).

If governments were to increase prices "while implementing policies to protect the interests of poor farmers has the potential to advance both efficiency and environmental sustainability goals" (UNDP 2006, p. 147).

"By enshrining the polluter pays principle in tax provisions and enforcing strong environmental laws, government policies can enhance the water resource base (UNDP 2006, p. 147).

A1.8 Direct Influences on Educational Attainment

"No society can consider itself truly developed without its citizens' being educated." (UN DESA, 2003, p. 48). Education has long been regarded as a valuable tool for human and societal development. Since the proclamation of the Universal Declaration of Human Rights in 1948, education has been deemed a right. The endorsement of education's role in a country's development and demographics is continuously recognized by the UN in any major gatherings. Educational attainment is not simply expressed through access and attendance in primary and secondary schooling, and beyond, but in universal access, stressing the importance of inclusive and equitable education for all, that is to say eliminating gender disparity in education, and ensuring all ages are able to access education. For this study, educational attainment is measured by the percentage of people who have undertaken schooling beyond the primary level. The Millennium Development Goals initially set out the goal for universal primary education, however with the acceptance of the new Sustainable Development Goals states one of their education goal aims to be "by 2030, ensure that all girls and boys complete, free, equitable and quality primary and secondary education leading to relvant and effective learning outcomes" (Abel et al., 2016, p. 14295). This addition which is included in our descriptor definition, has been recognized as a result of the findings that universal primary education is not sufficient enough for poor nations to exit poverty, and that secondary education is required (Abel et al., 2016). Our definition does not explicitly include mention of inclusive and equitable access for boys and girls alike but it is to be assumed to be part of this descriptor, as we recognize the significant importance of educational access for females, especially in our country groupings of low and lower middle income countries.

The UN Concise Report (2003) references evidence of the "catalytic role" (48) primary education plays in socioeconomic development for the most disenfranchised in a low income society. A Mingat and Tan (1996) study further supports this theory that primary education served the greatest benefit as an investment for low income countries, for other income levels, returns were higher with investment in secondary and tertiary levels of education as a result of pre-existing high levels of primary education rates. Based on this information, it can be argued that in low income countries the focus should be on investing in primary education, with less resource allocation to subsequent levels of education. As it stands, Africa's low and lower-middle income countries primary school enrolment ratio vary with Eritrea at the low end of the spectrum with 36%, while Sao Tome and Principe have the highest ratio at 97% (World Bank Group, 2013). There is evidence of significant progress to date with primary school completion rates more than doubling in eight Sub-Saharan Africa countries from 1990-2009 (World Bank Group, 2013).

"Education is a long term investment associated with near-term costs, but, in the long run, it is one of the best investments societies can make in their future." (Lutz, Cuaresma & Sanderson, 2008, p. 1048)

"Globally, sub-Saharan Africa has the largest gender disparities in education: the region hosts 55 per cent of the world's out-of-school children and 53 per cent of its out-of-school adolescents. Of the 34 million out-of-school children in the region, half will never enrol." (UNFPA, 2016, p. 37)

Direct Influences on Educational Attainment

- Urbanization
- Quality of Governance
- Sanitation

Descriptor Relationship: Urbanization to Educational Attainment
The following are examples from literature attesting to the relationship between urbanization and education. "Expanding education systems in urban areas is easier and costs less than expanding it in rural areas. Returns to education are thus generally found to be higher in urban than rural areas. The effect of urbanization on education is generally positive" (Arouri et al., 2014, p. 3).

"Urbanization improves access to basic education for all. Expanding education systems in urban areas is easier and costs less than in rural areas" (Arouri et al., 2014, p. 7)

Access to education is improved in an urban setting. With the concentration of people in urban areas, the costs associated with growing educational services is also less costly in an urban setting versus a rural setting. The percentage of the population attending school is expected to be higher as urbanization continues. Furthermore there is family and individual incentive to seek further education, beyond primary level for example in an urban setting as the return on investment in education is higher and more evident in an urban setting than in rural areas.

