Gendered Climate Justice: Identifying Vulnerability in Tanzanian Waterscapes

By
Emma Elizabeth Seagle

Honors Essay
Department of Geography
University of North Carolina

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I. INTRODUCTION

Water access is a critical issue on the global scale. The World Health Organization estimates that 780 billion people lack access to proper water and sanitation facilities worldwide (West, Hirsch, and El-Sadr, 2013). Access to safe drinking water and proper sanitation is a basic universal need and human right. Yet, inadequate water supply and water contamination account for one third of all deaths in developing countries and pose a serious threat to the achievement of the Millennium Development Goals (MDG), a set of targets established by the U.N. for 2015 (Kiongo, 2005). Water access is key to building capacity, creating markets, adapting to changing environments, promoting education, and improving health and overall human development (Bour, 2004). Adequate water supply also contributes to food security and positive social development. According to the U.N, in 2012, sub-Saharan women spent roughly 200 million hours per day collecting water, summing to 40 billion hours in one year (United Nations, 2012).

The issue of water security is particularly prominent in Africa where, in 2005, a mere 38% of countries were on track to achieve water related MDGs. Specifically goals to reduce the proportion of people living without access to safe drinking water by 50% have not been met (Kiongo, 2005). Tanzania has achieved minor progress towards these goals; however, is not expected to attain the originally established U.N. criteria by the 2015 deadline (Tanzania, 2011). This study investigates the impact of water infrastructure and women's empowerment on women's health and well-being, and identifies vulnerability through combining these relationships with climate change predictions.

The deepening water crisis in Tanzania exacerbates poverty and poses severe problems for health, education, and development in the country. Due to the gendered nature of water collection, women are particularly vulnerable to the detrimental health and socioeconomic consequences of limited water resources (Ehrhardt, 2009). This vulnerability stems from social, historical, spatial, and ecological factors that produce a self-sustaining and reinforcing system of inequality and social order (Sultana, 2009). The lack of proper infrastructure and monitoring systems throughout the country also prevents equal and regular access to clean water within reasonable walking distance (Baumann et al, 2005). Recent concerns regarding water access and security are increasing in intensity due to rapid population growth, land use shifts, and climate change (Dessu and Melesse, 2012). This change, paired with environmental degradation, leads to potential water catchment deterioration and a decrease in water quality (Kiongo 2005). The interaction among political, historical, social, and ecological systems also leads to questions regarding who bears the burden of unwanted climate change: the global north or south, and women or men. Together these factors interact to dramatically impact women's health and well-being, in Tanzania, as well as, many countries around the world (Bour, 2004).

This Study

Tanzania is characterized by an ever-increasing demand for water due to high fertility rates, population growth, and a climate marked with long, and in some regions biannual, dry seasons (Dessu and Melesse, 2012). This water crisis is fueled by significant human induced land use and climate changes that complicate the collection and distribution of clean and safe drinking water. Therefore, water supply and procurement remain significant problems throughout much of the country, especially in rural and remote areas that lack capital and proper infrastructure (Noel, Soussan, and Barron, 2007). Boreholes are common sources for water extraction, yet issues of sustainability, sanitation, and government regulation and responsibility are called in to question as many of these mechanisms are frequently found broken or otherwise inadequate (Fontana and Natali, 2008). Further problems develop at the social level when one examines the complicated and gendered nature surrounding Tanzanian waterscapes and where responsibility for water procurement rests (Arora-Jonsson, 2011). Yet the potential effects of future climate change on women's health have not been adequately assessed.

Previous literature has assessed the ecological outcomes of climate change, including its impact on species distribution, ecosystem function, and temporal variability in weather systems; however, there is a lack of analysis that directly examines the effects of climate on women's health from the lens of water availability, procurement, and the built environment. The IPCC acknowledges this and admits to academia's shortcomings in its claim:

> Disasters affect men and women differently on a number of levels, including economically, socially, psychologically, and in terms of exposure to risk and risk perception. However, there remains a general lack of research on sex and gender differences in vulnerability to, and impacts of climate change especially health-related impacts (WHO, 2011).

The IPCC is echoed by the Indian Government's National Action Plan on Climate Change (NAPCC, 2008) that acknowledges general impacts of climate change on health, yet fails to explain the gendered complexity of the crisis and generate a plan to solve this global issue that drastically influences the livelihoods of women across the world. The NAPCC states,

> The impacts of climate change could prove particularly severe for women. With climate change there would be increasing scarcity of water, reductions in yields of forest biomass, and increased risks to human health with children, women, and the elderly in a household becoming the most vulnerable…special attention should be paid to the aspects of gender (NAPCC, 2008).

Unfortunately, these blanket statements produced by national governments, the World Health Organization, and many others do little to highlight and dissect issues of social structures, governance, and infrastructure; and certainly lack the initiative to solve such problems. Additionally, little action has been taken to understand the complex interaction among climate change, women's empowerment, and the built environment, as well as, their tangible impact on women's health now and in the future. Such neglected perspectives pose major questions that require deeper investigations into how, when, where, and who is influenced. Our world, our waterscapes, and our societal relations are rapidly changing as we speak, and therefore, the answers to these questions require immediacy before human health is detrimentally impacted.

In turn, this study quantitatively integrates women's empowerment and the built environment in order to analytically examine the effect of climate change and water accessibility on women's health. This research examines and highlights regional disparities within Tanzania that can be used to create locally tailored solutions, as well as, provides a framework for gender climate justice within Tanzania. I also examine how the urban-rural dichotomy, poverty, and the environment interplay and act to reinforce inequality, gendered divisions of labor, and poor water management policies and practices. Understanding the interaction of these factors allows for identification of discrepancies, as well as, systems that produce ideal model examples. Ultimately, my aim is to assess the linkage between these variables and geographically locate vulnerable areas where water and gender equality policies and programs should be targeted in order mitigate the effects of climate change on women's health and wellbeing.

This relationship also builds upon new theories of gender climate justice. Men and women are disproportionally affected by climate change, yet the differential impacts are poorly understood. In light of climate change, women are faced with unique challenges and difficult choices in order to adapt, improvise, and survive. However, these tactics have been traditionally overlooked due to severe marginalization and high gender and social inequality. Therefore, this study adds to a greater understanding of gender differences and provides evidence for the need for greater gender climate justice.

Tanzania

The United Republic of Tanzania has a total area of 945,090 square kilometers, separated into the mainland and Zanzibar (Unguja and Pemba), and a total population of 43.6 million

(Ponzetti and Dhanani, 2013). This East African country borders Kenya, Uganda, Rwanda, Burundi, The Democratic Republic of Congo, Zambia, Malawi, and Mozambique, as well as, the Indian Ocean in the east. The country is administratively divided into twenty-six regions, with roughly 23% of the population living in urban areas and 77% in rural areas (Marobhe, 2007). Germany initially colonized the region in the late 1800's, but it was later controlled by Britain following World War I. Independence was achieved in 1961, and the country was ruled under a socialist regime until the mid-1980's (Rowhani et al. 2010). As will be noted later, the history of Tanzania plays a key role in water policy and gender issues throughout the country.

The diverse landscape of Tanzania includes coastal lowlands, volcanic highlands, and the Great Rift Valley, which is home to Africa's highest peak: Mount Kilimanjaro. This landscape is divided into nine water catchment basins, which are important to water policy divisions and understanding regional differences and conflicts (Lein and Tagseth, 2009). Today, the country relies heavily upon subsistence agriculture, with all agricultural and livestock practices accounting for roughly half the country's gross domestic product (DHS, 2010). These agricultural practices are also highly dependent on water and irrigation systems (DHS, 2010), and therefore, there exists ties into gender institutions within the country.

I focus specifically on Tanzania as a place where issues of health, climate change, infrastructure, and women's empowerment remain at the forefront of both the social and ecological research. Tanzania is a combination of extremes and these extremes are highlighted in my data and the interaction among the variables of this study. The country is facing significant climate change, yet is currently ill equipped to deal with the impacts of this change due to historical and institutional social constructs and a severe lack of adequate water infrastructure. Additionally, women's exclusion from the community of male-dominated decision makers presents challenges to understanding and solving problems related to infrastructure and health. These concepts combine to create an intricate interaction, as well as, produce complex problems in Tanzania and throughout other regions across the globe. This study highlights and dissects these interactions in order to facilitate solutions in the future.

II. BACKGROUND

Water and Women's Health

Water procurement places significant physical, mental, and social pressure on those responsible, particularly when water is scarce, and can detrimentally affect individual health and wellbeing (Dufaut, 2012). In Tanzania, the gendered nature of water collection places a disproportional burden on women, which can result in severe health consequences, not only on the water collectors, but their families and communities as well (Noel, Soussan, and Barron, 2007). As managers of water procurement, women interact with this natural resource beginning from the time where it is extracted from the ground or collected from the surface to the time of use and consumption. Throughout this interval, their bodies and immune systems are bombarded by the numerous physical, chemical, and psychological insults that tarnish their health and, in doing so; produce significant societal and human development challenges (Geere, 2010). It is important to note that although the health impacts from water procurement have been qualitatively evaluated and speculated upon, there are few studies that directly and quantitatively examine the impact of walking distance and water collection on health. This lack of analysis displays the relevance of my study and analysis.

The easiest and most apparent health insult to identify is the physical burden. The arduous task of carrying water jugs that can weigh between 20-25 kilograms requires significant strength and skill (Dufaut, 2012). Most women throughout Tanzania carry the water either on their heads or strung around their backs, with the head method preferred by most. This head loading imposes significant strain on the axial skeleton, causing severe inflammation, and increases susceptibility to spondylitis and disc degeneration (Buckle and Devereux, 2002). A study conducted by Jager et al. (1997) found 65.7% more cases of spinal degeneration in women carriers than non-carriers. Additional evidence of this physical burden can be found in a study completed by Geere et al. (2010) who examined the health impacts of carrying water in Limpopo Province, South Africa. Geere et al. (2010) found that 69% of participants, women who were identified as the main water collector for their home, reported neck pain, while 38% noted significant back pain on a regular basis. This research group also found a strong positive correlation between the distance walked and the severity of the pain, concluding that water carrying methods using the back and head can cause detrimental musculoskeletal disorders and disabilities (Geere et al, 2010). Catastrophic injuries to the spine can also occur, killing women or leaving them permanently paralyzed. The risk of these events increases in young and elderly women (Dufaut, 2012).

On average, this head loading technique is acquired by the age of nine, when bones are still growing and substantial muscle has not yet developed (Dufaut, 2012). Incidence of pediatric deformities and spinal structure complications in young girls are in many instances attributable to this water collecting method. Pelvic and neck damage is also common in children who struggle to distribute the jug's weight evenly upon their backs and those who lack proper instruction from older women regarding lifting and carrying techniques (Buckel and Devereux, 2002).

In Tanzania, a head strap made of strong cloth or hemp is worn to more easily balance the water, yet this strap does little to relieve neck and back strain or decrease the risk of injury (Dufaut, 2012). Even with the aid of these straps, the weight of the water pushes women into stooped walking positions, which strains muscles and can permanently damage bones by causing stress fractures, and even permanent fatigue damage with daily repetition (Jager et al. 1997). In large households, some women must make multiple trips to the local water source each day, further exhausting and straining back and neck muscles (Mukheibir, 2010). This damage translates to early degenerative complications in bones, joints, and soft tissues, particularly when combined with a poor diet lacking sufficient minerals and nutrients that promote bone and muscle stability (Buckel and Devereux, 2002).

Additionally, environmental hazards including bumpy roads, raised roots, unpaved paths, and slippery slopes make carrying water both challenging and exponentially more dangerous (Dufaut, 2012). During the rainy season, some women must traverse slick and uneven pathways, particularly in rural areas that lack paving. In contrast, exposure to high temperatures during the warmer months, paired with long walking distances, causes numerous heat-related illnesses such as heat stroke, exhaustion, and rash (West, Hirsch, and El-Sadr, 2013). Young, pregnant, and ill women are particularly affected by the strain of these environmental hazards, walking long distances, waiting in long lines, and lifting heavy pump handles and jugs (Zakar, Zakar, and Fischer, 2012). Nonetheless water is essential to household function and regardless of the conditions, distance, or health implications, women generally remain the sole procurers.

Studies estimate that in some parts of East Africa, the energy of retrieving water requires up to 27% of daily caloric intake. Such high expenditure decreases the immune system's ability to fight infections and leaves little energy for other household and economic activities (West, Hirsch, and El-Sadr, 2013). Such unhealthy and uneven caloric output only increases more when piping is faulty or water sources are polluted, as the distance women must walk to access clean water increases. Increased distance and need also brings concerns of adequate sleep as women arise earlier in the morning and compromise their rest to procure water for their families (Bour, 2004). Studies reveal a strong negative correlation between chronic fatigue and immune system response, where inadequate sleep compromises an individual's ability to combat infection (Zager et al. 2007).

Additionally, it is important to note that the issue surrounding water access and health is not always water shortage, but rather time shortage (Allen, Qaim, and Temu, 2013). Large families or agricultural practices that necessitate large amounts of water require women to make choices between thirst and household needs, between hunger and sanitation. Increased time collecting water translates to less time completing other essential chores and agricultural duties, and in turn, sleep and energy are compromised (Blackden and Wodon, 2006). This issue has led many women to choose closer water sources, compromising hygiene and sanitation, and therefore, threatening the health status of the entire family and surrounding community (Thompson et al. 2000). This choice has unfortunately become a common livelihood strategy for women across much of Africa.

However, the decision to procure water from a closer, but contaminated source could be detrimental, or even fatal. Particularly when water is scare, a greater proportion of women are willing to risk drinking water they know is contaminated with pathogens in order to satisfy both their family's thirst and domestic needs (Noel, 2007). In many cases, the closer sources that women choose are areas of standing water or damaged boreholes, which serve as microbial incubators, particularly during hot and humid days. Often stagnant water is also contaminated with animal and human feces that cause diarrheal and parasitic diseases (Baggeley, 2006). The dispersal of these diseases is not limited to the women collecting water, but rather spreads throughout the household or even community, via the water jug or human contact. For instance, invisible parasites brought back from a water source may enter the community through the fecal-oral route, while mosquitos brought back in the jug may infect a child with malaria as they bathe (McMichael, Woodruff, and Hales, 2006).

Common water related diseases in Tanzania include schistosomiasis, typhoid, diarrhea, and trachoma. A Tanzanian study conducted by McCauly and Lynch (1992) discovered 60% of preschool children had active trachoma in 1992. Although this number has changed since the release of this study, it is important to note that the majority of cases traced the disease's source to unsanitary and parasitized water used to wash their faces (McCauly and Lynch, 1992). Additionally, a more recent analysis conducted by Baggeley et al (2006) revealed a positive correlation between distance to water source and trachoma prevalence in the Rombo district. Contraction of schistosomiasis is directly related to gender-assigned tasks including water collection, child bathing, washing clothes, cooking, and agricultural activities (Dufaut, 2012). Repeated episodes of diarrheal or parasitic diseases, particularly in children, may result in significant dehydration and malnutrition leading to compromised growth and immunity (Tumwine, 2002).

Sources of standing water also act as breeding grounds for disease vectors, such as mosquitos that carry malaria and dengue (Tumwine, 2002). This is particularly common in areas where mosquitos have adapted to urban environments and breed in close proximity to humans. Increased contact with these vectors multiplies the chance of contracting the disease, especially for pregnant women due to decreased immunity during the first two trimesters (Garner and Gulmezoglu, 2002). The risk of abortion, stillbirth, delivery of low birth weight infants, and premature delivery increases with infection. Concerns of low iron and anemia are also prevalent in women with malaria. Additional concern arises for women who fetch water during early hours of the day due to high exposure during peak mosquito biting times around dawn (Garner and Gulmezoglu, 2002). The longer a woman must walk to reach the water source in the morning, the longer she is exposed this period of high activity.

HIV/AIDS care is also strictly dependent on access to sanitary water sources. This interaction between HIV/AIDS and water is an important issue in Tanzania where HIV infection prevalence ranges from 1% in Pemba to 14.8% in Iringa (National Bureau of Statistics, 2013). Lack of clean water leads to higher morbidity and mortality rates in general, but particularly for people living with HIV/AIDS due to poor immune response and high susceptibility to diarrheal and skin diseases (Tumwine, 2002). People living with HIV/AIDS require roughly 20-80 additional liters of clean water per day due to episodes of diarrhea and other sanitation purposes (West, Hirsch, and El-Sadr, 2013). However, when very high volumes of water are required, many caregivers choose location over sanitation, further exacerbating illness (West, Hirsch, and El-Sadr, 2013). Lack of adequate access also complicates medication adherence and increases the chance of secondary infections (West, Hirsch, and El-Sadr, 2013).

However, the health burden of water collection is not limited to physical encumbrances and disease. Psychological and social problems also develop due to isolation and high household expectations (Blackden and Wodon, 2006). Due to a system framed by historical gender patterns and social institutions, some women ensure all others have been fed, bathed, and cared for before caring for themselves (West, Hirsch, and El-Sadr, 2013). This translates to women not receiving enough water to properly bathe, wash clothes, or drink and eat. In turn, fewer calories are consumed leading to less energy for women to repeatedly procure water, and a vicious cycle based in societal constructs and poor infrastructure develops. Additionally, stress revolved around adequately supplying for a family also breeds poor health habits regarding eating and sleeping (Bour, 2004).

The gendered nature of water collection also places mobility, social, and economic constraints on women (Ehrhardt et al. 2007). Although some women enjoy the social aspect of collecting water, procurement particularly in rural areas where there are fewer companions and longer walking distances can cause severe social isolation, producing emotional problems such as depression and personal devaluation (Blackden and Wodon, 2006). Social networks also provide a buffer for disease with the spread of knowledge and health assistance. Instead of these networks, the isolating patterns of water collection increase the risk of rape or violence against women (West, Hirsch, and El-Sadr, 2013).

The health issues centered on water collection do not stop at the individual level, or even at the household. The scope of the problem lies at the national level as advancement in education, economic development, and the creation of infrastructure is dependent upon the health of a nation. However, the World Health Organization also notes the importance of the reverse relationship: health is dependent upon development policies and programs that prioritize issues of equality and poverty reduction (WHO). Increasing the health status of a nation equates to fewer children missing school, parents missing fewer work days, and fewer children dying from preventable infectious diseases. The ability to free populations from debilitating diseases and public health problems marks extraordinary progress and provides dividends for both individuals and communities. Although some progress has been made, Tanzania remains in a water-related public health crisis, with severe impacts on women's health and wellbeing.

Water-Gender and Society Relations

Gender norms are framed within a larger social institution shaped by history, experiences, power relations, choices, and boundaries (Sultana, 2011). The structure and maintenance of gender rely on these factors and their reinforcing context. Therefore, global gendered preferences and understandings emerge embedded within a broader context of governance, struggles, and relationships (Arora-Jonsson, 2011). This framework has and continues to establish expectations and patterns for individuals that are built within a particular social context, and that become intertwined with and engulfed by understandings of normality (West, Hirsch, and El-Sadr, 2013). Such patterns are interwoven in all aspects of life including jobs, economic activity, politics, and family. This uneven view form society breeds psychosocial problems and greatly impacts women's wellbeing (Blackden and Wodon, 2006). Yet, similar to many other institutions, the manner in which these gendered identities and patterns manifest differs according to context and culture across the globe (Sultana, Mohanty, and Miraglia, 2013).

In Tanzania, and across much of the world, gender presents itself within the landscape of water collection and household activity (Sultana, 2009). Policy and historical discourse situate economic and social decisions regarding water within the male domain. However, women are expected to be the sole providers and managers (Arora-Jonsson, 2011). This gender disconnect creates an unjust system of marginalization due to the lack of voice women have in regards to control over a resource that is primarily secured and used by women. Consideration of these practices as a gendered institution brings questions of power, division of labor, and patriarchal structures to the realm of waterscapes. According to Crow and Sultana (2002), there exist key gendered differences in experiences with water, which have led to a system plagued by injustice and inequality. This gendered division of labor within the household is reinforced by established barriers that promote systematic subordination and female exclusion from water related decision-making processes (West, Hirsch, and El-Sadr, 2013).

However, it is important to note that this issue of women's vulnerability rests in the framework of power, not knowledge or capability. Women hold an untapped virtuous knowledge of water-related issues and can be key players in making sound ecological-based decisions (Arora-Jonsson, 2011). Tanzanian women understand how often and under what circumstances the well runs dry, and can easily connect a child's illness to a particular water source. Instead, their vulnerability stems from the institutional framework that silences their voice in such decision making processes (Figueiredo and Perkins, 2012). Women are not victims of their bodies, abilities, or knowledge, but rather the institution of gender and the stigmas and social constructs that surround it (Arora-Jonnson, 2011).

Tanzania's diversity lends the country to various trends in gender relations across time and space, and over time patriarchal systems have developed into the norm. However, Dorothy Hodgson (1999) argues relations regarding severe subordination and notions of wife ownership are attributable to the interplay of culture and political forces during British colonial rule. In turn, the social incorporation process between the colonists and the colonized shifted the contours of gender relations within Tanzanian society. Hodgson (1999) particularly refers the Maasai population as the site of these institutional shifts, yet Maddoc (1996) supports Hodgon's arguments and applies her concepts to all of Tanzania, citing that colonists imposed a strict gendered division of labor, prizing men as the success of economic activity, while regulating women into domestic tasks that limited their control and voice within the household and community. Colonial policies persisted far after independence, and further pushed women into the informal sector, often excluding them from holding or using money altogether (Maddox, 1996). This led to a strict division of labor, placing males in charge of economic activity and wage earning, leaving women in charge of domestic chores including collecting water, cooking, and some agricultural activity. In turn, gender relations have evolved into a struggle of power and voice, with larger institutions of government and colonial legacies reinforcing patterns of inequality throughout recent history (Maddox, 1996). In 2009, Tanzania ranked 125th out of 155 countries in the Gender-related Development Index (Unites Nations in Tanzania, 2011).

Additionally, current environmental struggles relating to drought and water scarcity reinforce gender inequalities and power relations throughout the world, including places within Tanzania (Figueiredo, 2013). In this case, social and ecological factors align within the realm of waterscapes that prevent women from market participation or wage work (Aroroa-Jonsson, 2011). For instance, drought, or simply the onset of the annual dry season, forces women to walk farther to boreholes and limits their opportunity to start a small business selling crafts, as well as, spend time with their families (Baggeley, 2006). These water-society relations combined with high demand create a system of inequality, social exclusion, and injustice, leading to what Sultana labels as an overlooked "struggle for the full rights of citizenship" (Sultana et al. 2013). However, Sultana et al. (2013) also argue that knowledge around climate and water, as well as, climate change solutions lie in the silenced voices of women. Their knowledge is virtuous yet trapped by societal barriers and an outdated and historical notion of gendered-institutions (Arora-Jonsson, 2011).

Women are almost exclusively the sole providers of water in the East African region, yet have little voice in management, use, and distribution decisions (West, Hirsch, and El-Sadr, 2013). Due to historically established gender norms and gender power distribution, women are expected to perform all tasks related to the retrieval and use of water, including cooking, washing, and bathing family members (Bour, 2004). In Sub-Saharan Africa, an overwhelming 71% of households report that women are the sole collectors of water (West, Hirsch, and El-Sadr, 2013) and a large majority of Africans who spend more than two hours per day collecting water are women (Fontana and Natali, 2008). In highly marginalized regions, a mere 9% of men are involved with water procurement, and only when the distances are too great for the women in the household to physically manage (Buor, 2004). In this instance, the dire needs of the family and husband overcome the gendered system of water procurement. This leads to an interesting contradiction to the normal water collection system. For instance, in households rooted in deep poverty, the strength of the gendered division of labor weakens, as both men and women collect water as a means of survival. However, this pattern is only seen in a small portion of the population, where the need for survival outweighs established gender hierarchies (Blackden and Wodon, 2006).

In addition, if older women are unable to supply sufficient amounts of water, societal and familial pressures may force young girls to drop out of school and aid in supplying for their family (Garriga, 2007). Roughly 72% of school-aged girls are involved in water collection, sometimes sacrificing their education which holds the key to women's empowerment and is the central tool that aids in breaking traditional gender norms (Fontana and Natali, 2008). In order to adequately supply for their families and remain in alignment with gender normality and expectations, many girls begin collecting water by the age of nine. If kiosk or borehole lines are long or the distance to water is far, classroom time is lost and girls fall behind in school (Fontana and Natali, 2008). Although water procurement is not the sole cause of school dropout rates, the combination of this responsibility with other socio-economic, cultural, and religious factors drastically increases the rate of female dropout, particularly in poor and rural areas. Education is considered the cornerstone to economic and social development, yet gender disparities complicate this pathway to development (Garriga, 2007). Widening gaps in equality due to water security create an unbalanced education system, which has serious implications for future social progress.

Gender relations are not the only factors influencing water access and collection. Rather two additional vital influences are important to consider in water-society associations: class and the rural-urban divide. Societal injustices and marginalization manifest themselves not only within gendered institutions, but also according to race and class (Crow and Sultana, 2002). Due to the intersection of water asymmetry and societal heterogeneity, water-society relations have developed into unequal systems based on hierarchy and discrimination against lower social classes. In Tanzania, the Chaga, Haya, Nyamwezi, Sambaa, and Zaramo have been classified as the most marginalized ethnic groups according to Elu and Loubert (2013). Unequal and insufficient amounts of water prove challenging to societal relations and have led to unequal hydrological and economic feedbacks that harm these marginalized groups. Collective action in both cities and villages has emerged to combat issues of management, yet these systems are plagued by asymmetric access, voice, and quality of community organization (Arora-Jonsson, 2011).

Material and monetary inequality in Tanzania limits water security through cost, time, and agency. Rich and influential households retain preferential access and rights due to their power and ability, and therefore the quality, reliability, and cost of water varies with social stratification (Blackden and Wodon, 2006). For example, households that have secured land and money, experience high levels of water security because of either ownership of a private pump or the ability to purchase water. "Water rights" must be purchased, sometimes excluding the poor from secured water access altogether (Lein and Tagseth, 2009). Property relations, however, also act as strict boundaries between the poor and the wealthy, excluding households from particular water sources. In cases where villagers have access to a communal water source, exclusive associations based on power and wealth form that limit the water rights for many (Blackden and Wodon, 2006). Furthermore, population growth and expansion fuels an association's incentive to privatize the water, causing further water security issues for the poor (Madulu, 2003). Poor women are doubly disadvantaged: first by the lack of water access, and secondly, by the low priority of women's health and devaluation of their work and knowledge of water (Crow and Sultana, 2002).

Part of this asymmetry evolves from the unidirectional flow of water. This issue is particularly pertinent in communities that lack adequate boreholes, and therefore, must retrieve water from natural sources, such as lakes or rivers (Blackden and Wodon, 2006). Settlements downstream of any particular area have limited ability to control how water is used and what substances reenter the water system from communities upstream. These substances may include chemicals, fertilizers, and fecal matter. This pattern drives the price of upstream land upwards, creating a reinforcing system of inequality that severely impacts the health of poor women who collect the water and the community members that consume it (van Koppen et al, 2004). Due to the unidirectional flow of water and lack of government monitoring and intervention this system of inequality continues. Biophysical heterogeneity also generates patterns of inequality as geology, climate, rain, and catchment areas are not uniform across the country (Dessu and Melesse, 2012).

Additionally, many boreholes are also privately funded or maintained by local funds (Lein and Tagseth, 2009). Therefore, those living in poverty lack the maintenance reserves and in turn have no choice but to walk further for water or resort to unsanitary conditions. Bardhan and Dayton-Johnson (2001) argue that collective action on issues of water and wealth inequality display a U-shaped relationship. Low inequality implies few can afford the cost of collective action, while high inequality generates resentment and lopsided deals. This curve indicates how an unequal water system perpetuates water access and the burden of poverty. Additionally, women are almost always excluded from collective action and receive few benefits from these efforts (Bardham and Dayton-Johnson, 2001).

Geographic location, specifically the rural-urban divide, also differentiates access to water. Disregarding sanitation for the time being, rural boreholes are more sporadically placed and monitored less frequently than boreholes in urban areas (Baumann et al. 2005). Urbanized regions also contain more resources and incentives for government action, leading to more frequent borehole placement (Elliott, 2011). Electric boreholes are less common in rural areas, forcing women to resort to less sanitary water sources (de Palencia, Jimenez, and Perez-Foguet, 2012). Although the distance urban women travel for water is shorter, urban pollution and close living quarters breed diseases that can enter the water system through either fecal contamination or water system runoff (McMichael, Woodruff, and Hales, 2006). Additionally, women from urban households that lack piping spend up to two hours per day collecting water from kiosks, and are exposed to many of the physical health burdens of water collection (Thompson et al, 2000). Piped water systems are also poorly maintained leading to frequent system failures in urban regions. As seen here, both rural and urban women are victims of the gendered nature of water procurement.

Understanding the intersection of water, gender, social class, and poverty is crucial to development. In a survey conducted by Makonu, Manase, and Ndamba (2004), women ranked reducing distance to water sources as a top priority in development, while men simply ranked the need for clean water, with no comment on source or distance. This discrepancy of thought around the roles of women, independent of water source distance, inhibits collaborative efforts within communities and the Tanzanian national government to effectively improve health and well-being (West, Hirsch, and El-Sadr, 2013). Although some progress has been made, the marginalization of women, particularly around the realm of water collection and consumption, leads to fundamental health and educational issues that compromise societal cooperation and action in efforts of development.

The Built Environment and Water Infrastructure

In this study, the built environment refers to water infrastructure built for the purpose of water collection and transport. Adequate water supply and proper sanitation throughout Tanzania depend on the quality and spatial distribution of this built environment (Baumann et al, 2005). A study completed by the United Nations, discovered that only 24% of households have a direct water connection in Africa, meaning the other 76% travel to procure water (Mukheibir, 2010). More focused studies from Tanzania report that some women travel beyond 10 kilometers to secure water, taking the whole day and leaving little time to care for children, complete other housework duties, or secure additional sources of income outside the home (Madulu, 2003). These issues of time and distance are directly correlated to adequate and appropriate water infrastructure. Geographic location, capital, wealth, weather, and sustainability of infrastructure interact to determine how far women must walk to procure water. There exist four main sources that Tanzanian citizens utilize to collect or purchase water: boreholes, piping, the natural environment, or stores/kiosks (Elliott et al, 2011). These water sources vary tremendously in cost, sanitation, and ability to withstand natural disasters (Elliott et al, 2011), and therefore, differential and unequal access play a significant role in determining the health of women and communities (Crow and Sultana, 2002).

In urban and peri-urban areas, surface sources are traditionally the most commonly used water sources, yet as cities have developed and expanded in area and population, the use of shallow wells and piping systems within city limits has drastically increased (Marobhe, 2007). However, short distances between pit latrines and water sources in city environments present concerns of contamination and spread of disease (McMichael, Woodruff, and Hales, 2006). For example, the rise in private water development in Dar es Salaam has led to an increase in shallow wells; however, many of these are contaminated with fecal matter due to poor city infrastructure and sanitation management (Kjellen, 2006). Some of those who are able to afford well construction in this city have now begun to sell their water as a means of income, further spreading these disease pathogens across communities and the city (Kashaigili, 2010). Piped water is reserved for those wealthy enough to own land and resources in order to build piping systems, as well as, pay the source's owner for the water (Thompson et al. 2000).

Similar to piped water, the ability to purchase water from vendors is limited to those with sufficient monetary capital. Both piping and store-bought sources are more common in urban areas due to resource availability and locational proximity to markets and infrastructure development (Kashaigili, 2010). However, those who live in peri-urban regions and slums normally lack piping systems or monetary means to purchase water, and therefore, women have no choice but to resort to sources of standing water or shallow boreholes in these areas (Blackden and Wodon, 2006).

In rural areas, water collectors continue to heavily rely on natural resources including streams, lakes, ponds, rivers, and canals. These sources mark a complete lack of infrastructure and are most likely to harvest harmful disease organisms, pollution, and fecal contamination. Geographic location relative to these sources influences walking distances for women. However, the location of these sources also varies between wet and dry seasons (de Palencia, Jimenez, and Perez-Foguet, 2012), and is drastically influenced by natural disasters, such as drought or flooding, that may deem these sources unusable (Dessu and Melesse, 2012). Such fluidity and change according to season and climate place a heavy burden on women, particularly during unpredicted events.

In contrast, boreholes encompass a broad spectrum of systems that mechanically extract groundwater, and are the most common man-made sources of water in Tanzania (Baumann et al, 2005). Yet their effectiveness depends on consistent and adequate government or private maintenance, sufficient groundwater supply and flow, appropriate geologic composition and recharge capability, and weather and climate conditions (Garriga, 2007). Unfortunately, missing pieces to understanding this interaction, within Tanzania specifically, complicate efforts for water infrastructure improvement and sustainable development. For instance, little is known in regards to Tanzanian hydrology, a key concept that would speed the development of efficient and sustainable borehole construction and water extraction (Kashaigili, 2010).

As of 2005, for Tanzania to reach the 2015 Millennium Development Goals, the country needs to drill 14,000 hand pump boreholes and an additional 1,500 boreholes that utilize motorized pipe systems (Baumann et al. 2005). Yet data from a 2010 analysis estimated the cost of these systems ranges from USD 6,000 for basic boreholes to USD 12,000 for mechanized electric systems (Kashaigili, 2010). Additional costs are also added as the depth of digging increases. Unfortunately, individual and community poverty limits the type of borehole built, or even the building of one altogether, revealing a barrier of access due to monetary and social inequality. Maintenance issues also arise in rural areas due to a lack of surveillance, repair knowledge, and equipment to fix problems, further highlighting different socio-economic and urban-rural water collection burdens and disparities (Baumann et al, 2005). The national government funds the construction of some boreholes, yet inadequate organization presents significant problems for locating areas in need of construction or maintenance. For instance, the

Ministry of Water and Irrigation in Dodoma contains a national borehole database; however, many boreholes are not recorded, and others are incomplete and missing locational coordinates (Kashaigili, 2010).

Current policy in Tanzania defines adequate access to water as 1 water point per 250 people within a radius of 400 meters (Brokonsult, 1978). However, the service of each water point depends on three significant factors: type, functionality, and seasonality – variables that range significantly between regions, and even villages. Official governmental counts estimate 16,124 boreholes throughout the country; however, this is a rough approximation due to poor monitoring and tracking systems (Baumann et al, 2005). Additionally, only, 1,497 of those, a mere 9.3%, are classified as electric or diesel piped systems (Tanzania, 2011), which, according to Mark Elliott et al (2011), are the only fully reliable sources during dry conditions and drought. This aggregate number is also not fully representative due to the incorrect assumption that all of these boreholes are functioning properly. Rather many have been broken for years, or their function is reduced to periods of consistent rainfall during the wet season(s) (Fernandez de Palencia and Perez-Fogurt, 2012).

Weather and climate are also key factors in determining how far women must walk to procure water. Boreholes are dependent upon consistent rain that enters the ground to recharge the hydrologic system. However, drought may leave many boreholes unusable for long periods. According to Madulu (2003), nearly half of the water sources in villages run dry for as much as a quarter of the year, leaving women no option but to travel greater distances to provide for themselves and their families. Even if a water source is fully functional, there still exists a high risk of poor water quality due to agricultural, industrial, or fecal contamination (Noel, 2007). Contamination is least likely to exist in deep wells; however, these sources are also the least accessible due to a lack of infrastructure, capital, and government implementation (Fernandez de Palencia and Perez-Fogurt, 2012). In a study completed by Fernandez de Palencia and Perez-Fogurt (2012), the availability of clean water in Tanzania dropped by 40% once quality and seasonality data was overlaid with water point data.

Borehole sustainability is a product of adequate depth, groundwater availability, recharge ability, and weather (Baumann et al, 2005). In general, the deeper the borehole is drilled, the longer it will remain an adequate water source. However, hydrogeological factors including recharge and rock formation complicate Earth's ability to store water. The total ground water recharge per year is estimated at 3,725 MCM (0.4%), a very low rate compared to other regions of the world (Kashiagili, 2010). However, the factors above vary across space and interact to create diverse rain catchment areas and aquifer types, leading to spatial distinctions in groundwater levels across the country. Nonetheless, this low recharge, combined with limited research and knowledge of the Tanzanian underground hydrologic system, prevents adequate building strategies, as well as, the ability to cater style and depth of a borehole to a specific area (Kashiagili, 2010). Many boreholes and wells run dry quickly because they were initially built too shallow or upon rock formations not conducive for water extraction. These problems and lack of knowledge create unsustainable systems that do little to reduce the burden of water collection and further marginalize women.

The drilling industry is also plagued by insufficient human capacity, lack of equipment, and too few private sector consultants (Baumann et al. 2005). These fundamental problems further exacerbate issues related to borehole functionality, weather, and human health and development. The operation of the Drilling and Dam Construction Agency (DDCA) underutilizes the skills and knowledge of its employees and, according to Baumann et al. (2005), the industry would benefit from turning these employees into private contractors. However, a lack of equipment and purchasing capital would still result in poor borehole development. Current equipment is old and unreliable, slowing, or even halting, construction projects (Kashiagili, 2010). Additionally, private consulting firms are relatively new to the country and lack human and monetary capacity to build and grow upon. At the moment and DDCA controls 60% of the market, leaving little room for small private firms to take root (Kashiagili, 2010).

Further problems arise in government drilling regulations. Drilling permits are required, yet the professional assessments of drilling companies lack consistency and no renewal process exists, which ultimately harms the quality and performance of boreholes (Kashiagili, 2010). Additionally, locational drilling guidelines are rarely enforced, leading to unsustainable construction that negatively impacts the environment, and in turn, human health. Due to this instability, many boreholes are decommissioned after just one year due to this unsustainable activity and lack of proper maintenance following these drillings, placing a heavy burden once again on women (Kashiagili, 2010).

Even if there is adequate water in an area, conflicts over water rights to infrastructure and natural resources present significant challenges to women. Examples of water conflict are not endemic to Tanzania, but rather plague the history of almost every country. Conflict arises when ease and safety of access to another source is limited (Dungumaro and Madulu, 2003). Water scarcity leads to competition and disagreements over water rights in regards to access, use, and security. The irregular distribution of fresh water sources in Tanzania exacerbates water conflicts based on ethnic and socioeconomic inequality, interstate disputes, domestic and agricultural use disputes, privatization verses public access, change in consumption patterns, and demographic changes. In recent years with the addition of population growth and expansion, ecological security and water access have become tools of power and control. A study by Peter Gleick (1993) found that per capita water availability in 1990 was 2,780 cubic meters per year, yet predicts that per capita water availability in 2025 will be reduced to 900 cubic meters per year. This 68% decrease will undoubtedly generate water conflict and friction in the future (Gleick, 1993). Whether this friction is rooted in policy or economics, women become the victims. Such conflict inhibits water collection and a woman's ability to take care of herself and her family. Loss of water sources due to conflict equate to increasing isolation and marginalization due to an inability to meet gender expectations.

Lack of water infrastructure creates significant public health challenges. In her ethnographic narrative "To Open Oneself is a Poor Woman's Trouble," Sydney Spangler (2011) recalls her experience in a Tanzanian childbirth center. She writes how the birthing attendant was gone for hours collecting water for the center, while a line of women in labor waited for her return. One woman even moved to the floor because she was scared the attendant would not be back in time to catch her baby. Yet her choice of moving to the floor presents questions of sanitation and indicates how a lack of proper water infrastructures leads to numerous public health problems (Spangler, 2011). Unfortunately, in this case, the birthing attendant had little choice. Water, particularly uncontaminated water, is vital in medical settings such as hospitals and birthing clinics, and although the narrative says little about where the woman retrieved the water, she most likely walked considerably far. This example illustrates how crucial water, particularly uncontaminated water, is to the health and wellbeing of Tanzanians. Water sustains life and proper and effective water infrastructure improves social, health, and economic development (Blackden and Wodon, 2006).

Climate Change

The current climate in Tanzania manifests in significant temporal and spatial variation attributable to the country's complex land, water, and atmospheric systems. Spatially, the country ranges from a tropical climate on the eastern coast to a temperate climate in the highlands. In northern regions, bi-modal rainfall regimes present long rains between March and May, with shorter rains from October to December. In contrast, the southern regions witness a uni-modal regime with rainfall occurring between December and May (Aryeetey-Attoh et al, 2010). Average annual rainfall ranges from 600-800 mm. In regards to temperature, the coastal regions are the warmest between January and June, with temperatures averaging above 23°C. In contrast, cooler regions of the country include the eastern and western mountain ranges of the Great Rift Valley (Paavola, 2008). The Tanzanian climate is also shaped by two major climate events: the El Nino-Southern Oscillation (ENSO) and the North Atlantic Oscillation (Rowhani et al. 2010).