Descriptor Relationship: Quality of Governance to Educational Attainment
Education is crucial to socioeconomic development in all societies, with notable impacts to population and economic well-being (UN DESA, 2003). Since the turn of the 21st century, areas in Africa have gained acceptance for the strong global knowledge economy. This shift has sparked significant growth in higher education enrolment (Kruss et al., 2015). Gupta & Abed (2002) find "that corruption lowers expenditure on education" (230). They go on to add corruption also lowers the quality of the education. "For a given tax system, the higher the level of corruption, the lower the tax revenue and the lower the resources available for funding public provision of certain services, including education" (Gupta & Abed 2002:462). Furthermore, "most corrupt countries choose to spend less on education, since it does not provide as many lucrative opportunities for government officials as other components of spending do (Gupta & Abed, 2002:227). They conclude that "when corruption is reduced the social gains, as measured by improvement in health care and education indicators, are immense" (Gupta & Abed, 2002:265).

Descriptor Influence: Sanitation to Educational Attainment
"Children are prone to the contagion of waterborne diseases without adequate water and sanitation services. When not sick, children and their caregivers without proper access to such services have to allocate their leisure time in order to meet their water and sanitation needs. It is through these health and leisure time use changes that access to water and sanitation services impacts the educational attainment of children" (Ortiz-Correa, 2016, p. 31).

"Estimates suggest that access to water and sanitation services has a positive and significant effect on schooling when measured by the completed number of school years" (Ortiz-Correa, 2016, p. 31).

For children living without access to sanitation or clean drinking water they are more likely to fall ill with a parasite or waterborne disease, which in turn prevent them from being able to attend school (Ortiz-Correa et al., 2016). In addition to the increased risk of illness, children, especially girls may be called upon by the family to collect water. The act of transporting water great distances takes away from a child being in school. There is a positive relationship between improved access to sanitation, and increasing educational attainment, both in the sense of increasing the number of children in school, and in improving their academic standing.

"Women and girls are responsible for water collection in 8 out of 10 households with water off premises, so reducing the population with limited drinking water services will have a strong gender impact." (WHO & UNICEF, 2017, p. 11)

"The World Health Organization estimates that every $1 invested in better access to water and sanitation can re- present returns ranging from $4 to $12. In addition to the economic returns of these investments, the access to such services is essential for the realization of human rights for all" (Ortiz-Correa et al., 2016, p. 31).

A1.9 Direct Influences on Quality of Governance

The definition of good governance is constantly evolving. A Fayissa & Nsiah (2010) article on "The Impact of Governance on Economic Growth: Further Evidence for Africa" examines a number of different definitions beginning with Schneider (1999) definition of good governance as "the exercise of authority, or control to manage a country's affairs and resources" (Fayissa & Nsiah, 2010, p. 2). The United States Agency for International Development includes "values of accountability, transparency, and participation" (Fayissa & Nsiah, 2010, p. 2). And lastly, they include the definition from the United Nations Development Programme in which good governance is defined as "striving for rule of law, transparency, equity, effectiveness/efficiency, accountability, and strategic vision in the exercise of political, economic and administrative authority" (Fayissa & Nsiah, 2010, p. 2). The LICs and LMCs in Africa are not often associated with stable good governance records and are often crippled by stints of corruption and instability. In the past agencies such as the World Bank have attributed blame on lack of good governance in Africa, for their continued struggles in development (Akokpari, 2004). Across literature there is a common consensus that good governance is essential for development.

Influences on Quality of Governance:

- Income per capita
- Urbanization
- Educational Attainment

Descriptor Relationship: Income per capita on Quality of Governance

There is a positive relationship between income per capita and quality of governance. As income increases, specifically in an equitable manner, promotes inclusion, and gives people a voice and a stronger desire for accountability. Dryden-Peterson et al., (2014) observe that improvements to economic equality improves political stability, increases citizens demands, and reduces violence and corruption. Likewise, Alesina & Perotti (1996) find that income inequality promotes political instability. Futhermore, their results find that "political stability is enhanced by the presence of a wealthy middle class" (Alesina & Perotti, 1996, p. 2). Based on the evidence from literature we are further speculating that as income increases there is greater demand for rule of law in government, stability, and less tolerance for corruption. Overall the relationship is rather weak and represented with lower values than the stronger reverse influence of governance to income.