At the large scale, earth's climate is rapidly changing with significant disruptions felt across all regions of the world. Such disruptions are a result of rising carbon dioxide levels that manifest in unforeseen and statistically significant warming and cooling patterns on earth (Dessu and Melesse, 2012). Atmospheric concentrations of carbon dioxide and other greenhouse gases have been increasing in concentration since roughly 1750 due to both human and natural drivers of change, however, today scientists confidently agree that most of the change observed within the past 60 years is due to anthropogenic causes (Paavola, 2008). Increases in carbon dioxide are a result of burning fossil fuels and rapid land use change, whereas, the rise in methane and nitrous oxide is due to agricultural activities (Alley et al, 2007). A greater understanding of recent environmental changes and their spatial impact on humans originates from the integration of spatial technologies, broader coverage tools, and a wider variety and higher quality of satellite measurements. Satellite rainfall estimates (REFs) and general circulation models (GCMs) are increasingly used to simulate past and future climate patterns. GCMs are typically used in hydrological studies; however, their performance in Africa is relatively less investigated and data proves to be scarce and permeated with scale errors. As described below, broad and complex issues arise with changing climate, and therefore it is necessary to examine particular regions at a smaller scale in order to understand the local impact of this change on humans (Paavola, 2008).

Nonetheless, these tools have provided evidence of oceanic and atmospheric temperature increases, snow and ice cap melting, and sea level rise. Studies indicate that eleven out of the last twelve years have been classified as the warmest years on the Earth's surface (Bulkeley, 2013). This warming resulted in an average sea level rise of 3.1 (2.4 to 3.8) mm per year globally between the years 1961 and 2003, due to thermal expansion and ice cap melting (Alley et al, 2007). Additionally, although precipitation patterns have proven highly variable at the global scale, generally rainfall increased for North and South America, northern Europe, and central Asia and decreased in the Sahel, Mediterranean, and parts of southern and eastern Africa (Mukheiber, 2010). Climate change has also resulted in the increased intensity of weather events, such as tropical storms and droughts (Zakar, Zakar, and Fischer, 2012).

Tanzania has witnessed similar patterns of change compared to those at the global scale, with the most recent decades marked by increasing temperatures and large variability in precipitation (Paavola, 2008). This change continues to detrimentally impact the water sector, coastal resources, livestock and agricultural industry, forest conservation, and human and animal health within the country (Dessu and Melesse, 2012). However, the hydrologic system, including all sources of freshwater, is particularly vulnerable to temperature and precipitation, and this vulnerability leads to severe economic and social stress (Zakar, Zakar, and Fischer, 2012). Such stress has significant repercussions for health and development within the country. Below I outline the scientific perspectives of climate change within the country, the limitations to these studies, and how climate change, water procurement, and gender interact in Tanzania.

Since 1960, the mean annual temperature in Tanzania has increased by an average of 1°C (McSweeney, New, and Lizcano, 2010) and future predictions indicate that this pattern will continue to increase with exponential gains within the country (Dessu and Melesse, 2012). For instance, studies predict a 1.5°C-2°C increase within the first half of the century, with this figure doubling to 2°C-4°C by 2100 (Noel, 2007). The severity of these warming patterns is predicted to be higher during the dry season and in the interior regions (Rawhani et al. 2010). Additionally, future rainfall projections display a complex seasonal pattern in the future, with significant increases in January and February for the south, and increases in March, April, and May for the north. Studies also project an increase in the aggregate number of heavy and infrequent rainfall events (McSweeney, New, and Lizcano, 2010). Interior regions are predicted to experienced prolonged dry seasons and drought, with a 20% reduction in precipitation (Rawhani et al. 2010). Annual runoff from the three major rivers (Ruvu, Pangani, and Rufiji) is also expected to decrease by 6-10% by 2100 (Argrawala et al, 2003). These climate change patterns contribute to changes in ecological landscapes and the hydrologic system, significantly impacting water availability (Dessu and Melesse, 2012). One study revealed that a 10% increase in temperature correlated to a 30% decrease in hydrologic output (Legesse, Vallet-Coulomb, and Gasse, 2003). This exponential pattern of increasing water insecurity poses significant questions for future generations and development.

One of the most significant effects of these changes is shifting availability and spatial distribution of freshwater sources across the country (Dessu and Melesse, 2012). Although total rainfall is expected to increase in some areas, the amount is not consistent throughout the year, yielding significant shocks during the dry season and a decrease in aquifer recharge ability during the wet system (Taylor et al. 2013). This is explained by the inability for soil to uptake large amounts of water at one time, particularly following long dry periods. In turn, the water leaves via runoff rather than reentering the ground and aquifer system. Additionally, the Mount Kilimanjaro water catchment region will lose its glacier and ice caps, a key source of water, in the coming century leading to detrimental consequences to water availability. Sea level rise will also limit freshwater sources due to the inward intrusion of salt water, and in turn, an overall decrease in water availability on the eastern coast (McMichael, Woodruff, and Hales, 2006). This climate change is expected to produce, and already has, significant destabilizing health effects on poor and marginalized populations (Mukheibir, 2010). By 2025, all of Tanzania is predicted to be classified as either "high water scarcity" or "beyond the water barrier" (Falkenmark, 2011).

Scholars argue sustaining a state of good health within a population ultimately depends on the stability of the factors that control it, one being a stable environment (Zakar, Zakar, and Fischer, 2012). Yet, climate change, including change in the atmospheric and biophysical conditions that support human life, has led to significant environmental imbalances that impact health (McMichael, Woodruff, and Hales, 2006). Specifically, one of the main factors in this imbalance is increased water insecurity, which directly impacts the health of women, as well as, whole communities. Below, I outline three aspects of climate change that will potentially influence women's health and wellbeing.

The first category includes water stress due to extreme events such as heat waves, as well as, short, but strong precipitation events. Increasing temperatures stimulate high evaporation levels, and in turn, limit the number of viable water sources, as well as, decrease the total amount of water within each catchment region (Dessu and Melesse, 2012). This lack of water equates to longer lines in the heat and decreased water availability (Zakar, Zakar, and Fischer 2012). Additionally, large storms and heavy, but quick, downpours produce high volumes of runoff which can transport fecal and waste water to unwanted areas, such as freshwater basins (McMichael, Woodruff, and Hales, 2006). Climate change also produces a higher variance in ENSO events, bringing high variability between excessive rainfall now and significant drought, and therefore, producing harmful and unpredictable shocks (Paavola, 2008).

Microbial and vector proliferation in response to climate change also works to negatively impact human health. Significant climactic changes may tip the fragile ecological balance and trigger an increase in vector related epidemics, such as malaria or cholera (McMichael, Woodruff, and Hales, 2006). For instance, cholera bacteria multiply at a more rapid pace in high water temperatures, increasing the chance of consumption from contaminated warm water sources. New rainfall patterns also influence vector dispersal patterns, while warning average temperatures increase the spatial survival ranges of many disease agents, sometimes introducing them into areas that are not normally endemic to a particular vector (McMichael, Woodruff, and Hales, 2006). Additionally, in areas of increasing temperatures, the diversity and quantity of birds, frogs, and other mosquito predators decreases, increasing the range and population of mosquitos. This increases the potential that malaria infected mosquitos will come into contact with humans as an increasing number of water sources are shared by both populations (WHO, 2013).

The final category, loss of livelihood, leads to impaired nutrition, displacement, and increased poverty when coping strategies and resources are limited. These widespread climate changes have brought significant challenges to people across the globe, particularly those that lack resources for adaptation and mitigation processes (Paavola, 2008). Mitigation requires an understanding of the technological, economic, and social aspects of this change, as well as, resources and capital to instigate adaptation efforts. However, climate change mitigation adaptation strategies vary across region, socio-economic class, culture, and gender, and therefore, many livelihood strategies exist to combat and mitigate the effects of climate change throughout the country (Zakar, Zakar, Fischer, 2012). For instance, income diversification is a common solution for agricultural farmers (Paavola, 2008). For farms where women procure water for agricultural purposes, this livelihood strategy provides some alleviation for women and the burden of carrying water (Aryeetey-Attoh et al, 2010). However, water still remains essential for other household activities. Farmers have also responded by employing intensification and cultivation extension techniques, yet with more crops, a larger system of irrigation and water is needed (Paavola, 2008). Additional factors including social status and poverty also influence access and ability to diversify; therefore significant burdens are placed on rural poor women as climate systems change (Blackden and Wodon, 2006).

Human actions have amplified climate change, yet the imbalanced distribution of the causative sources poses questions related to responsibility, in addition to, health and development problems rooted in impact inequality (Arora-Jonsson, 2011). A more recent facet of climate change, climate justice, has recently taken root in academia. As a form of environmental justice, climate justice is an ethical issue of both local and global scale. This theory highlights the unequal burdens of climate change and exposes unbalanced practices and consequences (Terry, 2009). For instance, the theory behind the ecology of climate justice rests in the notion that the industrialized Global North produces a majority of greenhouse gas emissions, yet the harmful effects drastically impact the livelihoods of people in the Global South who have emitted only a small fraction of these gases (Hayward, 2007). In turn, climate justice platforms call for a greater focus on social approaches at the global scale, as well as, action to reduce harmful effects on marginalized and poor groups of society (Terry, 2009). Yet, climate justice also brings controversial development questions such as the right of developing nations to grow through similar industrial patterns as the Global North in order to achieve equivalent economic and human development gains, yet at the same time, further sacrifice the natural environment (Hayward, 2007).

Issues of climate justice also introduce a new and underdeveloped concept: gender climate justice. Under this concept, there can be no climate justice without gender justice (Terry, 2009). Women, particularly those who are poor and severely marginalized, face numerous barriers that limit their ability to adapt, including the near complete exclusion from the discourse surrounding climate change (Sultana, Mohanty, and Miraglia, 2013). For instance, The UN Framework Convention and the Kyoto Protocol barely mention any interaction between the changing environment and its effect on women's livelihoods (Arora-Jonsson, 2011). However, in many places throughout Tanzania, women and their means of collecting water are the first to be impacted by climate stress and change.

It is important to note that the discourse around the health effects of climate change is at an early stage, and therefore, there exists lurking variables or unexplored factors behind these notions. Nonetheless, scientists agree that climate change will ultimately negatively impact health, wellbeing, and development, particularly in vulnerable populations with limited resources for adaption and mitigation (Alley et al, 2007). Currently, the majority of research that exists focuses on thermal stress, infectious diseases, and food yields (McMichael, Woofruff, and Hales, 2006). However, recent shifts in the focus of academia have led to a greater concentration on broader social and demographic factors. This study will add to this emerging and undeveloped discourse.

Water History and Policy in Tanzania

Water is crucial to life, however economic limitations and spatial disparities in distribution lead to the abuse and misuse of this vulnerable resource (Bour, 2004). Therefore, the need for effective water supply, distribution management, and efficient control is vital. An important facet to the problem of unequal and inadequate water access lies within policy breakdowns and poor distribution practices, which stem from clear institutional gaps both the local and national level in Tanzania (Garriga, 2007). Tanzanian institutions lack cohesion and crucial coordination, which continue to create barriers to efficient and effective management. Therefore policy enforcement varies significantly across time and space, and is embedded within unequal economic, cultural, and administrative systems (Figueiredo and Perkins, 2012).

Prior to colonial rule, resource management policies varied according to leadership regimes, and in many cases, water disputes were settled with conflict leading to a change-sensitive system of organization. During this period, the highest level of management rested at the community, and therefore, conflict revolved around ethnic groups and conquests (Sokile, Kashaigili, and Kadigi, 2003). The arrival of the first colonists brought Tanzania under German rule, yet little change was instated to the informal water sector (Sokile and van Koppen, 2004). However, the demand for water and the aspirations of the colonists increased in the early 1900s under British rule, and the first constitutional water law was established: the 1923 Water Ordinance (Lein and Tagseth, 2009). This law, as well as, numerous regulations that followed, was instigated to benefit the colonists and held little regard to the native Tanzanians. During this time period, water laws and any form of man-made water extraction tools were confined to urban areas and limited to the colonists' use (Sokile, Kashaigili, and Kadigi, 2003).

Unfortunately, post-colonization brought few changes to this system plagued with favoritism and inequality. However, over time this open, yet unequal, policy morphed into a more restrictive practice with the launch of the Arusha Declaration in 1967 (Lein and Tagseth, 2009). This law declared natural resources to be collectively owned and abolished any existing water use fees (Sokile, Kashaigili, and Kadigi, 2003). Five years following the Arusha Declaration, local governments were abolished, stealing any lasting control local communities retained over water access and consumption. With a national government marked by male dominance and corruption, women had little say in water use and management, particularly following the destruction of local administrations (Lein and Tagseth, 2009).

In the 1970s, Tanzania adopted the Rural Water Supply Program that aimed to provide safe and accessible drinking water to every citizen within 400 meters of their residence (Madulu, 2002). Water was provided for free, nonetheless, the proportion of the rural population with access to piped water decreased from 28% to 19% between 1978 and 1988. Much of this decline is attributed to land use changes, poor governance, and implementation of unsustainable extraction techniques (Garriga, 2007). In 1974, the Water Utilization Act was signed, which replaced the Water ordinance and shifted focus to regulation and control (Lein and Tagseth, 2009). This law and its framework, with minor amendments, are still used today (Sokile, Kashaigili, and Kadigi, 2003).

Tanzania adopted the River basin Management approach in 1981, which created nine water drainage basins in the country: Pangini, Ruvu, Rufiji, Ruvuma, Lake Nyasa, Lake Rukwa, Lake Tanganyika, Lake Victoria, and the Internal Basins (lakes Eyasi, Manyara, and Bubu)

(Sokile and van Koppen, 2004). Sound in theory, this law divided the land in catchment regions to more accurately control and monitor resources. Then in the 1990s, policy shifted to focus more heavily on gender norms, with the new National Water Policy passed in 1991 (Lein and Tagseth, 2009). The goal was to provide safe drinking water to 95% of the population by 2002; however, 2002 estimates by the Ministry of Water and Livestock Development indicate that only 50% of rural and 73% of urban residents had access to safe water sources (United Republic of Tanzania, 2002). Unfortunately, the focus of this new policy was too narrow and lacked a comprehensive analysis of gender norms. Additionally, women became seen as the solution in the stakeholder's eye, and the goal of improving larger societal constructs such as women's marginalization was lost, leading to severe social and gender gaps in understanding who uses water (Lein and Tagseth, 2009). Politicians used women as a symbol to improve the water system, however, implementation of this policy and strategies, still largely excluded women's voice and understandings.

A new water policy document, signed in 2002, emphasized the river basins as water administration boundaries and prioritized basic necessity use for individuals (Sokile and van Koppen, 2004). However, other livelihood social and economic uses outside the realm of necessity were subject to further approval from government on a case-by-case basis. This policy also states "in order to realize the objectives of water resources management, all water uses, especially water use for economic purposes, will be charged for" (Lein and Tagseth, 2009). Volumetric pricing for water was defined, which created a more stable system of extraction, yet limited access to the poor (Lein and Tagseth, 2009). Then in 2003, the World Bank released a statement that said all "water resources should be managed holistically and sustainably…ensuing participation and treating the resource as an economic as well as social good," (Lein and

Tagseth, 2009). However, Tanzania has struggled to move past this rhetoric and tangibly implement practical and efficient systems of water management. Unfortunately, this statement also lacks clarification for who participates: men, women, or both?

Today, water belongs to the state and therefore, those that wish to extract water must have a license, called a "water right," from a water officer. However, traditional water rights based on inheritance and local customs are also acknowledged within this system, leading to legal pluralism plagued by controversy and unstable coexistence (Sokile and van Koppen, 2004). Small farmers suffer most from these laws that favor the formal and estate sector over small subsistence agriculture. Further problems arise from license distribution barriers and competing demands between irrigation, traditional norms, and growing economic sectors (Sokile and van Koppen, 2004).

Recent policy also steers toward "decentralization by devolution," with a shift in water control to local levels of government (Garriga, 2007). However, inadequate coordination, lack of capacity, and poor management framework plague the water sector and prevent efficient solution implementation (Sokile and van Koppen, 2004). Recent reforms aim for equity, efficiency, and environmental conservation with the ultimate objective to achieve the MDGs.

This study intends to integrate these variables and previous analysis to understand the interaction among women's health, climate change, water infrastructure, and women's empowerment. I complete this analysis in a quantitative manner and support the results with a case study that highlights two regions within Tanzania. Ultimately, the results of this study will contribute a greater understanding of climate change and women's health, as well as, add to the small, yet growing discourse of gender climate justice. This study quantitatively integrates women's empowerment and the current state of water infrastructure in order to examine the effect of climate change and water accessibility on women's health.

III. METHODS

As outlined in the introduction, four core variables were assessed in this study: women's health, women's empowerment, water infrastructure, and both historical climate patterns and future climate change. This study quantitatively integrates women's empowerment and the built environment in order to analytically examine the effect of climate change and water accessibility on women's health. A composite index for the first of these three variables was created, lending to a quantitative assessment of the correlation between water infrastructure and health, as well as, women's empowerment and health. These index values and correlation analyses were then overlapped with climate data and used to identify vulnerable areas in need of focused policy and increased intervention.

Women's Health

Women's health data was obtained from both the 2010 Tanzania Demographic and Health Survey (DHS) and datasets from the National Bureau of Statistics (NBS) in Tanzania. The DHS is a nationally representative probability survey of 10,300 households selected from 475 sample points (Tanzania DHS, 2011). However, only 9,741 households were found to be occupied during the time of this study and 9,623 were successfully interviewed. Therefore the household response rate was extremely high: 99%. The sample points were selected from a list of enumeration areas in the 2002 Population and Housing Census. In turn, 25 sample points were selected in Dar es Salaam, 90 in Zanzibar, and 18 in each of the mainland regions. The National Bureau of Statistics conducted the DHS survey from December 19, 2010 through May, 23, 2011 (Tanzania DHS, 2011). Individual interviews of women between the ages of 15 and 49 were conducted in one third of all households to provide a more in depth analysis. A total of 10,139 women were interviewed, producing a response rate of 96%. This DHS sampling provides separate statistics for each region, as well as, divides regional data into rural and urban categories

(Tanzania DHS, 2011). The NBS is a nationally representative survey database where information is compiled from censuses, personal interviews, randomized surveys of households and institutions, and GIS projects (National Bureau of Statistics, 2013). The Population and Housing Census (PHC) published in 2012 by the NBS was used for health data as well.

Three variables that pertain to women's health were selected to include in this study from the surveys mentioned above: life expectancy (NBS), percent of women with no anemia (DHS), and percent of women above 145cm (DHS). Life expectancy is calculated as the number of years a newborn infant would live if mortality patterns at the time of birth continued throughout his or her life (World Bank). Stunting is defined for women as measuring shorter than 145cm (Tanzania DHS, 2011). Both stunting and life expectancy are overall measures of health and may be affected by water procurement patterns. Diagnosed with a blood test; anemia is defined in the DHS as a hemoglobin level below 7g/dl, or 9g/dl in pregnant women. This test was optional and therefore, the number of participants that agreed to this assessment varies between regions; however, no significant patterns in response rate were observed that could indicate substantial bias (Tanzania DHS, 2011). Anemia is a more narrow measure of health compared to life expectancy and stunting, but many studies indicate positive correlations between incidence of anemia and walking distance to water, as well as, energy expenditure. It is recognized that many other factors aside from water procurement influence these health variables and therefore the health index is not heavily relied upon at the end of this study (Garner and Gulmezoglu, 2002). However, according to previous studies and theories, of the health variables collected, quantified, and available at the regional level, those included in this study most directly relate to health complications caused by water procurement. Other health related variables were excluded due to either the lack of aggregation to the regional level or the inability to segregate data by gender.

Anemia and stunting data were aggregated to the regional level, as well as, urban and rural areas within each region. This data was extracted from the DHS as a percentage using STATA, and a survey weight was applied using DHS recommendations. This weighting prevents misrepresentations in the data due to the potential that some sub-groups are over or under-represented, therefore, correcting for disproportionate sampling. Life expectancy data was only available at the regional level, but was applied to both urban and rural areas.

The three health variables were then individually regressed with one another to determine their relationship. This linear regression analysis before index calculation is crucial to properly identify any potential bias that strong correlations may add to the index. For example, if two variables show a strong association with one another, the final index score may be inflated. When the life expectancy of each region and stunting in each region were compared, the correlation coefficient value ranged from 0.1302 for the entire region, 0.0283 for rural, and 0.0049 for urban. A regression analysis between anemia and stunting revealed a correlation value of .00005 for the entire region, 0.1589 for rural areas, and 0.0039 for urban areas. Finally, the comparison between life expectancy and anemia produced values of 0.0097 for the entire region, 0.0004 for rural areas, and 0.0259 for urban areas. These significantly low correlation coefficient values indicate no relationship, concluding that there is no data bias that may produce overstated index scores.

Therefore, an overall health index score was calculated for each region, as well as, the rural and urban areas within each region. Each health variable was weighted equally and index calculations were modeled after the Human Development Index (HDI), an exemplary model for overall index calculations (UNDP, 2011). The format of the HDI calculations was used due to the similarity in variables and goal of this study with that of the Human Development Report.

Percent values for lack of anemia and no stunting were converted into decimal form (by dividing by 100). Life expectancy was compared to the life expectancy of the entire country (57.4). These individual variable scores were then multiplied and the cube root was taken to produce a comprehensive women's health index score per region. Final index scores range from 0 to 1. Life expectancy data for Pemba South and Zanzibar North were available, and therefore, index scores were not calculated for these two regions.

Women's Empowerment

Similar index scores were created for women's empowerment. These scores included three variables which were also obtained from the 2010 Demographic and Health Survey: percent of women with some secondary education, percent of women who participate in health decisions for their household, and percent of women who participate in purchasing decisions for their household. These variables were chosen as a strong representation of the degree of women's empowerment. The amount of secondary education also relates to water procurement, one of the many reasons young girls miss school. Again linear regression analysis was performed between these variables. Correlation values for the regression analysis of participation in purchasing and education were 0.0677 for the entire region, 0.045 for rural areas, and 0.0929 for urban areas. Regression analysis correlating participation in health and education produced r^2 values of 0.0019 for the entire region, 0.0015 in rural areas, and 0.0091 in urban areas. These values indicate no correlation between variables. However, as expected, when participation in health decisions and participation in household purchasing were compared, a stronger correlation was witnessed (r^2=0.4007). Nonetheless, this association is only moderately positive and, therefore, does not add significant bias to the index calculations.

Women's education levels and the degree of female input in household decision making were then weighted equally and an index value was calculated for each region, as well as urban and rural areas within each region. Although the Human Development Report does not produce this particular type of index, as it does the health index, a similar formula model was used for study consistency (sample calculation included in the Appendix, Part A). To calculate the final index score, percentages for each variable were converted into decimal values, and these values were than multiplied and the product was raised to the 1/3 power.

Water Infrastructure

To create the water infrastructure (built environment) index, the number and type of boreholes was examined, in addition to, the percent of the population that is within 15 minutes of walking distance to the nearest water source and water production versus demand for drinking water. The number and type of boreholes for each region was obtained from a research study conducted by Baumann et al. (2005) that examined the NRWSSP Investment Plan Budget for Tanzania. This data source is not as recent as other sources used in this study; however, data related to water infrastructure is poorly collected and maintained, as mentioned in the introduction, and in turn, this was the most recent and reliable source. Therefore, later in the study, this index is broken down to examine the effect of the individual variables as well. The ratio of drinking water production versus demand in 2010 was obtained from the National Bureau of Statistics (NBS, 2013), while walking distance was obtained from a collaborative study conducted by the Ministry of Water and Livestock Development, WaterAid, and the NBS (NBS. 2013).

The first variable within the water infrastructure index, boreholes per capita, measures the number of boreholes per region compared to the total population in that region. Population data was obtained from the NBS (NBS, 2013). Additionally, as mentioned earlier, electric piped water sources are the only type of boreholes that retain a high guarantee of positive output when faced with significant drought or water scarcity (Elliott et al, 2011). Therefore, the second variable, "adaptive capacity," was calculated for by dividing the number of electric boreholes by the total population in each region. The final two variables did not require further computation.

Similar to the other index scores, the variables within the water infrastructure score were regressed with one another to determine potential index score bias. A comparison of boreholes per capita and adaptive capacity yielded a mild correlation (r^2=0.3545), while the comparisons of boreholes per capita to walking distances and to water production ratios yielded no significant correlations (r^2 = 0.0396 and 0.0678 respectively). When adaptive capacity was regressed with walking distance and water production ratios, no association was observed (r^2 = 0.0825 and 0.0213 respectively). Finally, an r^2 value of 0.0045 was recorded when walking distance was compared to production ratios. These insignificant correlation values indicate no index calculation bias in this portion of the study.

Percentages were converted to decimals and these four variables were weighted equally to create an index value for each region. Again, similar to women's empowerment scores, the HDI does not calculate water infrastructure or built environment index scores; however, the formulas used are easily applicable to this index and their use ensures consistency within the study. The four variables were multiplied with one another and then raised to the ¼ power. It is important to note here that multiple regions were excluded from the built environment index due to the lack of available data in the study.

Climate Change

The analysis of climate change in this study differed slightly from the previous index calculations. Composite index values were not created for each region due to the larger quantity of variables, differences in projection models utilized, uncertainty in predictions, and inability of even the most recent models to adequately and accurately aggregate to a regional level. Various types of data and models were used due to these uncertainty patterns and a general lack of data specific to Tanzania.

Past drought data was obtained from the Center of Hazards and Risk Research (CHRR) at Columbia University (2005). The CHRR data is a 2.5 degree resolution raster dataset from the International Research Institute for Climate Predictions (IRI) Weighted Anomaly of Standardized Precipitation (WASP). Calculations for this data set accounted for average monthly precipitation patterns from 1980 to 2000. Drought events were identified as a deficit of 50% of the median value for three consecutive months.

Data regarding future average total rainfall predictions for the years 2046-2065 was obtained from the Climate Change Model Portal of the World Bank (2013). The General Circulation Model (GCM) utilized by the World Bank employed a CNRM-CM3 A2 emissions scenario (World Bank Group, 2013). This coupled general circulation model is the third version of the ocean-atmosphere model initially developed at the Centre National de Recherches Meteorologiques in Meteo, France. Although more recent models (CM4 and CM5) have been produced, drought analysis has not been conducted using these. Additionally, although resolution has improved with more recent versions, CM3 models include the same past data variables as the more recent versions and significant bias in this model is found to reside only in oceanic temperatures, therefore producing little bias in this study of Tanzania (Voldoire et al, 2013). The A2 emissions scenario also provides greater information from an impacts and adaptation standpoint, and consequently is commonly used in analysis (NARCCAP, 2007). In turn, this model was chosen due to available drought analysis, lack of significant land bias, and suitability of resolution.

Additionally, previously analyzed datasets from the UNDP Climate Change Country Profile were also used in order to examine temperature, number of hot days, annual rainfall, and number of heavy rainfall predictions (McSweeney, New, and Lizcano, 2010). The UNDP dataset employed a General Circulation Model under the SRES A2 scenario (McSweeney, New, and Lizcano, 2010), similar to the World Bank model cited above. This datasets is not a primary source and, is therefore, prone to author bias. However, this bias is minimized through comparison of other models used in this study and verification with literature.

Index Analysis and Case Study

Linear regression was performed on the calculated index scores to determine the separate effect of water infrastructure and women's empowerment on the health and wellbeing of women at the regional level. A combined (added) empowerment and infrastructure score was also regressed with the women's health index score. Additionally, each individual variable score was regressed with each health score variable. This individual analysis ensured that the index scores did not dilute the effects of individual variables.

Additionally, the regions were grouped into larger districts (Bauman et al. 2005): Western (Tabora, Shinyanga, and Kigoma), Northern (Kilimanjaro, Tanga, Arusha, and Manyara), Central (Dodoma and Singida), Southern Highlands (Mbeya, Iringa, Rukwa), Lake (Kagera, Mwanza, and Mara), Eastern (Dar es Salaam, Pwani, and Morogoro), Southern (Lindi, Mtwara, and Ruvuma), and Zanzibar (Unguja North, Unguja South, Town West, Pemba North, and Pemba South). Zanzibar was excluded from these calculations due to lack of data for many of its regions. Variables within these regions were averaged and regression was completed in a similar manner to individual regional regression above. This data displays larger regional patterns that could be due to climate or political systems.

Similar linear regression analysis was also performed to determine the correlation between empowerment and health in both urban and rural areas. The built environment was excluded from this regression due to the inability to aggregate data smaller than the regional level. Again, regional data was averaged to determine any larger district effect. Urban and rural data was also compared in order to examine differences related to water procurement.

Each variable was also ranked and the rankings were qualitatively evaluated to determine regions where women are most vulnerable due to significant climate change, marginalization, and lack of infrastructure. A threshold, established as the bottom 15%, was set to determine the four regions with the lowest index scores for each respective variable. This threshold was established to eliminate any error from the identification of a single region. Finally, the index scores were overlaid with past and future climate data to determine patterns and identify potential vulnerable regions. Areas with low scores in one or more indexes, and that are expected to experiences significant climate change, were marked as vulnerable regions.

Finally, two differing regions were chosen to analyze these patterns and the complexity of the interaction observed in this study: Dodoma and Singida. These regions were chosen because both are facing significant climate change as shown by the World Bank Group (2013), CHRR (2005), and the study conducted by McSweeney, New, and Lizcano (2010). Yet, women's empowerment, water infrastructure, and health varied drastically between the two regions. Therefore, a case study was performed that compared these two areas to determine differences in policy, as well as, explain differences in coping with climate change. All results were then applied to the theory of gender climate justice.

In general, Pemba North, Pemba South, Zanzibar North, Zanzibar South, and Town West were excluded from data analysis due to a significant lack of data within these regions, lending to the inability to calculate accurate index scores. In some cases, the individual data of these regions are used to show patterns or differences; however, few major conclusions can be drawn from within these areas. The analysis steps above were also completed with the inclusion of the regions Dar es Salaam and Kilimanjaro, as well as, with the exclusion of these regions. The reasons for this exclusion will be discussed in the results and conclusions of this study.

IV. RESULTS AND ANALYSIS

This section will first examine index score results and correlations, noting particular patterns and associations at the regional level, as well as, differences between urban and rural areas within Tanzania. These correlations and patterns will then be overlapped with climate change data to identify vulnerable regions. Vulnerable regions are defined as areas where climate change has the potential to negatively impact the health and wellbeing of women. It was predicted that positive associations exist between women's empowerment and health, as well as, the degree of water infrastructure and women's health. This hypothesis is likely true, however, the data displays weak trends after analysis. Therefore, this investigation will conclude with a case study to display the importance of scale within these relationships. The case study compares two contrasting regions, Mara and Dodoma, to dissect scale specific local issues that both hinder and aid improvements to women's health. In turn, this case study is crucial to revealing spatial differences past the quantitative regional analysis of this study.

Index Analysis

Both the regional level water infrastructure index scores and women's empowerment index scores were regressed with health data to determine their effect on the health and wellbeing of women in Tanzania. Regression assessing the correlation between women's empowerment and health displays a minor positive association ($r^2 = 0.08$, Figure 4); however, this relationship is weak given the low correlation coefficient value. Therefore, although the relationship is positive, the variability in the data yields little confidence for definitive conclusions in this analysis. Nonetheless, other studies have provided strong evidence and support of this relationship. In a study completed by Ehrhardt et al. (2009), the authors argue the importance of gender empowerment through access to education, sexual reproduction resources, economic opportunity, and access and ability to make healthcare decisions. Ehrhardt et al.'s

(2009) analysis examined similar women's empowerment variables as this study; however, utilized different variables to measure health (including DALYS). The authors also discuss health impacts that are qualitative, such as psychological effects which are not measured by census or survey methods. Therefore, given evidence of current gender inequality, and evidence from Ehrhardt et al. (2009) and similar studies, it is likely that a stronger positive relationship between empowerment and health exists in Tanzania.

Nonetheless, regression of empowerment and health analysis indicated that two regions, Dar es Salaam and Kilimanjaro, are clear outliers (Figure 4). These observation points rest far from the sample mean, which implies that these regions are likely to be socially, culturally, or physically different from subsequent regions and that such differences impacts health and women's empowerment. For instance, Dar es Salaam is a major urban center within a country that is generally rural, the wealthiest region within the country by a margin of up to 80% (98.2% of Dar es Salaam citizens are within the fourth or higher wealth quintile for the country), and the *de facto* capital that links Tanzania to the rest of the world (DHS, 2010). Therefore, the city holds many opportunities for women, increasing the women's empowerment score within this country. In this region, women are also not walking as far to retrieve water and, in turn, have more time to attend school or work. Cities also provide a more diverse array of options for women that increase empowerment, including better access to markets and jobs within the formal and informal sector. On the other hand, although the empowerment index score is high for Dar es Salaam, the health index score is lower than to be expected. This may be attributable to high urban poverty rates, particularly within large slum settlements in Dar es Salaam. Urban areas can also act a demographic health sinks due to crowding, poor sanitation, and water contamination (Jenkins et al. 2013). Similar to Dar es Salaam, on average, Kilimanjaro citizens are considerably wealthier, with 68.9% within the fourth or higher wealth quintile for the nation (DHS, 2010). This wealth, particularly the increased power women hold over purchasing decisions, yields increases in health services and educational facilities (NBS, 2010). Kilimanjaro also sits high upon the world stage as a tourist destination and has the highest literacy rate within the country (DHS, 2010). These facts easily differentiate both Dar es Salaam and Kilimanjaro from the other 24 regions within the country. This high variability between regions also implies that although a relationship between empowerment and health may exist, it may not be detectable at this scale.

Initial regression analysis of the built environment and health reveal a slightly negative correlation ($r^2 = 0.009$, Figure 5a). However, Dar es Salaam and Kilimanjaro are again the two outliers in this relationship, and when they are removed from the data, a more positive trend develops ($r^2 = 0.06$, Figure 5b). After further examination of this association, two trajectories exist (Figure 5c). Both trajectories display a positive correlation between water infrastructure and health, yet the slope of each line differs. These trajectories correlate with specific geographic patterns, indicating spatial clusters within the data. Regions with low index values for both infrastructure and health, including Dar es Salaam, Iringa, Lindi, and Morogoro, are all located with southeastern Tanzania. Clusters observed in the upper trajectory are located within northern Tanzania; while a majority of regions along the lower trajectory (low health values) are within central or western Tanzania (Figure 5c). This discrepancy and separation of data into two patterns is likely due to the many complicated factors that determine health. However, this positive correlation is important to note, and similar correlations have been observed. Buor's (2005) study discovered strong correlations with walking distance and water quality to the health of women.

As previously explained, not all of the health variables pertain directly to the health and wellbeing of women who procure water, but rather they are surrogate data. Therefore, regression was also performed with the infrastructure and empowerment index scores using life expectancy data. Life expectancy is the most accurate description of overall health and therefore this regression analysis controls for variability in anemia and stunting rates that are not always related to water procurement. A positive, yet insignificant, correlation exists between women's empowerment and life expectancy ($r^2 = 0.17$, Figure 6). Regression of water infrastructure and life expectancy displays a similar pattern as the relationship between health and infrastructure (neutral correlation, but turns positive when the data points Dar es Salaam and Kilimanjaro are removed from the data, $r^2 = 0.06$, Figure 7a and 7b).

Regression analysis was also performed to analyze the impact of infrastructure on women's empowerment. Once Dar es Salaam and Kilimanjaro were removed from the dataset, a weak, yet positive trend existed (Figure 8). It is likely that a more positive relationship would exist if data was available to separate water infrastructure into urban and rural areas. This existence of this relationship is reinforced by other studies that confirm a positive relationship between greater female employment, increased gender equality in decision making, and increased self-esteem in areas with high quality infrastructure (Mfinanga and Kaswamila, 2014).

To analyze the effect of both water infrastructure and women's empowerment on health, water infrastructure and women's empowerment scores were added. The compiled index scores display a positive correlation with both life expectancy and health index scores ($r^2 = 0.18$ and 0.12 respectively, Figure 9 and 10). However, this relationship significantly strengthens when 3 regions, Dar es Salaam, Rukwa, and Mara, are excluded as outliers. The significance of Rukwa and Mara as outliers is revealed below in the identification of vulnerable regions. Additionally, within these analyses, two trajectories, as well as, clusters similar to those found within the infrastructure analysis exist. Other studies have not examined the combined interaction of these three variables together.

Individual Regression

Additionally, considering the large amount of surrogate data used in this study, each individual raw variable was compared to other variables outside its own index in order to dissect and fully analyze associations. This individual analysis also revealed many patterns that may have been masked by the use of compiled index scores.

Positive associations were found between participation in health and life expectancy (Figure 11), water production and participation in health (Figure 12), and percent within 15 minutes of walking distance to water and participation in health (Figure 13). When participation in purchasing decisions was regressed with each variable, a positive association was also found with life expectancy (Figure 14). Positive correlations also exist between electric boreholes per capita and life expectancy (Figure 15). Water production and percent with no anemia display a small positive correlation (Figure 16). On the other hand, when examining education, a relatively stronger positive association existed between percent with some secondary education and water production (Figure 17). Regression between other variables showed neither a positive or negative association.

These positive correlations indicate that water infrastructure may influence general health and women's empowerment. In many of these associations, the strength of the correlation (measured by the correlation coefficient, $r^2 < 0.1$) is weak due to high variability between regions and the influence of multiple outliers. Additionally, Kilimanjaro and Dar es Salaam remain constant outliers throughout the datasets. Nonetheless, obvious positive trends exist and the positive nature of these associations indicates that factors of empowerment and infrastructure may be related to health, as well as, one another. However, clusters were also identified within the data leading to a further examination of scale.

Analysis of Larger Geographic Areas

The above associations, while positive in nature, are weak correlations that do not display significant validity in terms of strength; however, after further examination of the data, there appear to be some clusters according to the larger geographical areas defined within the Demographic and Health Survey: Western (Tabora, Shinyanga, and Kigoma), Northern (Kilimanjaro, Tanga, Arusha, and Manyara), Central (Dodoma and Singida), Southern Highlands (Mbeya, Iringa, Rukwa), Lake (Kagera, Mwanza, and Mara), Eastern (Dar es Salaam, Pwani, and Morogoro), Southern (Lindi, Mtwara, and Ruvuma), and Zanzibar (Unguja North, Unguja South, Town West, Pemba North, and Pemba South). Therefore variables were averaged between these regions and linear regression analysis was performed. Zanzibar was excluded from this study due to the lack of available data.

A positive association exists within these larger geographical areas between women's empowerment and health (r^2 = 0.19, figure 18) and water infrastructure and health (r^2 = 0.03, Figure 19). Particularly for the latter relationship, when Dar es Salaam and Kilimanjaro are excluded, the strength of this correlation increases significantly. Additionally, when each of these averaged index scores is regressed with life expectancy, rather than health, similar positive patterns emerge. Compiled index scores (empowerment and infrastructure added) also display a positive correlation with health and life expectancy (r^2 = 0.23 and 0.49 respectively, Figure 20 and 21). These positive trends indicate clustering of regional areas that could be due to issues of overarching geographical themes that plague entire water catchment regions, such as climate, policy, and other unknown influences.

Rural Urban Analysis

However, regions are not homogeneous. There also exists a rural urban gap that produces differences in resources, access, and, capital that may influence the relationship between water infrastructure, women's empowerment and the environment. It was predicted that there would exist significant rural and urban differences within each variable, as well as, the trajectory and strength of correlations between rural and urban areas. Water infrastructure was excluded from this portion of the analysis due to the inability to aggregate these variables to a level smaller than the region.

In terms of women's empowerment, only one region recorded a higher women's empowerment score in rural areas when compared to urban areas: Iringa (Table 2). On average, urban scores were 77.5% higher than rural scores, with a percent difference range of 0.93% (Kilimanjaro) to 167.01% (Manyara). Additionally, all regions, except Iringa and Tanga, record higher participation in health in urban areas, with significantly large differences recorded in Manyara and Mwanza. A more varied pattern between urban and rural is seen in participation in household purchasing. Large discrepancies exist in secondary education in all regions except Iringa and Kilimanjaro (DHS, 2010).

On the other hand, the state of health varies significantly between urban and rural areas with rural areas averaging 0.59% higher than rural areas (Table 2). This difference ranged from 18% in Kagera to -6.16% in Mwanza. In terms of anemia, there is little pattern between urban and rural areas, with the only significant differences occurring in Dodoma (rural areas 20% higher prevalence than urban), Mara (rural areas 15% higher prevalence than urban), and Singida (rural areas 14% higher prevalence than urban areas) (DHS, 2010). Stunting varies significantly with no identifiable pattern.

In rural areas, results of linear regression analysis display a positive correlation between women's empowerment and both health (weakly positive, $r^2 = 0.25$, Figure 21) and life expectancy ($r^2 = 0.12$, Figure 22). However, these correlations are very weak. Individual variable analysis also displays a positive correlation between secondary education and life expectancy. When the larger DHS defined geographic areas are examined, positive and moderately strong associations exist between empowerment and health ($r^2 = 0.58$, Figure 23), as well as, empowerment and life expectancy ($r^2 = 0.46$, Figure 24). Correlations also exist between participation in health and life expectancy and participation in health and absence of stunting.

For urban areas, there exists a positive correlation, although weak, between women's empowerment and both health ($r^2 = 0.02$, Figure 25) and life expectancy ($r^2 = 0.14$, Figure 26). Individual variable analysis also revealed positive associations between health and participation in health decisions. Strong correlations also exist between participation in health and life expectancy and participation in household purchasing and life expectancy. Other moderately positive correlations in urban data include the percent of some secondary education and life expectancy. When the larger DHS defined geographic areas were examined, positive and relatively strong associations existed between empowerment and health ($r^2 = 0.58$, Figure 27), as well as, empowerment and life expectancy ($r^2 = 0.46$, Figure 28).