Descriptor Relationship: Urbanization on Quality of Governance

There is a weak relationship between urbanization and quality of governance, with planned outcomes slightly restricting low governance, and slightly promoting high governance. The social cohesion that tends to increase with urbanization is "very closely linked to governance, particularly at the local level" (OECD, 2005, p. 3).

"an active civil society and broad-based participation by ordinary citizens in the affairs of their communities and local authorities" (UN Habitat, 2016, p. 108)

"rapid urbanization, the demand for equal access to better public services will continue to increase"

Descriptor Relationship: Educational Attainment on Quality of Governance

There is a positive relationship between educational attainment and quality of governance. Dryden-Peterson et al., (2014) find that higher levels of educational attainment contribute to three important elements of good governance: "voice and accountability, control of corruption, and political instability and violence." As higher percentages of the population gain access to education beyond the primary level, they are likely to be more informed, and in turn more engaged in the political system. Furthermore, education improves social cohesion, and knowledge, increasing involvement in government, and demand for accountability from government officials. As a higher percentage of the population attains schooling beyond the primary level, they are likely to become more aware of government programs, and engage in political discussion, in turn seeking more from their government.

A1.10 Direct Influences on Sanitation

"A major risk factor for infectious diseases and mortality is the lack of safe water, sanitation and hygiene (WASH) services, which disproportionately affects sub-Saharan Africa" (UN ESC, 2017:6)

"Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and feces. An improved sanitation facility is one that hygienically separates human excreta from human contact. Improved sanitation generally involves physically closer facilities, less waiting time, and safer disposal of excreta." (Van Minh & Nguyen-Viet, 2011, p. 64). As it stands, access to sanitation in Africa's LICs and LMCs is low. "The UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water GLAAS indicates that 2.5 billion people do not have access to improved sanitation and around 1 billion people are forced to practice defecation in 90% of the rural areas" (Ortiz-Correa, 2016, p. 31). The current Sustainable Development Goals aim to address sanitation by ending open defecation, achieving universal access to basic sanitation services. In 2015, a total of 181 countries recoded basic drinking water service coverage levels in excess of 75%, and 154 countries for 75% coverage in sanitation services (WHO & UNICEF, 2017). The countries with strikingly low coverage levels where almost entirely located in sub-Saharan Africa.

In our study's definition of sanitation, we are including parasite prevalence, as the incidence of parasite contamination and the spread of waterborne diseases increases significantly with limited access to proper sanitation services and safe and clean drinking water. There are five main routes for which water-related diseases spread: "waterborne diseases (like cholera and typhoid), water-washed diseases (for instance, trachoma), water- based diseases (such as schistosomiasis), water-related and vector-borne diseases (such as malaria, filariasis, and dengue), and water-dispersed infections (such as legionellosis)" (Ortiz-Correa et al., 2016, p. 31). By improving access to sanitation services and clean water, the incidence of these diseases can be significantly reduced. As such, a low pathway where more than 20% of the population lacks access to sanitation, the incidence of parasites and waterborne diseases will be high, and inversely with the high pathway there will be less of a likelihood of contamination.

When it comes to access to safely managed drinking water sources, sub-Saharan Africa's coverage is about 24%, with greater access in urban areas (WHO & UNICEF, 2016). This coverage is ten percent lower than the global estimate for all least developed countries.

Influences on Sanitation:

- Average Income per capita
- Urbanization
- Extreme Poverty
- Quality of Governance

Descriptor Relationship: Income per capita on Sanitation

Higher levels of income per capita increase access to sanitation, as individuals are able to afford better facilities such as toilets and water infrastructure. An example from Cheru (2005), Addis Ababa, Ethiopia illustrates sanitation provisions undertaken by people in the absence of proper infrastructure. These include drains, open spaces, and waterways. Others has access to shared pit

latrines, but these facilities also lack proper waste systems. Ultimately, waterborne sanitation systems are far too expensive for the majority of the population. Furthermore, in examples of privatized service provision, households that lack high enough income cannot mean the costs and are denied these water and sanitation services.

Low income areas are often not serviced with effective and essential waste collection services or infrastructure.

"poor populations, vulnerable populations and people living in remote communities or informal settlements often do not have the financial means to obtain or connect to existing water and sanitation services, let alone pay for the cost to sustain these services." (WHO, 2017, p. 37).

Descriptor Relationship: Urbanization to Sanitation

"Within developing countries, urban sanitation coverage is 71%, while rural coverage is 39%."(Van Minh & Nguyen-Viet, 2011, p. 64)

Urbanization taking place in Africa's LICs and LMCs is taking place at rapid rates. This rapid urbanization, along the medium and high pathways leads to deteriorating infrastructure and the delivery of basic services such as clean water and sanitation services. To date, "the rapid expansion in urban population has occurred without the needed expansion in basic services" (Cheru, 2005, p. 5). This is currently the case as urbanization rates are surpassing the rate at which infrastructure can be expanded to accommodate the additional people. However overall, despite the stress on services with the influx of people moving into urban centers, the provision of sanitation services still remains higher than in urban areas, therefore the relationship is illustrated as positive.

The following quotes from literature further support the direct influence between urbanization and sanitation:

"While universal use of private toilets accessible on premises remains the ultimate goal, high-quality shared sanitation facilities may be the best option in the short term in some low-income urban settings. Sixteen of the 24 countries in which at least one person in five has limited sanitation services are found in sub-Saharan Africa (Figure 21). In these countries, the proportion sharing facilities is larger in urban areas." (WHO & UNICEF, 2017, p. 15).

"For example, Angola has relatively high coverage of basic drinking water compared to other countries in sub-Saharan Africa, but there is an 40 percentage point gap between urban and rural areas and a 65 percentage point gap between the richest and poorest quintiles." (WHO & UNICEF, 2017, p. 34).

Of those who still must practice open defecation, 9 out of 10 people live in rural areas (WHO & UNICEF, 2016).

According to the WHO (2017) urban areas receive upwards of three times the funding for sanitation and drinking water services than rural areas, even though access in rural areas is lower

than urban. The concentration of people allows for the funding to service a greater number of people.

"30 Yet the combination of rapid demographic growth, growing demand for essential urban infrastructure and social services, and inadequate resources to deliver these services creates severe challenges for urban governance. Local governments are increasingly unable to satisfy the scale and composition of demands coming from urban civil society. It is thus not surprising that the fundamental issues of urban life, from housing to water to waste removal to basic health care and education all become politicized and create opportunities for conflict" (Cohen, 2009, p. 12-13).

Descriptor Relationship: Extreme Poverty on Sanitation

Extreme poverty limits access to safe clean water and sanitation services, and increases exposure to open sewers, environmental risks, parasite prevalence and unsanitary water and services. "The urban poor are overexposed to environmental risks and life threatening diseases associated with inadequate water provision; diarrhoea, cholera and other water-borne diseases" (Cheru, 2005, p. 9).

"Open defecation is one of the clearest manifestations of extreme poverty" (WHO & UNICEF, 2015, p. 5).

Descriptor Relationship: Quality of Governance to Sanitation

The following excerpts from literature illustrate the relationship between quality of governance and access to sanitation. "Weak local government creates and exacerbates problems including the lack of appropriate regulatory structures and mandates; poor or no planning; lack of or poor data; lack of disaster risk reduction strategies; poor servicing and infrastructure (particularly waste management and drainage)" (Niang et al., 2014, p. 1225)

"One of the reasons for the slow progress in expanding improved sanitation coverage in the world, in general, and in developing countries in particular, is that policy makers and the general public have not fully understood the importance of the improved sanitation solutions. The governments in developing countries tend not to see improved sanitation as a necessary condition of economic development or source of improved welfare, and cost benefit analysis has not been commonly used to justify increasing spending on sanitation programs." (Van Minh & Nguyen-Viet, 2011, p. 64)

"Despite the importance of water and sanitation in the fight against poverty, however, African governments have paid scant attention to the need to formulate appropriate framework to guide the water and sanitation sector and to accelerate investment in order to expand service delivery effectively and efficiently" (Cheru, 2005, p. 8). Furthermore, with the minimal investment and political prioritization, the provision of these services in coverage and delivery is poor and well below adequate thresholds (Davis et al. 2003).