Poverty Analysis

Poverty and wealth also play a significant role in health, as well as, the ability to purchase water, dig boreholes, or fix water and sanitation facilities. Partial discussion of this poverty divide was analyzed earlier when considering Dar es Salaam and Kilimanjaro as outliers in this data. In turn, a further regional analysis was performed to assess the interplay of wealth in the interaction of women's health, water infrastructure, and women's empowerment. Little association was recorded between index scores and wealth; however a strong association was found between wealth and secondary education ($r^2 = .89$, Figure 29). Other positive correlations with wealth include water production and percent within 15 minutes of walking distance to water. This suggests that wealth and water infrastructure are related, and therefore, although not shown in this study, wealth may also be related to women's health as it pertains to water procurement.

Ranking by Region

Although few of the relationships above display strong correlation values, the weak correlations found combined with previous academic literature leads to the probable existence of a positive relationship between water infrastructure and health, as well as, women's empowerment and health. Therefore, understanding that these positive associations exist within both index analysis and individual variable analysis provides a solid platform to analyze climate data, as well as, locate potential vulnerable regions. Each region was ranked according to individual index scores. The top and bottom six regions are mentioned in this analysis, however, a full list of the rankings can be found in the appendix.

In terms of women's empowerment index scores, the regions scoring the lowest include Mara, Rukwa, Lindi, Manyara, Mwanza, and Mbeya. Those with the highest empowerment index include Kilimanjaro, Dar es Salaam, Tanga, Dodoma, Iringa, and Singida (Table 4). For the water infrastructure index, Kilimanjaro, Iringa, Dar es Salaam, Mtwara, Lindi, and Rukwa report the lowest scores, while Tabora, Ruvuma, Arusha, Singida, Dodoma, and Mbeya record the highest (Table 3). It is important to remember that Dar es Salaam is likely an outlier in this dataset. In terms of the health index, Mtwara, Pwani, Lindi, Shinyanga, Tabora, and Mwanza have the lowest scores, while Kilimanjaro, Manyara, Arusha, Singida, Tanga, and Kigoma retain the highest index values (Table 5).

Ranking with Urban and Rural Differentiation

Due to the significant differences recorded between urban and rural areas within each region, rankings were also performed after separating rural and urban records. Rural rankings were first assessed. For women's empowerment, Rukwa, Mara, Mwanza, Manyara, Lindi, and Tabora recorded the lowest index score, while Kilimanjaro, Tanga, Dar es Salaam, Iringa, Singida, and Dodoma recorded the highest (Table 7). In terms of health, the lowest ranked regions include Pwani, Shinyanga, Mwanza, Mbeya, Lindi, and Tabora. The highest ranking regions include Kilimanjaro, Arusha, Singida, Tanga, Rukwa, and Kigoma (Table 8). For urban women's empowerment, Mara, Lindi, Kigoma, Rukwa, Iringa, and Mbeya record the lowest index score, while Tabora, Dodoma, Kilimanjaro, Dar es Salaam, Kagera, and Manyara record the highest (Table 9). In terms of health index scores, Kagera, Lindi, Pwani, Dodoma, Mtwara, and Iringa have the lowest scores, while Kilimanjaro, Arusha, Manyara, Rukwa, Kigoma, and Tanga record the highest (Table 10). Low women's empowerment index values may indicate high vulnerability to climate change.

Climate Change Data Compilation and Analysis

Past drought data reveals the most severe and frequent droughts occurred within central and western regions of Tanzania. Of these, Ruvuma, Dodoma, and Iringa had the highest frequency of drought (CHRR, 2005), while Mbeya, Morogoro, and Rukwa also experienced moderate drought (Figure 34). In contrast, the majority of regions on the northeast coast, as well as, parts of southern Morogoro recorded more frequent rainfall patterns and fewer droughts. The regions with the lowest frequency of historical droughts include Mara, Dar es Salaam, and Zanzibar (CHRR, 2005).

An analysis of predicted future average rainfall between the years 2046 and 2065 from the World Bank Group identifies Dodoma, Manyara, Singida, and Arusha as vulnerable regions

(Figure 4) due to the lack of future rainfall (World Bank Group, 2013). Eastern Shinyanga, southeastern Mwanza, eastern Tabora, northern Iringa, northern Morogoro, and central Lindi also hold moderate risk (Figure 34). On the other hand, eastern and southern regions are expected to experience increases in annual rainfall, however, this increase is predicted to manifest in heavy and infrequent rain events (McSweeney, New, Lizcano, 2010).

Analysis completed by McSweeney, New, and Lizcano (2010) note an increase of at least 1 degree by 2030 and 5-7 degrees by 2060 across the country, with higher spikes of up to 9-10 degrees during summer months. Rainfall is estimated to increase roughly 10mm yearly by 2090; however, it is predicted to decrease by 10mm from the current level during the hottest months: June, July, August, and September (McSweeney, New, Lizcano, 2010). Percent rainfall change across the country is positive, yet Dodoma, Tabora, Singida, Ruvuma, Lindi, Iringa, and Mbeya will experiences a roughly 15% decrease during summer months. The percent of hot days in a year across the country is expected to increase to 40% of all days by 2060 and reach 50% (70% in summer months) of all days by 2090. Heavy rainfall events will increase by 5% in the north, yet this pattern diminishes to 0% further south (McSweeney, New, Lizcano, 2010).

Identification of Vulnerable Regions

With significant rainfall and temperature changes predicted across the country, Tanzanian waterscapes are likely to drastically change within the coming century. However, the ability to adapt depends on various factors, including water infrastructure and women's empowerment. Although the correlations between these variables and health assessed earlier revealed only weakly positive associations, the positive nature of these studies, backed by literature lends the confidence to assess vulnerable regions and predict where women's health may be negatively impacted by climate change. It is important to note that this assessment of vulnerable regions excludes health data. Vulnerable regions are qualitatively identified as areas facing significant climate change and at the same time are marked by poor water infrastructure and poor women's empowerment. This vulnerability analysis predicts regions where women's health and wellbeing could be most drastically influenced by climate change. Vulnerable regions identified from this study include Mara, Rukwa, and Lindi.

Mara held the lowest combined water infrastructure and women's empowerment regional score (0.241, Table 6), with the lowest recorded individual women's empowerment score of 0.161 (Table 4). In terms of water infrastructure, Mara lies within the bottom 46% of water infrastructure scores (Table 3). Similar patterns are seen when Mara is divided between urban and rural areas. The region records the lowest urban empowerment score and is only ranked above Rukwa in rural women's empowerment. Little data is available for past drought conditions, however, future predictions indicate low future average total rainfall (Figure 35). Rainfall predictions show an increase in 10mm by 2060, yet a net increase of 0mm during the dry season (McSweeney, New, and Lizcano, 2010). The region is predicted to increase 2.4°C by 2060 and 3.8°C by the end of the century. Additionally, the frequency of hot days is expected to increase by roughly 31% by 2060 and 46% by 2090, with increases exceeding 73% in the warmer months (McSweeney, New, and Lizcano, 2010). Women's health in Mara ranks within the bottom 34% of the health score distribution. Additional studies have also noted the high vulnerability of Mara due to the significant effect climate change will have on the hydrologic system of the Upper Mara River Basin, creating the potential for severe water scarcity (Mango et al. 2011).

Rukwa is also highly vulnerable, ranking only above Mara in the combined infrastructure and empowerment scores (Table 6). This region rests within the bottom 46% of water infrastructure (Table 3) and the bottom 1.2% of the empowerment score range (Table 4). Rukwa records the lowest rural empowerment score and rests within the bottom 17% of urban empowerment scores (Table 7). Past drought history in Rukwa is relatively minimal (Figure 34); however, future rainfall averages indicate high chances of drought within the future (Figure 30). Temperatures are predicted to increase 1.5°C within the next 15-20 years, while increases of up to 5-6°C are expected to occur by the end of the century (McSweeney, New, and Lizcano, 2010). The proportion of hot days annually is predicted to rise to 44% by 2060, and up to 76% by 2090. A 10% increase in precipitation annually is also predicted by 2090, however, a negative 30% decrease is anticipated during summer months (June, July, August and September) and a mere 1% increase during October, November, and December (McSweeney, New, and Lizcano, 2010). Additionally, Rukwa is the only region where the change in percent rainfall in heavy events and the change in maximum 1-day rainfall will actually decrease by 2090 during the summer months. The current state of health in Rukwa is relatively average, ranking within the bottom 45% of all region scores. Nonetheless, without proper infrastructure and gender equality, the health status for women could be detrimentally impacted by future climate change. Other studies have identified Rukwa's vulnerability to climate change in relation to ecological, as well as, socio-economic outcomes (Manase, Gara, and Wolanski, 2010).

This study also indicated high women's health vulnerability to future climate changes in Lindi due to poor infrastructure and high women's marginalization. In the combined water infrastructure and women's empowerment scores, Lindi ranked third to last, with only by Mara and Rukwa ranking lower (Table 6). Lindi ranked third to last in individual women's empowerment (Table 4) and fifth (bottom 35%) in water infrastructure index values (Table 3). Lindi also records a low health index score, scoring higher than only Mtwara and Pwani. Poor health, combined with poor infrastructure and empowerment create issues of adaptation and mitigation to climate change. Additionally, Lindi ranked second to last in urban empowerment scores (Table 9), and within the bottom 18% of values for rural empowerment (Table 7). Historically, Lindi has experienced moderate to high levels of drought for areas where data is available in the region (CHRR, 2006), and future rainfall predictions from the World Bank Group predict similar patterns of low average total rainfall in the future. The research of McSweeney, New, and Lizcano (2010) support these predictions, with rainfall during the summer months decreasing by roughly 1-10mm (9% decrease) by the end of the century. Additionally, annual temperatures are expected with rise by 1°C by 2030 and 3.5°C by 2090. Models predict an increase in percent hot days to 31% (52% in summer months) by 2030 and 52% (82% in summer months) by 2090. Few studies site Lindi as a region of high vulnerability to climate change compared to other areas, such as Morogoro and Tabora. Nonetheless, previous studies have not examined vulnerability as it pertains to women's health specifically, and therefore, a focus on ecological factors or agricultural effects will produce different results.

Additionally, given data regarding rural-urban divides and poverty, rural and more impoverished areas appear, as predicted, more vulnerable to climate change than urban and wealthier areas (Table 2). This difference is due to increases in resources, capital, access to jobs outside of agriculture, and access to markets in an urban and high wealth setting. In turn, these resources provide a larger variety of mitigation methods to combat climate change and ensure one's wellbeing.

However, in contrast to these regions with high vulnerability, there also exist regions that, although facing significant climate change, are not labeled as vulnerable in this study due to high empowerment and water infrastructure index scores. Below, I flush out some of the reasons for these disparities in a case study that compares and contrasts Dodoma and Mara, one of the highest ranked vulnerable regions in this study.

Case Study Comparison

Dodoma has faced some of the most drastic and significant drought and temperature increases within Tanzania across the past fifty years according to the Center for Hazards and Risk Research at Columbia University (2006). Nonetheless, the region ranks high in regards to women's empowerment and water infrastructure. Dodoma rests within the top 25% of water infrastructure index values (Table 3) and records a women's empowerment index score within the top 4 rankings (Table 4). Dodoma's health index score rests around the mean, yet life expectancy has increased at a rapid rate of 17% from 42 in 2003 to 49 in 2010 (NBS, 2010). Other regions average a roughly 5% increase in life expectancy, with some even experiencing a recent decline. In turn, although future climate change models predict significantly low levels of rainfall and drastic temperature increases, Dodoma is relatively prepared to endure this change in regards to infrastructure and women's empowerment, and appears to have already done so. This lack of vulnerability can be attributed to proper infrastructure implementation and policy, and correlates with a significant positive impact on women's health and wellbeing. Other studies have also labeled Dodoma, and several surrounding regions including Tabora and Singida, as areas most ecologically vulnerable to drought and water stress (The World Bank Group, 2013). However, this analytical and subsequent case study displays a different story in terms of women's health vulnerability.

In terms of infrastructure, Dodoma borehole drilling patterns significantly differ from other regions. According to Baumann et al. (2005), deep drilling methods are employed for a large portion of Dodoma boreholes, resulting in an average depth of over 100 meters. In turn, these deeper boreholes yield significantly larger shares of water compared to other regions with shallow boreholes. Average yield in Dodoma boreholes is roughly $30m^3$ per hour, a return that surpasses other regions by 30-90% (Baumann et al. 2005). This depth also increases the sustainability during drought, as deeper boreholes are more likely to provide water than more shallow wells in times of water stress (Elliot et al. 2005).

It is also important to note that a mere 20-30% of sites in Dodoma are suitable for dug wells, a very low proportion when compared to Mara (41-50%) or Rukwa (60-70%), regions that are classified as vulnerable (Baumann et al. 2005). Nonetheless, more boreholes exist and operate more efficiently in Dodoma on a smaller portion of land. Additionally, in Dodoma, the number of current boreholes nearly matches the number of existing potential sites for new boreholes. This implies that Dodoma has adequately capitalized on the borehole market, and that such action has proven successful, correlating to improved health and wellbeing for women (Kashiagili, 2007). I recognize that significant physical geographic and geologic components exist, and spatial disparities in these components interact to influence number and yield. However, surrounding regions with similar soil, recharge levels, and geologic composition; such as Singida, Tabora, or Manyara (Baumann et al. 2005); record drastically different results in water infrastructure. Therefore, this implies further influences, beyond the physical waterscapes, including policy, poverty, and other unknown factors outside of geographical and geological limitations.

Proper implementation strategies and policy in Dodoma have proven key to improving water access and, in turn, women's health and wellbeing. A crucial source for such high performance lies in the program framework implemented by the World Bank and WaterAid (Garriga, 2007). However, it is important to note that the organization title or presence did not produce these positive results, but rather the type of policy and the processes of implementation, which hold potential for replication by private firms and governments across the country (Noel, 2007).

WaterAid's sustainable approach, with the goal of improving access to the most vulnerable, such as women, focused on enhancing local capacity, implementing GIS monitoring programs, and facilitating power decentralization (Garriga, 2007). WaterAid's main partnership is with the government, demonstrating that this cooperation is one of the essential links to creating a sustainable and integrated project within both rural and urban areas. The involvement of both the local and national government also provided local ownership, developed capacity, and facilitated education and long-term commitment. This implementation strategy has proven effective. WaterAid implemented water schemes have an overall functionality of 70%, and an increased source sustainability of over 50% in many villages. Additionally, the World Bank has also acted as a driver behind improving private infrastructure development, rural access, social integration, and scaling of service delivery. The functionality of these water schemes reaches 100% at some sites of implementation (Garriga, 2007). It is also important to note the success of these projects reaches outside of the Dodoma region. The World Bank, WaterAid, and Ingenieria Sin Fronteras have implemented similar projects within Singida and Tabora. The success of these smaller and more varied projects is reflected within the index score calculation and comparison of water infrastructure in this study.

Additionally, the Ministry of Water and Irrigation (MoWI) and dejure capital are located within Dodoma and, in turn, the region receives increased access to the services it provides due to close proximity (Garriga, 2007). There also exists a high participation rate in water planning decisions within the region, ranging from 78.6-92.9% across districts, as well as, a high willingness to pay (85.7-100%) (Mfinanga and Kaswamila, 2014).

Nonetheless, Dodoma rests far behind other areas of the world in terms of water infrastructure development and women's empowerment, and still requires significant improvements in water infrastructure and gender relations to adequately face and adapt to climate change. Additionally, Dodoma is not entirely homogeneous with various ethnic groups and a significant rural-urban divide. Therefore, some of these projects and policies have yet to positively impact highly marginalized areas.

In contrast to Dodoma, Mara records extremely low infrastructure and empowerment scores, and therefore, this study has labeled the region as one of the most vulnerable to future climate change. Yet Mara is an interesting paradox. The region has over 10,000 square meters freshwater, which equates to more water per capita than any other region (NBS, 2013). In turn, clearly the problem is not necessarily lack of water, although this will be a challenge in light of future climate change, but poor infrastructure for proper extraction and distribution of water. A high proportion of non-working water supplies exacerbated by ethnic conflicts, lack of infrastructure, severe poverty, and limited project implementation results in a system vulnerable to severe ecological change (Garriga, 2007). Unfortunately, a similar narrative is also seen in Rukwa and Lindi.

The average depth of Mara boreholes is roughly 62 meters, resulting in a yield of less than $5m^3$ per hour (Baumnann et al. 2005). Contrasting this to Dodoma, Mara boreholes are roughly 40% more shallow and only yield 17% of the average yield in Dodoma. Only Rukwa ranks lower in yield than Mara. Additionally, there exist a large proportion of shallow boreholes (0-30 meters deep), which present significant challenges for water extraction during times of water stress (Baumann et al. 2005). Distribution of infrastructure also plagues the region, presenting significant issues of inequality and, in turn, differential impacts on women according to spatial location. For instance, more boreholes exist in the Mumosa District of Mara, yet the Tarume District holds a higher population (NBS, 2013). Water conflict between both ethnic groups within Mara, as well as, along the border of Kenya also hinder project and policy success. Additionally, recent efforts have been centered on conservation and preservation of biodiversity within the region. Conservation projects, including the WWF Mara River Basin Management Initiative, while important to conserving water sources in light of climate change, do little towards infrastructure and gender equality improvements (Mango et al. 2011). Few sustainable projects have focused on these issues within Mara.

Subsequently, this analysis and case study have provided a snapshot of the interaction among infrastructure, women's empowerment, health, and climate change. Positive relationships were discovered between infrastructure and empowerment that led to the ability to identify Mara, Rukwa, and Lindi as areas vulnerable to the negative impacts of climate change on women's health and wellbeing. However, many of the relationships examined in this study provided inconclusive and insignificant evidence. In the next section, I will provide an explanation for these patterns and analyze the validity of this study.

V. DISCUSSION

Women's marginalization and the built environment profoundly impact women's health and wellbeing. Although the quantitative evidence in this analysis is weak, in general, this study supports the hypothesis that poor women's health and wellbeing are associated with high women's marginalization and the lack of appropriate water infrastructure in Tanzania. This study also provided a framework to identify three regions, Mara, Rukwa, and Lindi, where women's health is most vulnerable to future climate change due to poor infrastructure and high women's marginalization. The impact of climate change on women's health in regards to water procurement alludes to larger questions regarding gender climate justice not only in Tanzania, but around the globe.

Initial analysis of the data revealed few trends; however, once Dar es Salaam and Kilimanjaro were identified as outliers within the data, positive associations were discovered between infrastructure and women's health, as well as, empowerment and women's health. These associations are weak and do not display quantitatively significant results. However, given previous studies of the larger East African region, this relationship likely exists with higher confidence than what is displayed within this study, indicating that potential flaws of analysis related to scale and data used may exist. These issues will be discussed later in this section. Nonetheless, these relationships are incredibly important to understand and dissect in order to assess women's health as it pertains to water procurement. In the past, issues of water procurement were generally approached by only one angle, such as borehole count (Bour, 2004); however, this method only dissects a small part of the whole problem. To create a sustainable and lasting system of improved water collection, a cultural understanding of women's roles within the community and traditionally established gendered divisions of labor, alongside an analysis of the built environment, is required. Therefore, this first portion of the study holds high relevance and significance due to its holistic manner of analysis that accounts for various factors that influence women's health.

This study also, as predicted, revealed significant gaps in health and empowerment between rural and urban areas. Rural areas consistently scored lower than urban areas in both health and women's empowerment rankings, and, although, differences in water infrastructure between rural and urban areas were not assessed in this analysis, previous studies have revealed significant gaps between rural and urban water and sanitation facilities as well. These relationships display that not only regional discrepancies surrounding water collection exist, but gaps between urban and rural areas also exist within regions. This rural-urban pattern is consistent across the entire country, and is a pertinent issue, considering that the majority of the population living in rural areas. Therefore, understanding the barriers to this urban-rural divide is crucial to improving women's health as it pertains to water procurement. It is recognized that the health gaps between rural and urban areas may be due to other factors, such as limited medical resources in remote rural areas; however, health data that examines the specific physical effects of water collection has yet to be extensively collected.

Additionally, regional clusters were discovered in the data, which could account for the weak relationships recorded when all regions were examined. Instead of precise linear relationships among health, infrastructure, and empowerment, areas similar in terms of location, government, and climate appear to cluster. After further analysis, it was discovered that these regional clusters coordinated with larger geographical areas defined by the Demographic and Health Survey, indicating policy, resource allocation, and physical geography may influence water procurement and, in turn, women's health. Therefore, it is important to apply this relationship at all scales to fully understand various other influential factors, as well as, their scale of influence. However, further data collection and statistical research will need to be completed in order to determine the validity of these relationships at the community level.