"There are three main challenges in improving the access and quality of water and sanitation services: first, the significant investments in operation and maintenance; second, lack of

governance policies promoting private sector involvement; and, third, difficulties in setting appropriate pricing structures [39,9]." (Ortiz-Correa, 2016, p. 32)

"Governments invest in water and sanitation services infrastructure, aiming at achieving full coverage, mainly because of the effects on health: healthier children perform better in school; healthy adults are more productive at work and can take better care of their offsprings; health improves the capital base of the society, because healthy people can save more for retirement; healthy societies have more dynamic economies, because the ratio of workers to dependents increases; and, finally, healthier societies attract more investment and tourism [8]." (Ortiz-Correa, 2016, p. 33)

"Cholera is primarily associated with poor sanitation, poor governance, and poverty" (Niang et al., 2014, p. 1222)

Individuals that are not served by proper sanitation and water infrastructure systems will be forced to seek out other open water sources that may be contaminated putting them at heightened risk (Cheru, 2005)

A1.11 Direct Influences on Technology Transfer

Technology transfer has been a valuable tool for climate change mitigation and adaptation and will continue to play a crucial role in the future (Philibert, 2004). Access to innovative technologies for low and lower-middle income countries will play a crucial role in climate change mitigation, and adaptation. In the past, low and lower-middle income countries have conditionally committed to global accords such as the Montreal Protocol and Kyoto Accord on the premise of acquiring technology. According to the IPCC Working Group 3, "International cooperation can play a constructive role in the development, diffusion and transfer of knowledge and environmentally sound technologies" (IPCC, 2015).

There is no apparent consensus on defining technology transfer, but overall the focus is on the diffusion and implementation of technologies, whether it be information, or hardware, from one stakeholder to another, either within a country, or between countries, governments, the private sector, NGOs, or other groups (IPCC, 2000), or more simply put "technology transfer means the use of equipment and/or knowledge not previously available in the host country" (Haites et al., 2006, p. 329). The technology being adopted presents the receiving party with an opportunity to address complex problems, through alternative methods, not previously accessible to them (Rogers, 2010). The literature available on technology transfer and its effectiveness is in a constant state of flux (Bozemen, Rimes & Yutie, 2015). . Disproportionately technology transfer research emphasizes "Out-the-Door" as a means of evaluating the effectiveness of the diffusion (Bozemen, Rimes & Yutie, 2015). The "Out-the-Door" criterion however fails to recognize whether the recipient of the transfer has implemented the received technology, or whether it has met local needs, it only focuses on the transfer itself (Bozeman, Rimes & Yutie, 2015). With varying definitions for technology transfer, there are also variations in the stages involved in the transfer. According to the IPCC's report on "Methodological and Technological Issues in Technology Transfer" there are five stages involved in technology transfer, 1. Assessment; 2. Agreement; 3. Implementation; 4. Evaluation; 5. Adjustment and Replication (IPCC, 2000). Rogers (2010) follows a similar pathway, describing the stages of the diffusion of innovations to be; knowledge, persuasion, decision, implementation, and confirmation.

"Innovation is a non-linear and non-sequential process" (Kruss et al., 2015, p. 2). Early literature on the importance of technological development to overall economic development, argued "that technical change and growth depends as much on social as on technical innovations. That is to say, it requires multiple processes occurring simultaneously in production, which in turn requires not just research and development capacity but a variety of skills at all levels of the firm, and processes and systems for harnessing these in order to ensure effective diffusion and adoption of technology (Freeman 1995; Dosi 1998; Lundvall et al. 2002)." (Kruss et al., 2015, p. 2). To date, "the overall track record of donor investments in AET within Africa is riddled with "false starts."(Eicher 2006, p. 5-6). According to Udo & Edoho (2000) information technology (IT) "which continues to revolutionize all facets of life in the developed world have the potential to affect African countries in historic proportions" (329).

In order for technologies to be successfully adopted they require a "support net," a term coined by Zeleny (1986). "This is the complex networks that support the proper implementation and improvement of the technology" (Udo & Edoho, 2000, p. 333). Unfortunately, with most African countries' low development status this support net is lacking. Even if IT was being transferred,

many African countries would lack the infrastructure for the technology to be successfully implemented.

International cooperation in climate change mitigation can have positive knowledge spillovers, and promote both the transfer and diffusion of knowledge and technology (IPCC, 2014C)

Direct Influences on Technology Transfer:
- Urbanization
- Extreme Poverty
- Educational Attainment
- Quality of Governance

Descriptor Relationship: Urbanization to Technology Transfer
Urbanization involves the concentration of people into urban areas, this concentration supports increased culture changes, persuasion, and diffusion of information, which promotes increased technology transfer, and specifically the successful adoption and implementation of technologies into society. "Today in knowledge-intensive globalizing economy where cities have played a central role as agents of innovation diffusion and socio-economic transformation." (Cheru, 2005, p. 5). Urban areas tend to have the sociotechnical infrastructure needed for successful diffusion of IT. "Sociotechnical infrastructure embodies society's institutions, facilities, and organized knowledge" (Udo & Edoho, 2000, p. 333). Furthermore, the support net needed for acceptance of technology often involves infrastructure such as electricity and telecommunications systems which are more common in urban areas.

The concentration of people in urban centres further promotes the diffusion of information and technology. Rogers (2010) Diffusion of Innovations observes that the diffusion of innovations is a social process, whereby social networks of peers' exchange information about new ideas. This diffusion and persuasion enhances the process of technology transfer. Diffusion is defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2010, p. 5). Based on this definition we are assuming that the process of technology transfer will be slightly increased by the concentration of individuals in urban centers.

"Agglomeration effects in cities affect knowledge sharing. By bringing together large numbers of people, cities facilitate the kinds of face to face interactions needed to generate, diffuse, and accumulate knowledge, especially in industries that experience rapid technological change" (Annez & Buckley, 2009, p. 14).

Descriptor Relationship: Extreme Poverty to Technology Transfer
Extreme poverty is an important measure of development status. In LICs and LMCs where there is rampant extreme poverty, the population lacks access to education, sanitation, and reliable water sources. Without these kind of important development measures having been reached, there is not an appropriate environment for technology transfer to take place. This observation of lower development status as a hindrance to technology transfer is observed in literature. "Abject poverty is major challenge that constrains the ability of African countries to take IT revolution seriously" (Udo & Edoho, 2000, p. 335). Furthermore "with low per capita income and declining

standard of living, policymakers in most countries are concentrating their efforts more on meeting the basic needs of the poor masses" (Udo & Edoho, 2000, p. 335).

Udo & Edoho (2000) aptly note that "the experiences accumulated over the years indicate conclusively that technology transfer requires significant investment by the recipient country" (Udo & Edoho, 2000, p. 334). Furthermore Udo & Edoho observe how low income per capita restricts the successful adoption of transferred technologies. With a greater emphasis in technology transfer literature surrounding development status and quality of governance,

Descriptor Relationship: Educational Attainment to Technology Transfer

Literature suggests a strong relationship between higher education and innovation capacity. In this study, our educational attainment descriptor looks at the percentage of people undertaking schooling beyond the primary level, that is secondary or tertiary levels of education. The 21st century has catapulted the global economy landscape to one largely governed as a knowledge economy. This in turn has sparked significant growth in higher education enrolment. Overall though, there remains a lack of strong support for higher education in Africa's low and lower-middle income countries which has limited regions' research capacity.

"A number of other benefits from investments in education and training have been identified. For example, studies have found that primary education contributes to better natural resource management, and more rapid technological adaptation and innovation; and that education is linked with the greater diffusion of information, which is crucial for boosting productivity." (UN DESA, 2003, p. 6).