Although not all of the correlations within the first half of this study revealed strong evidence for positive relationships among health, infrastructure, and empowerment, for the second part of the analysis, this relationship was assumed to be true based on previous studies. However, health data was not used in this portion of the analysis, due to its lack of specificity to water collection. Regions where the current state of women's health is vulnerable to future climate change, and where this change will place an even heavier burden on women due to gendered patterns of water collection, were predicted using climate change models. Temperature predictions across the country range from a 1°C-5°C increase throughout the coming century (McSweeney, New, and Lizcano, 2010), and therefore, due to a severe lack of proper infrastructure throughout all areas of the country, most regions within Tanzania will likely experience negative impacts. Such increases in temperature translate to women standing in long lines and enduring dehydrating conditions for long periods of the day. Changes in precipitation will also increase the number of seasonally nonfunctional boreholes and, in turn, increase the distance women must travel to collect water and provide for their households (Elliott, 2005). Longer walking distances translate into decreased total water collection due to the inability to carry heavy jugs for longer distances and the lack of time to make multiple trips (Fontana and Natali, 2008).

These factors combine to create a highly vulnerable atmosphere for Tanzanian women, particularly in Mara, Rukwa, and Lindi, and will continue to have detrimental health effects on both women and their families without the creation of beneficial policies and programs in the near future. Additionally, given rural-urban divides found in the first part of this study, it is likely that climate change will have the greatest negative impact on rural areas within these regions. Therefore, there exists a large need for focused policy from both the national and local governments, as well as, an increase in sustainable project implementation to reduce this vulnerability. It is also important to note that these predictions are time sensitive and if significant improvements in infrastructure and women's empowerment are achieved, the rankings and vulnerabilities of this study will need to be readjusted.

The relationship among climate change, women's empowerment, water infrastructure, and health is relevant and key to understanding scale and spatial differences in water related development challenges. When poor women's empowerment and poor water infrastructure exist within the same region, there is a high potential for detrimental health consequences to women surrounding the burden of water collection, as identified in Mara, Rukwa, and Lindi. Understanding the complicated factors, and more specifically their interaction, to produce this development challenge, is key to creating solutions, and represents the need for a well-rounded approach to development. Yet, like any model, there exists simplification in this study. The intricate interaction of factors examined is not limited to those within this analysis, but rather encompasses infrastructure quality, women's empowerment, divisions of labor, cultural practices, wealth, class divisions, and differences between communities. Nonetheless, this study begins to holistically address these factors as they pertain to water usage and women's health.

Proper and efficient water infrastructure, meaning deep boreholes and proper maintenance, is key to minimizing the health effects of climate change on women (Elliot et al, 2005), though this is only one factor in the equation to improve women's health. In Tanzania, water infrastructure construction, such as borehole drilling, is completed both privately and through the government. Government resources and ability are limited by both money and inefficiencies, and therefore, there exist significant country wide barriers that prevent access to proper water infrastructure throughout the country (Kashaigili, 2010). For example, those closest to city capitals and urban centers, such as Dodoma and Dar es Salaam, receive a greater proportion of resources. Additionally, the majority of borehole drilling is completed by the government due to its unwillingness to allow an increase in private competitors. Yet, the government lacks the ability and capital to adequately serve the entire population, let alone continue maintenance on previously drilled boreholes (Baumann et al. 2005). On the other hand, private construction depends upon community and individual wealth that varies significantly throughout the country, as well as, between rural and urban areas (Baumann et al. 2005). Evidence of this can be seen in the strong positive relationship found in this study between water production and regional wealth. Therefore, women's health is detrimentally impacted due to the lack of government assistance and monetary capital at the national, community, and individual level. Without these resources, many women are forced to face the multitude of health insults from walking long distances, waiting in lines, and consuming potentially contaminated water.

Women's empowerment and gendered divisions of labor within the country also play a crucial factor in determining the health burden of water collection on women, as well as, play a crucial role in understanding the potential impacts of climate change. As a whole, Tanzania ranks low on the global scale in terms of women's empowerment and gender equality; however, there also exists significant regional differences within the country (Elu and Loubert, 2012). This heterogeneity lends to the varying levels of women's empowerment, which is determined by both resource discrepancies and differences in gendered traditional values. Therefore, future policy and project implementation need to address these issues in order to effectively relieve the burden of water collection in Tanzania.

The relationship between water and climate change has been speculated upon by multiple climatologists, geographers, and health professionals alike. This paper intends to establish the complicated web of interaction between gender norms and expectations, the built environment, water collection, and climate change, and how these variables interact to affect women's health. The unique aspect of this study is the manner in which each of these variables was measured and evaluated, and in turn, this analysis provides an ideal and novel platform to spatially locate regions where policy should be targeted.

Nonetheless, due to the limited resources of this analysis, there exist some gaps and inconsistencies in the study. For example, one confounding variable that may have influenced data analysis is that Mara and Mwanza, two of the three lowest ranked regions, may have fewer boreholes due to the regions' close proximity to Lake Victoria, a potential water source. However, adaptive capacity (electric boreholes divided by total boreholes) was measured rather than the aggregate number to control for this potential bias. Lake water is also not a safe and healthy source of drinking water due to contamination, and therefore does not constitute as an effective solution. Additionally, primary data collection methods were not utilized in this study and, therefore, there exists a significant lack of data that directly and quantitatively evaluates the direct impact of water procurement on health. There also exists a lack of gender disaggregated data on the effects of water procurement below the regional data. For this study, DHS surrogate data was used to analyze the overall state of women's health. Considering the health data does not directly relate to water collection, this use of surrogate data is the most plausible reason that the health relationships found in this study are weak. The calculated health status could be attributable to numerous factors not related to water procurement. Unfortunately, few studies exist that quantify all health effects due directly to water procurement and none exist that encompass the entire country. Therefore, health index scores are not conclusive, but rather provide a comprehensive summary of health at the urban and rural regional level. This confounding variable was the prime motivation behind not combing health index scores with any other indexes.

Issues of scale are also present. This study provides an overview of Tanzania and identifies potential regions where women's health may be detrimentally affected by climate change. However, due to current technological limitations that hinder the ability to aggregate climate data to a smaller spatial scale, regional level analysis was performed. Yet, I understand that even regions are not homogenous in terms of culture, physical geography, wealth, and government resources. Therefore, it is pertinent that further research analysis be completed within communities before significant action is taken. This study simply provides large scale regional patterns, and identifies potential vulnerable areas in need of policy and resources.

Addressing the intersection between water scarcity, gender norms, and infrastructure requires both local and national action that considers societal complexities, as well as, changing land and climate. Throughout most of Tanzania, water supply services, especially in rural areas, fail to provide adequate facilities to sustain women's needs. In turn, water procurement becomes a significant burden to their health and wellbeing. Dodoma programs provide an effective model that integrates decentralized policy with borehole market maximization, and the implementation of this model strongly correlates with improvements in women's health. Such policy holds high potential to be replicated throughout other vulnerable regions.

In turn, policy throughout the country, but particularly in the identified vulnerable regions of this study, requires a comprehensive move from projects to sustainable programs that effectively integrates local governments, as the key enablers, and communities, as the prominent managers. It is also crucial to note that policy should not focus on the sheer number of boreholes, but also on type, sustainability, distribution, and depth (Elliot et al. 2005). Additionally, not only is it important to build, but also track and monitor boreholes, as over 90% cease operation within a year due to easily fixable problems (Kashiagili, 2007). Proper monitoring systems to ensure functionality, increased availability of spare parts, and GIS water point mapping should also remain top priority (Kashiagili, 2007). Finally, recognition of women as key players and prime sources of water knowledge is of utmost importance.

This study is not conclusive, yet establishes a framework to evaluate the interactions of gender norms, the built environment, and climate change. Overall, this analysis acts as a baseline and backdrop for future studies that can directly examine health variables, as well as, individual household data. Future studies should focus on the distribution of boreholes, particularly piped sources, within each region, rather than a summary examination of regional aggregate data. Additionally, more research should be completed that quantitatively assesses the health impacts of water procurement on women. Nevertheless, this study is applicable. Water availability is expected to become an increasing issue throughout Tanzania, and much of Africa, in the coming century. Therefore, it is becoming increasingly important to understand and address the intricate interaction among water scarcity, women's empowerment, and the built environment in order to implement appropriate policy that mitigates the impact of climate change on women's health and wellbeing.

In conclusion, barring the potential impacts of climate change on the women's health as it pertains to water procurement, a greater understanding and acceptance of gender climate justice is needed. It is important to understand that gender roles and understandings shape women's vulnerability, particularly for women in rural areas of Tanzania, as well as numerous others around the globe. This study simply fills a small hole in the void of knowledge regarding how climate change has and will differentially affect women and men. Due to differences in gender equality and the institution of gendered divisions of labor, even further analysis of the differential impacts on health and livelihoods is required in order to prevent future health and development challenges. However, this lack of knowledge regarding gender climate change is not endemic to Tanzania. An understanding of gender constructions, expectations, policies, and roles across cultures, regions, and countries is crucial to effectively reducing the impact of climate change on women. Yet this analysis of Tanzania is case sensitive and results may vary drastically in other countries that exhibit differing gender constructs or that rest at a differing level of development.

Discourse that combines gender issues and climate has just recently emerged, yet severely lacks in substantial knowledge and understanding at the global scale. Therefore, more gender-awareness research needs to be completed within various communities to gain a comprehensive understanding of climate change and women's health. Women, such as those within Tanzania, are a virtue to understating climate change, and therefore, need to be accepted into the local and global discourse as well. If the current discourse remains, the lack of attention to gender issues in the context of climate change will have detrimental social, health, and development repercussions.

Gender dimensions in regards to climate change and water procurement in Tanzania need to be addressed at a much deeper level. Therefore, this study begins to dive into the complexity of gender climate justice as it dissects the relationship between water infrastructure, women's empowerment, and health. The results can be used to examine regional and spatial patterns that lend to simple identification of vulnerable areas in need of infrastructure and policy. This knowledge lends to the ability to cope and adapt to climate change early and through preventative measures with help from communities, governments, and aid organizations. This proactive analysis and action will provide benefits not only to the health of women, but also the wellbeing, health, and development status of a nation.

VI. WORKS CITED

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VII. APPENDIX

A. Sample Calculation for Arusha

1. Women's Empowerment

Percent with some secondary education/100 =X

Percent participation in health decisions/100 = Y

Percent participation in purchasing decisions/100 = Z

$\sqrt[3]{X*Y*Z}$ = Final index score

Ex. $\sqrt[3]{0.5574*0.332*0.171}$ = **0.3163**

2. Women's Health

Life expectancy: $\frac{Eo-20}{life\ expectancy\ at\ birth}$ = X

No stunting % breastfeeding/100 = Y

No anemia %/100 = Z

$\sqrt[3]{X*Y*Z}$ = Final index score

Ex. $\frac{66-20}{57.4} = .801 = X$

$\sqrt[3]{0.801*.0.9918*0.6729} = \mathbf{0.81172}$

3. Water Infrastructure

Boreholes/capita = W

Electric boreholes/capita = X

Percent within 15 minutes of water source/100 = Y

Percent production vs. demand of drinking water/100 = Z

$\sqrt[4]{W*X*Y*Z} =$ Final index score

Ex. $\sqrt[4]{\left(\frac{382}{1288000}\right)*\left(\frac{87}{1288000}\right)*.658*.85} = \mathbf{0.10288}$

B. Index Scores

Table 1. Index Scores for each Region

Region	Women's Empowerment Index	Water Infrastructure Index	Women's Health Index
Arusha	0.31630087	0.102884	0.811721
Dar es Salaam	0.531374067	0.067862	0.687519
Dodoma	0.359778656	0.096178	0.704307
Iringa	0.344495734	0.062991	0.662623
Kagera	0.303495365	0.083765	0.727347
Kigoma	0.277722928	0.080625	0.744326
Kilimanjaro	0.545578893	0.052671	0.874109
Lindi	0.209396321	0.073661	0.643352
Manyara	0.216290154		0.819314
Mara	0.161066493	0.079351	0.715039
Mbeya	0.250109864	0.096133	0.662184
Morogoro	0.305516418	0.086903	0.66063
Mtwara	0.296970778	0.068735	0.634877
Mwanza	0.236333926	0.092397	0.654534
Pwani	0.323623625		0.635
Rukwa	0.165632539	0.078745	0.74271
Ruvuma	0.272459608	0.109262	0.720264
Shinyanga	0.285004219	0.093402	0.652156
Singida	0.33177104	0.097662	0.784685
Tabora	0.26599956	0.111132	0.653368
Tanga	0.403974965	0.079984	0.7453

*Four regions are excluded from this study due to lack of data

**Two regions (Manyara and Pwani) are missing water infrastructure data, but are still included in this study

Table 2. Rural and Urban Index Scores

	Rural		Urban	
Region	**Women's Empowerment Index**	**Women's Health Index**	**Women's Empowerment Index**	**Women's Health Index**
Arusha	0.230491658	0.8000465	0.479830263	0.818369175
Dar es Salaam	0.353979069	0.73449152	0.542684389	0.687519351
Dodoma	0.292228737	0.71660837	0.601185689	0.64596181
Iringa	0.352867371	0.67261201	0.319580756	0.6628587
Kagera	0.280528316	0.72802009	0.53239764	0.6143335
Kigoma	0.218768762	0.73595598	0.311246245	0.758019685
Kilimanjaro	0.544158519	0.88521462	0.549230632	0.874108523
Lindi	0.190175656	0.64508412	0.275260009	0.634420061
Manyara	0.187204702	0.7976539	0.499847602	0.813163676
Mara	0.144264204	0.71146043	0.251637981	0.668440158
Mbeya	0.219252842	0.64290827	0.341887683	0.680933712
Morogoro	0.227419132	0.65375494	0.39149146	0.690359499
Mtwara	0.224329479	0.65175642	0.420673577	0.650330089
Mwanza	0.16517593	0.64264032	0.422015573	0.684802849
Pwani	0.283081724	0.64211951	0.363132138	0.638381554
Rukwa	0.114788044	0.73952337	0.312574237	0.758856218
Ruvuma	0.247130823	0.72337196	0.371503683	0.739281861
Shinyanga	0.247643313	0.64263534	0.467142308	0.719204494
Singida	0.313830899	0.78826569	0.370496468	0.742032363
Tabora	0.205822548	0.64774546	0.605223517	0.667631632
Tanga	0.362612837	0.74716282	0.474250743	0.744263232

*Infrastructure data not available for urban and rural areas

Table 3. Water Infrastructure Regional Ranking from Lowest to Highest

Region	**Water Infrastructure Index**	**Ranking**
Kilimanjaro	0.052671	1
Iringa	0.062991	2
Dar es Salaam	0.067862	3
Mtwara	0.068735	4
Lindi	0.073661	5
Rukwa	0.078745	6
Mara	0.079351	7
Tanga	0.079984	8
Kigoma	0.080625	9
Kagera	0.083765	10
Morogoro	0.086903	11
Mwanza	0.092397	12
Shinyanga	0.093402	13
Mbeya	0.096133	14
Dodoma	0.096178	15
Singida	0.097662	16
Arusha	0.102884	17
Ruvuma	0.109262	18
Tabora	0.111132	19

Table 4. Women's Empowerment Ranking at Regional Level from Lowest to Highest

Region	**Women's Empowerment Index**	**Ranking**
Mara	0.161066493	1
Rukwa	0.165632539	2
Lindi	0.209396321	3
Manyara	0.216290154	4
Mwanza	0.236333926	5
Mbeya	0.250109864	6
Tabora	0.26599956	7
Ruvuma	0.272459608	8
Kigoma	0.277722928	9
Shinyanga	0.285004219	10
Mtwara	0.296970778	11
Kagera	0.303495365	12
Morogoro	0.305516418	13
Arusha	0.31630087	14
Pwani	0.323623625	15
Singida	0.33177104	16
Iringa	0.344495734	17
Dodoma	0.359778656	18
Tanga	0.403974965	19
Dar es Salaam	0.531374067	20
Kilimanjaro	0.545578893	21

Table 5. Women's Health Ranking at Regional Level from Lowest to Highest

Region	Women's Health Index	Ranking
Mtwara	0.634877	1
Pwani	0.635	2
Lindi	0.643352	3
Shinyanga	0.652156	4
Tabora	0.653368	5
Mwanza	0.654534	6
Morogoro	0.66063	7
Mbeya	0.662184	8
Iringa	0.662623	9
Dar es Salaam	0.687519	10
Dodoma	0.704307	11
Mara	0.715039	12
Ruvuma	0.720264	13
Kagera	0.727347	14
Rukwa	0.74271	15
Kigoma	0.744326	16
Tanga	0.7453	17
Singida	0.784685	18
Arusha	0.811721	19
Manyara	0.819314	20
Kilimanjaro	0.874109	21

Table 6: Combined Water Infrastructure and Women's Empowerment Scores

Region	**Combined Score**	**Ranking**
Mara	0.240418	1
Rukwa	0.244377	2
Lindi	0.283057	3
Mwanza	0.328731	4
Mbeya	0.346243	5
Kigoma	0.358348	6
Mtwara	0.365706	7
Tabora	0.377132	8
Shinyanga	0.378406	9
Ruvuma	0.381721	10
Kagera	0.387261	11
Morogoro	0.392419	12
Iringa	0.407487	13
Arusha	0.419185	14
Singida	0.429433	15
Dodoma	0.455956	16
Tanga	0.483959	17
Kilimanjaro	0.59825	18
Dar es Salaam	0.599236	19
Pwani		20
Manyara		21

Table 7. Rural Women's Empowerment Ranking

Region	**Women's Empowerment Rural Index**	**Ranking**
Rukwa	0.114788044	1
Mara	0.144264204	2
Mwanza	0.16517593	3
Manyara	0.187204702	4
Lindi	0.190175656	5
Tabora	0.205822548	6
Kigoma	0.218768762	7
Mbeya	0.219252842	8
Mtwara	0.224329479	9
Morogoro	0.227419132	10
Arusha	0.230491658	11
Ruvuma	0.247130823	12
Shinyanga	0.247643313	13
Kagera	0.280528316	14
Pwani	0.283081724	15
Dodoma	0.292228737	16
Singida	0.313830899	17
Iringa	0.352867371	18
Dar es Salaam	0.353979069	19
Tanga	0.362612837	20
Kilimanjaro	0.544158519	21

Table 8. Rural Women's Health Index Ranking

Region	**Women's Health Index**	**Ranking**
Pwani	0.64211951	1
Shinyanga	0.64263534	2
Mwanza	0.64264032	3
Mbeya	0.64290827	4
Lindi	0.64508412	5
Tabora	0.64774546	6
Mtwara	0.65175642	7
Morogoro	0.65375494	8
Iringa	0.67261201	9
Mara	0.71146043	10
Dodoma	0.71660837	11
Ruvuma	0.72337196	12
Kagera	0.72802009	13
Dar es Salaam	0.73449152	14
Kigoma	0.73595598	15
Rukwa	0.73952337	16
Tanga	0.74716282	17
Singida	0.78826569	18
Manyara	0.7976539	19
Arusha	0.8000465	20
Kilimanjaro	0.88521462	21

Table 9. Urban Women's Empowerment Ranking

Region	**Women's Empowerment Index**	**Ranking**
Mara	0.251637981	1
Lindi	0.275260009	2
Kigoma	0.311246245	3
Rukwa	0.312574237	4
Iringa	0.319580756	5
Mbeya	0.341887683	6
Pwani	0.363132138	7
Singida	0.370496468	8
Ruvuma	0.371503683	9
Morogoro	0.39149146	10
Mtwara	0.420673577	11
Mwanza	0.422015573	12
Shinyanga	0.467142308	13
Tanga	0.474250743	14
Arusha	0.479830263	15
Manyara	0.499847602	16
Kagera	0.53239764	17
Dar es Salaam	0.542684389	18
Kilimanjaro	0.549230632	19
Dodoma	0.601185689	20
Tabora	0.605223517	21

Table 10. Urban Women's Health Ranking

Region	Women's Health Index	Ranking
Kagera	0.6143335	1
Lindi	0.63442006	2
Pwani	0.63838155	3
Dodoma	0.64596181	4
Mtwara	0.65033009	5
Iringa	0.6628587	6
Tabora	0.66763163	7
Mara	0.66844016	8
Mbeya	0.68093371	9
Mwanza	0.68480285	10
Dar es Salaam	0.68751935	11
Morogoro	0.6903595	12
Shinyanga	0.71920449	13
Ruvuma	0.73928186	14
Singida	0.74203236	15
Tanga	0.74426323	16
Kigoma	0.75801969	17
Rukwa	0.75885622	18
Manyara	0.81316368	19
Arusha	0.81836918	20
Kilimanjaro	0.87410852	21

Table 11. DHS Geographic Area Index Scores

DHS Area	Women's Empowerment Index	Water Infrastructure Index	Women's Health Index
Western	0.276242236	0.095053	0.683283
Northern	0.37053622	0.078513	0.812611
Central	0.345774848	0.09692	0.744496
Southern Highlands	0.253412713	0.079289	0.689173
Lake	0.233631928	0.085171	0.698974
Eastern	0.386838037	0.065395	0.66105
Southern	0.259608902	0.083886	0.666164

Table 12. DHS Geographic Area Rural Index

DHS Area	**Women's Empowerment Index**	**Women's Health Index**
Western	0.224078	0.675446
Northern	0.331117	0.807519
Central	0.30303	0.752437
Southern Highlands	0.228969	0.685015
Lake	0.196656	0.69404
Eastern	0.28816	0.676789
Southern	0.242885	0.710497

Table 13. DHS Geographic Area Urban Index

DHS Area	**Women's Empowerment Index**	**Women's Health Index**
Western	0.461204	0.714952
Northern	0.50079	0.812476
Central	0.485841	0.693997
Southern Highlands	0.324681	0.700883
Lake	0.402017	0.655859
Eastern	0.432436	0.672087
Southern	0.336169	0.681202

Table 14. Correlation Values for Region Analysis

Variable X	**Variable Y**	**R^2 Correlation Value**	**Reference to Figure in Appendix**
Empowerment	Health	0.0813	4
Infrastructure	Health	0.0589	5
Empowerment	Life Expectancy	0.168	6
Infrastructure	Life Expectancy	0.0589	7
Infrastructure	Empowerment	0.0037	8
Compiled Infrastructure and Empowerment	Life Expectancy	0.1225	9
Compiled Infrastructure and Empowerment	Health	0.1767	10
Participation in Health Decisions	Life Expectancy	0.0484	11
Water Production	Participation in Health Decisions	0.0673	12
Walking Distance	Participation in Health Decisions0.251	0.0251	13
Participation in Purchasing Decisions	Life Expectancy	0.0919	14
Electric Boreholes	Life Expectancy	0.0605	15
Water Production	Rate of no anemia	0.101	16
Water Production	Secondary Education	0.1732	17
Wealth	Secondary Education	0.8862	30

Table 15. Correlation Values for DHS Region Analysis

Variable X	**Variable Y**	**R^2 Correlation Value**	**Reference to Figure in Appendix**
Empowerment	Health	0.1893	18
Infrastructure	Health	0.0284	19
Compiled Infrastructure and Empowerment	Health	0.2306	20
Compiled Infrastructure and Empowerment	Life Expectancy	0.4881	21

Table 16. Correlation Values for Rural Analysis

Variable X	**Variable Y**	**R^2 Correlation Value**	**Reference to Figure in Appendix**
Empowerment	Health	0.2453	22
Empowerment	Life Expectancy	0.1162	23
Empowerment (DHS region)	Health	0.55776	24
Empowerment (DHS region)	Life Expectancy	0.46	25

Table 17. Correlation Values for Urban Analysis

Variable X	**Variable Y**	**R^2 Correlation Value**	**Reference to Figure in Appendix**
Empowerment	Health	0.0219	26
Empowerment	Life Expectancy	0.1354	27
Empowerment and Infrastructure (DHS region)	Health	0.273	28
Empowerment and Infrastructure (DHS region)	Life Expectancy	0.7113	29

C. Analysis

Figure 1.

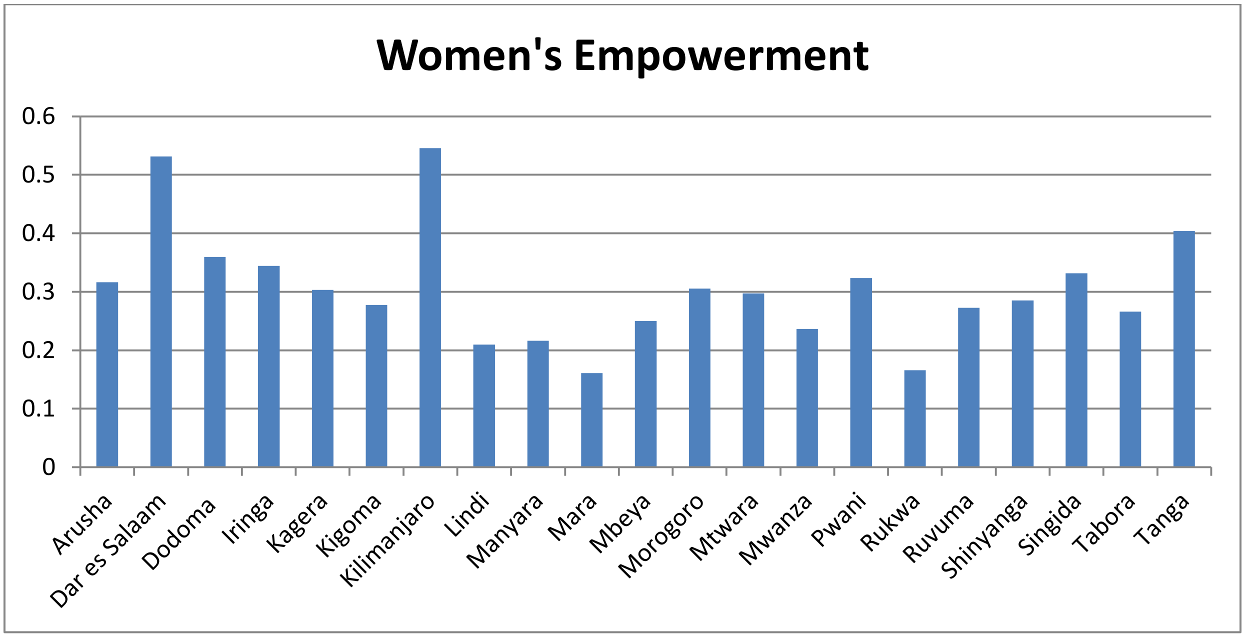


Figure 2.

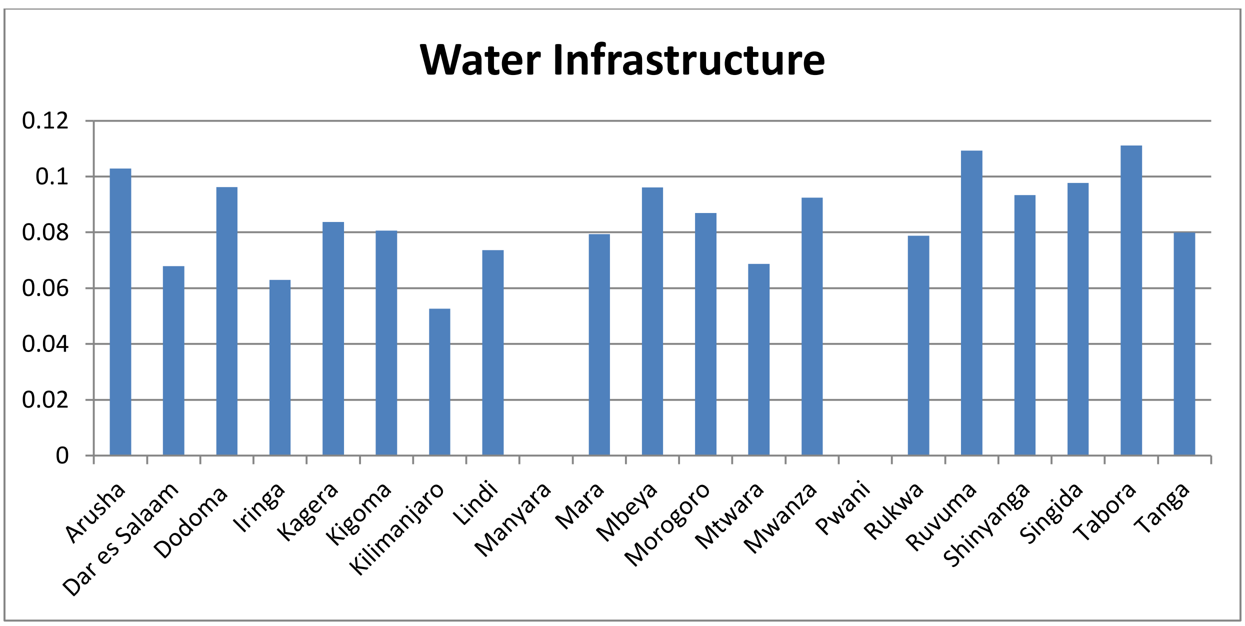


Figure 3.

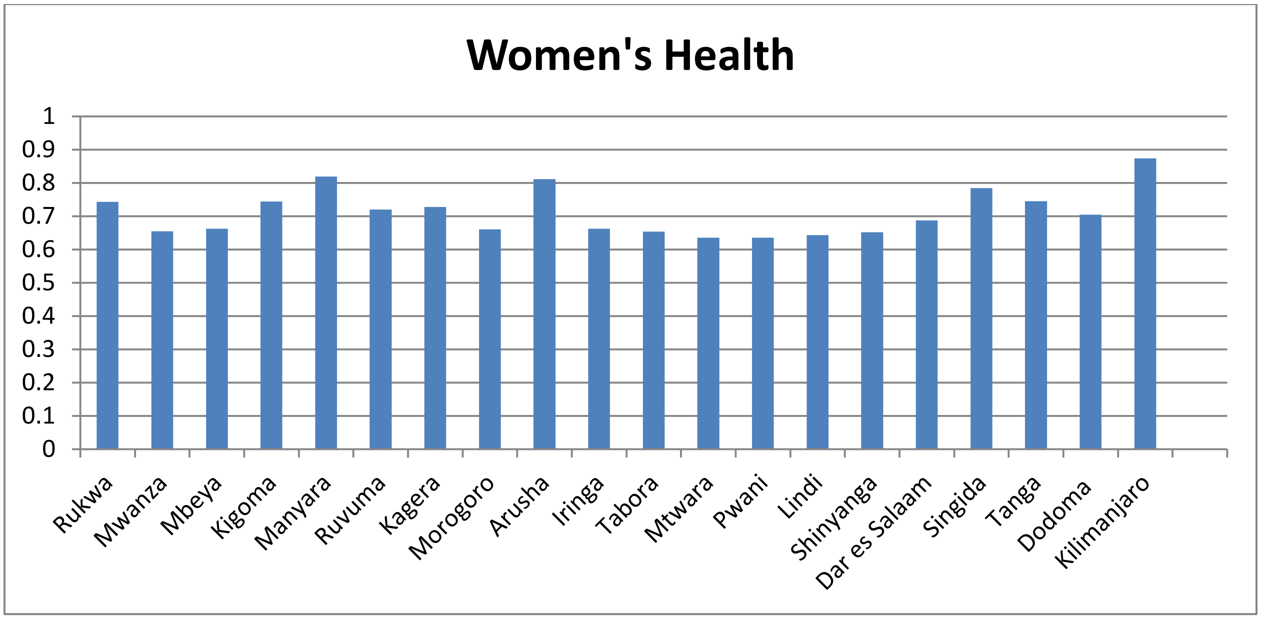


Figure 4.

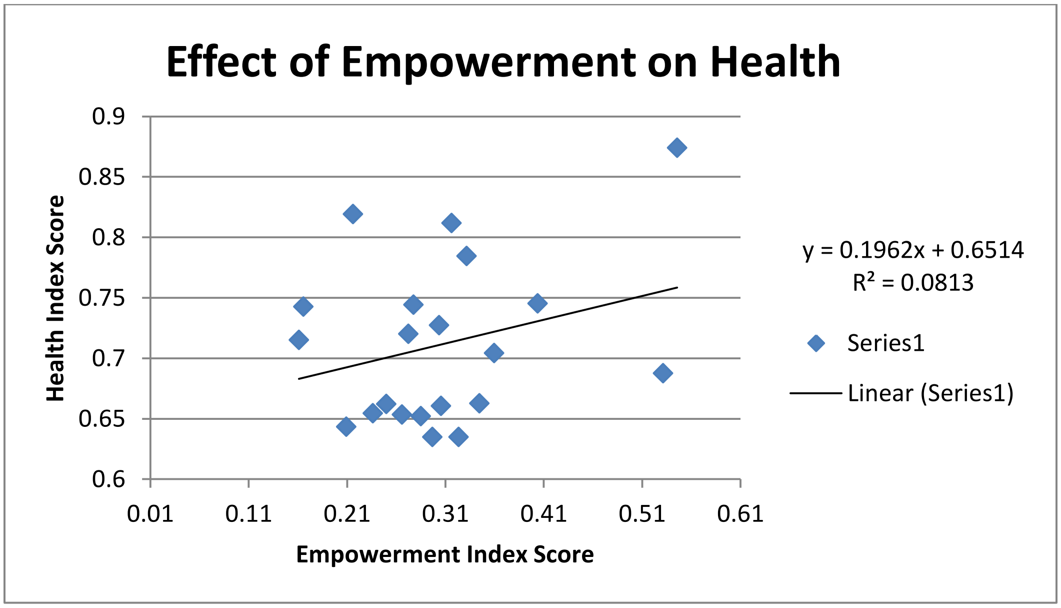


Figure 5a.

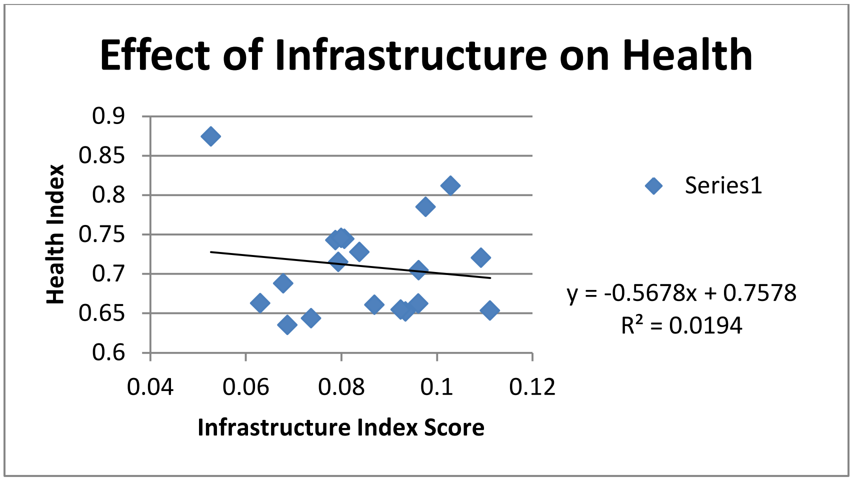


Figure 5b.

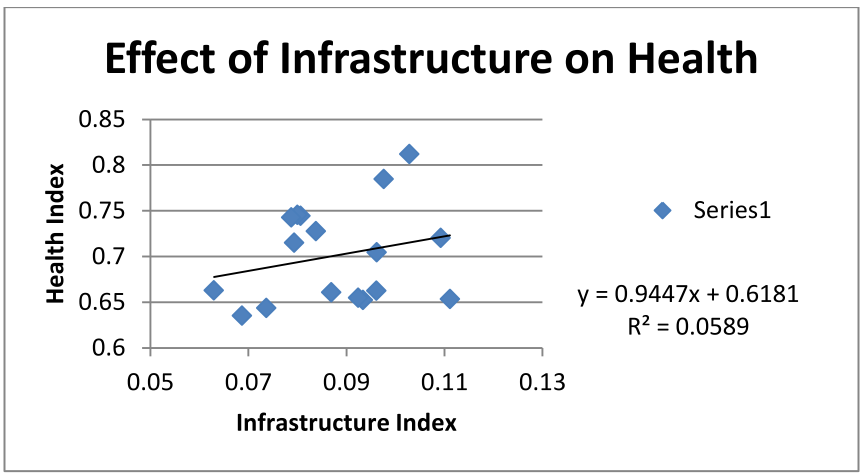


Figure 5c.

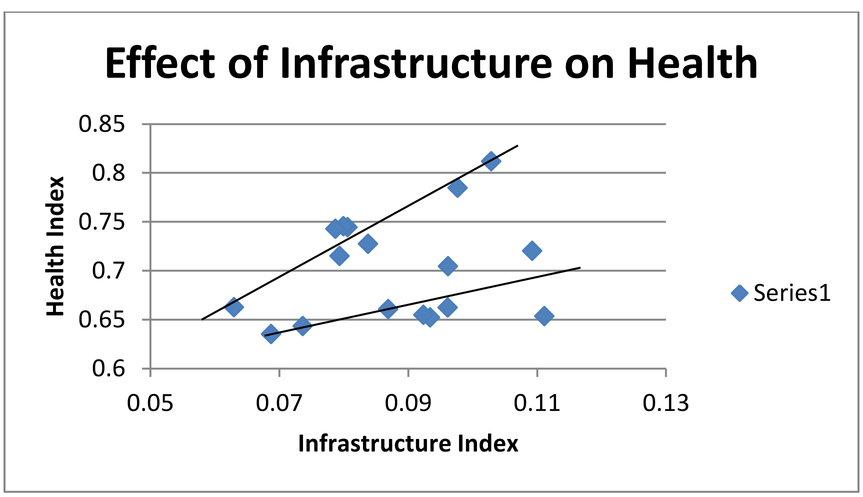


Figure 6.

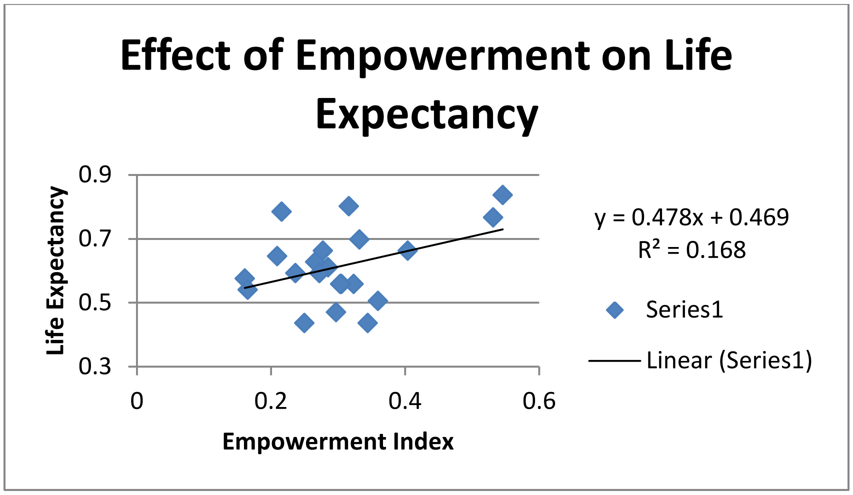


Figure 7a.

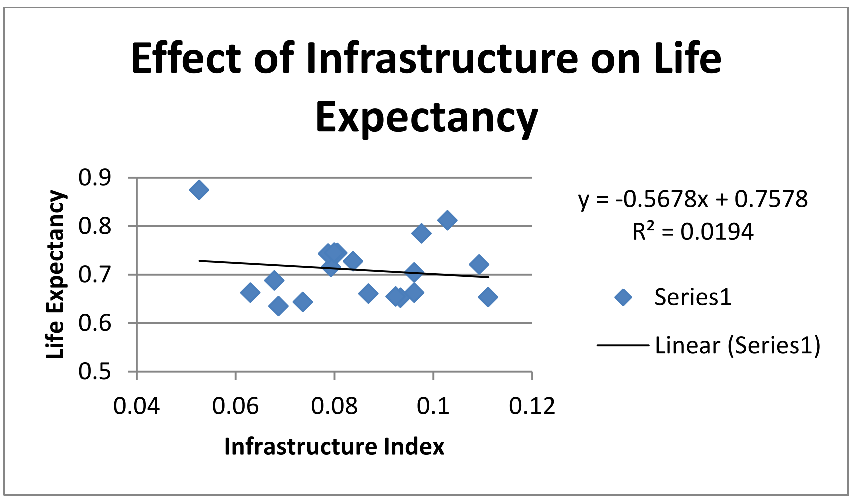


Figure 7b.

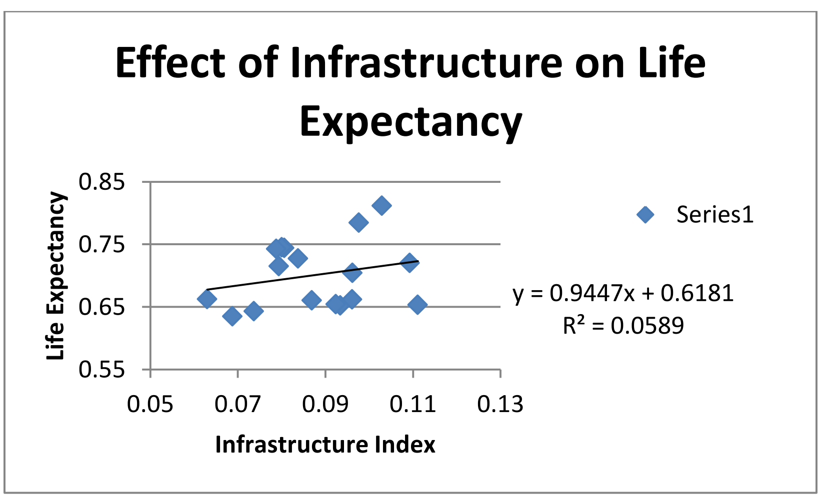


Figure 8.