Lall (1992 and 2001) looked at development economies and pushed the notion "that technology cannot simply be imported without investing in the technological effort to master, acquire, adapt and improve upon existing technologies (Lall and Kraemer-Mbula, 2005)" (Kruss et al., 2005, p. 2). This literature stresses the importance of building the capacity of developing economies through education to support the necessary skills and knowledge to master the new technology. This capacity building is necessary at all levels of organization. "Science and technology links and knowledge exchange with universities, research organisations and other organisations are critical for technological capability building, but equally so are linkages to those organisations or actors that build the skills required at all occupational levels of the firm." (Kruss et al., 2015, p. 3).

"Education capital determines the ability of a nation to develop new technologies and adopt existing technologies" (Arouri et al., 2014, p. 3). Udo & Edoho (2000) observe that "the process of technology transfer is person-oriented" (334). In order for technology transfer to be effective and take root, the recipient country needs a solid knowledge foundation and appropriate level of skills in their human resource pool to use, maintain, and adjust the corresponding technology.

Descriptor Relationship: Quality of Governance to Technology Transfer

Government is instrumental in orchestrating technology transfer and acquiring relevant and appropriate technologies for their country. Unlike company or corporate lead technology transfer,

the purpose of government directed technology transfer is to benefit citizens (Kremic, 2003). "Government wants the benefits of its research and technology developments to reach taxpayers. It also wants the public to recognize the value it adds, and the contribution it makes to public interests. Therefore, government will try to broadcast its technologies to as many as possible" (Kremic, 2003, p. 153). Therefore, the quality of governance plays a crucial role in ensuring appropriate technologies are acquired and with the highest benefit to local citizens and the economy. Kremic (2003) also observes that "the technology transfer process set point, or goal, is to deliver practical benefit to the public for their investment in the research and technology" (Kremic, 2003, p. 150). In good governance countries with limited corruption, the focus of policies is just that, to benefit the public.

For many hardware technologies to be successfully adopted they require a foundation to take root. "A basic challenge for host developing countries is to improve the local environment for ITT and its diffusion. Both FDI and licensing respond to such factors as an effective infrastructure, transparency and stability in government, and a reasonably open trade and investment regime" (Hoekman et al., 2005, p. 1590). This stability and transparency in government is essential to quality governance and ensuring the country has the necessary infrastructure and investment environment for a new technology to take hold. "Governments can reduce the technological distance between local and foreign firms by establishing innovation systems that encourage R&D, transfer knowledge from universities and public laboratories to domestic firms, and promote use of cost-saving technologies." (Hoekman et al., 2005, p. 1590).

An example from Eicher (2006) focuses specifically on the importance of technology transfer for agricultural productivity, as previously discussed in the agricultural productivity section, but references the role of government in supporting the acquisition of important agricultural technology. "Many African countries are relying on foreign aid to finance 30 to 40 percent of their agricultural research budgets" (Eicher, 2006, p. 19), compared to successful agricultural research countries such as Malaysia where the government finances 95% of agricultural research. "The government can play a critical role in investing public funds to support research, higher education and the promotion of export crops, and can creatively use trade to build up the economy." (Eicher, 2006, p. 19).

There is a strong consensus in the literature surrounding technology transfer and LICs and LMCs in Africa. "A national vision that meets national needs must be developed to ensure that the technological development is driven by the needs and participation of communities at local and national levels" (Udo & Edoho, 2000, p. 338). There is a resounding consensus that governments should take the lead as "''awareness catalysts'' by providing a policy framework and infrastructure and by promoting wider use of IT." (Udo & Edoho, 2000, p. 335). There is strong mention of political stability for supporting appropriate policies at the local and national level, to create an effective environment for research and development. African countries require good governance to implement technology policy; "a set of principles with which African countries can regulate their acquisition, utilization, and institutionalization of IT for the purpose of achieving national development objectives" (Udo & Edoho, 2000, p. 338). As a result of this strong relationship, and the agreement in the technology transfer scholar community, the relationship is reflected with -3 and +3.