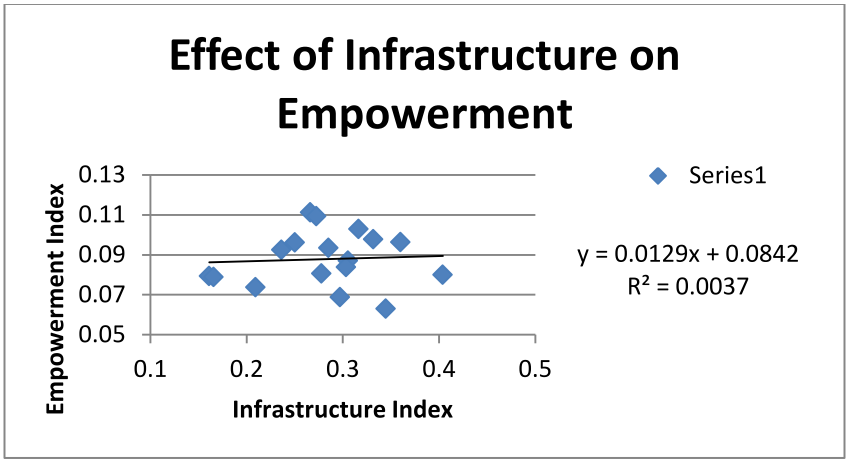


Figure 9.

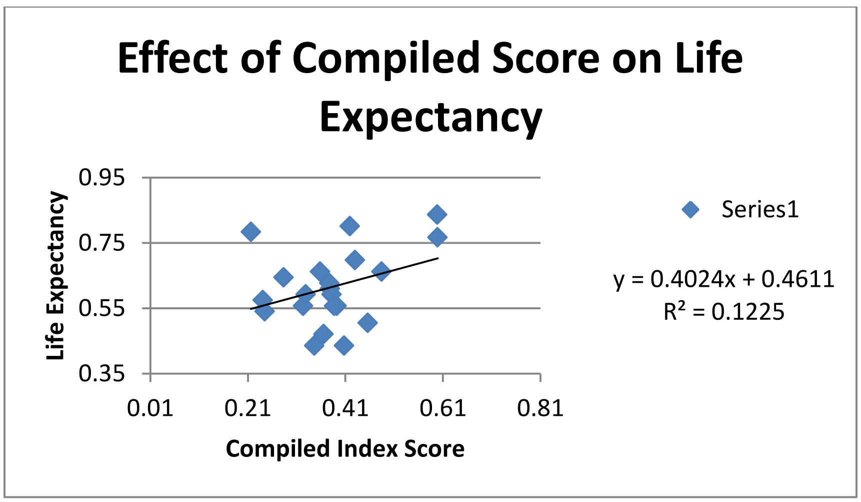
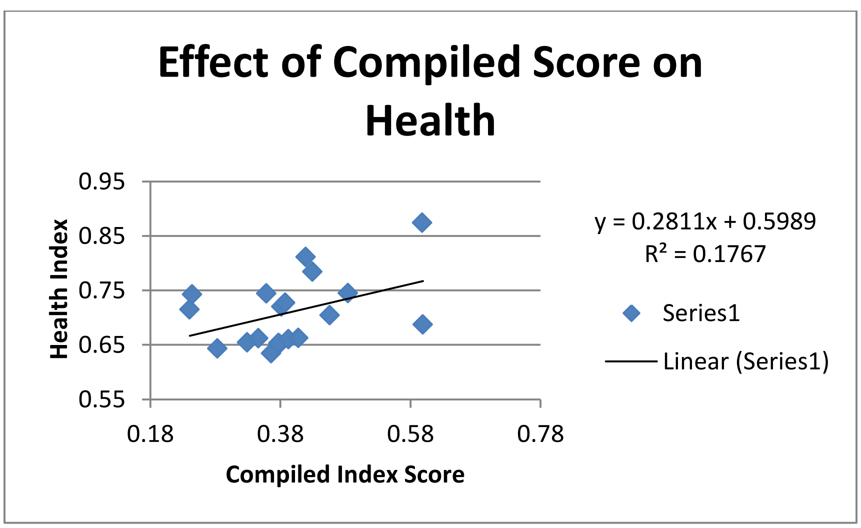


Figure 10.



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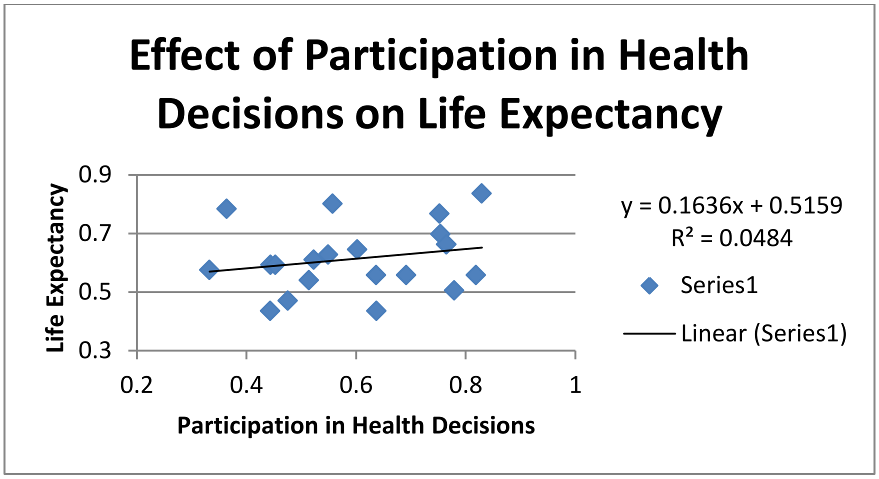

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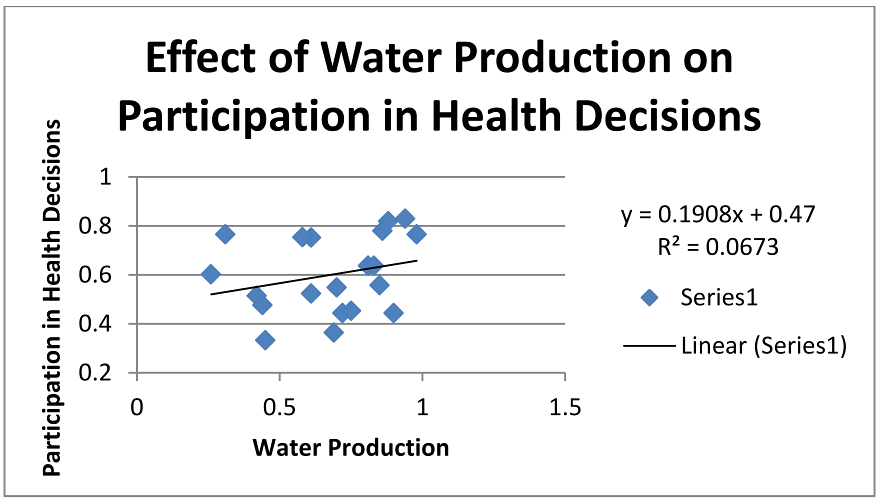

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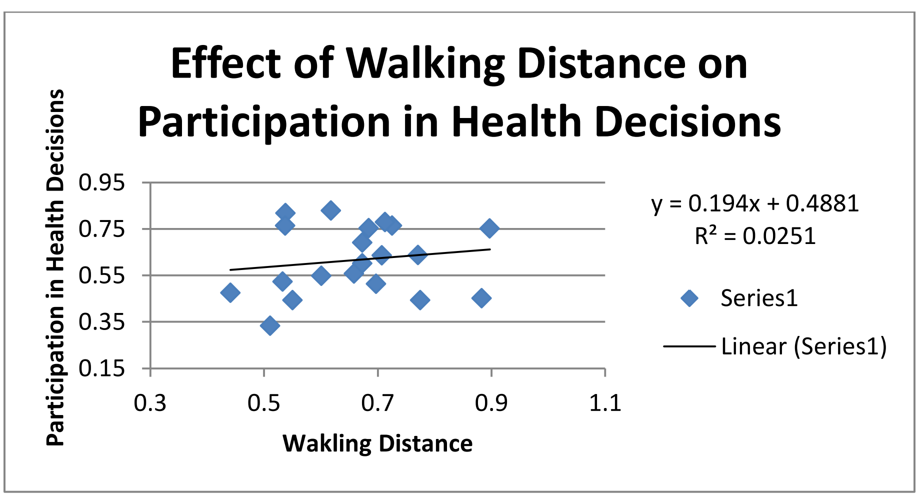

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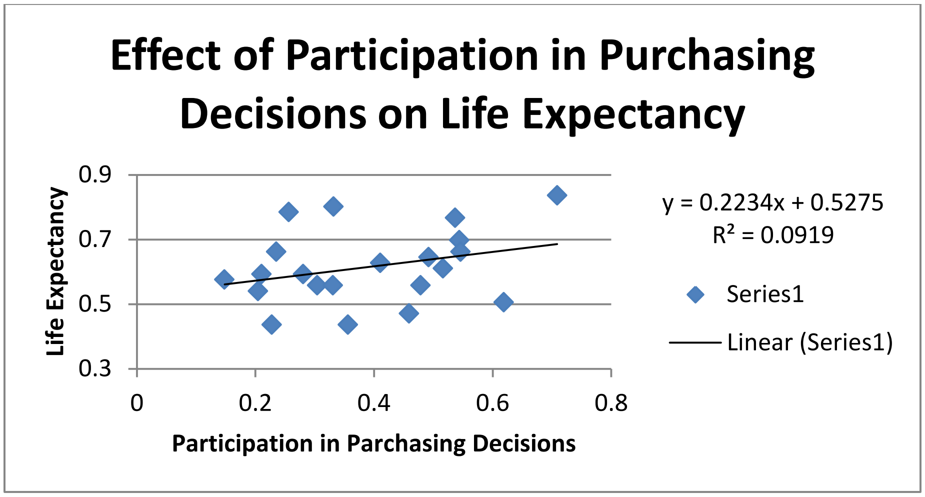

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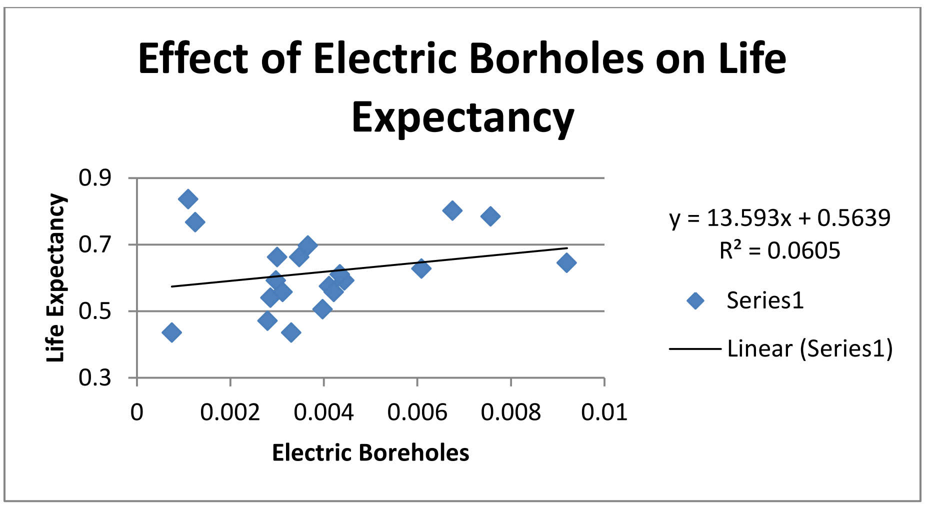
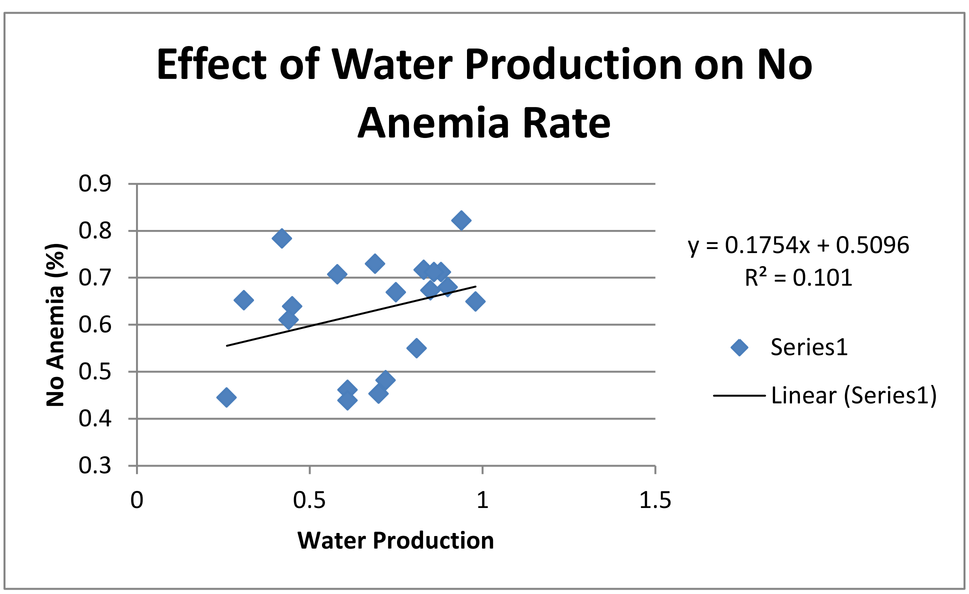


Figure 16.



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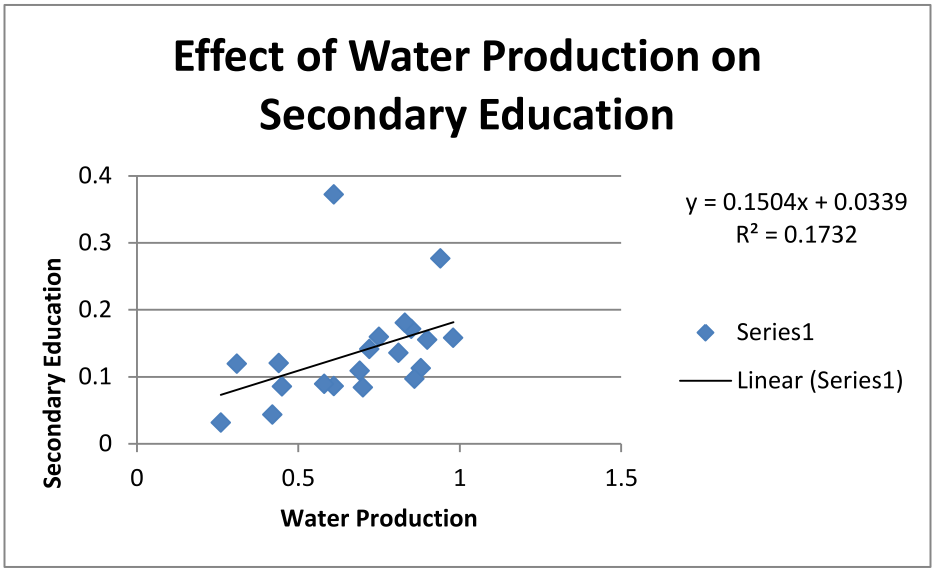


Figure 18.

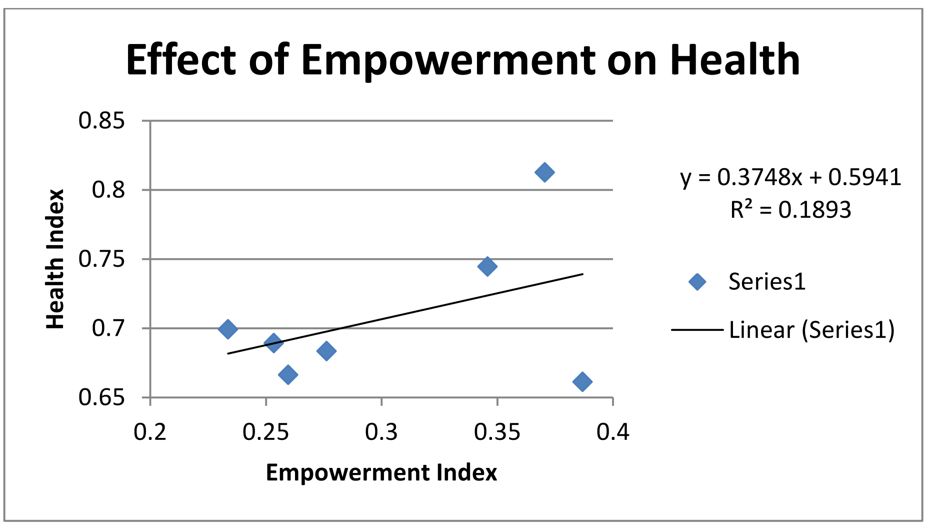


Figure 19.

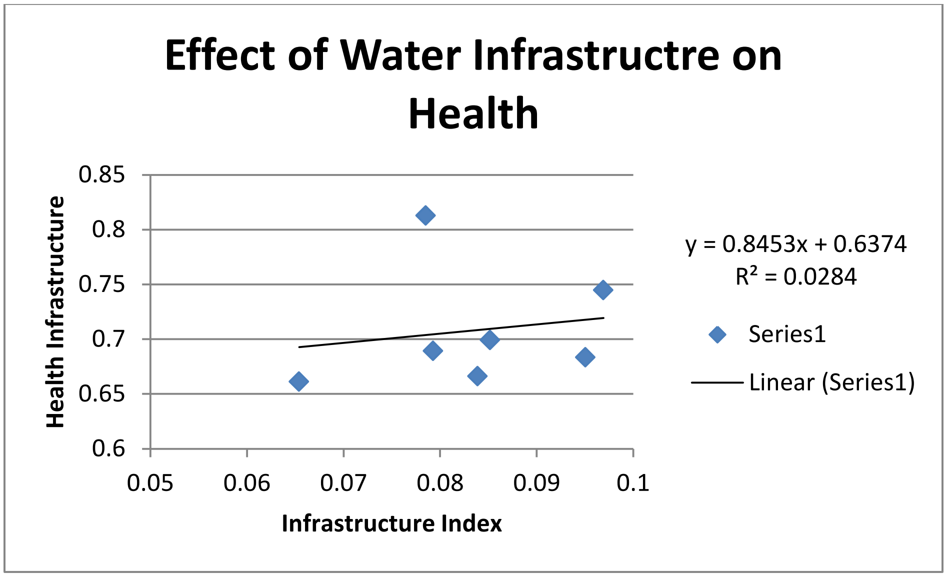
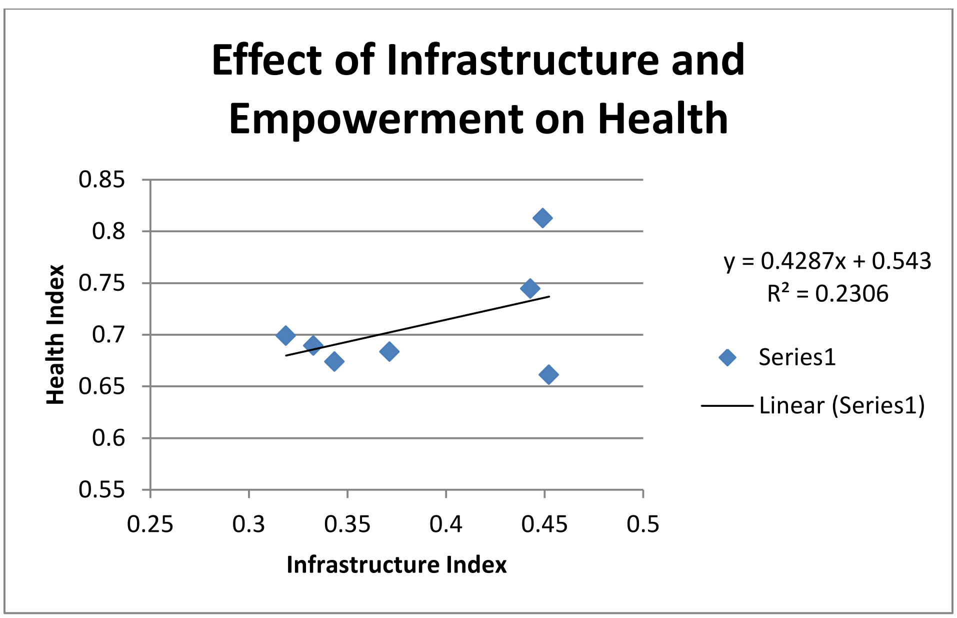


Figure 20.



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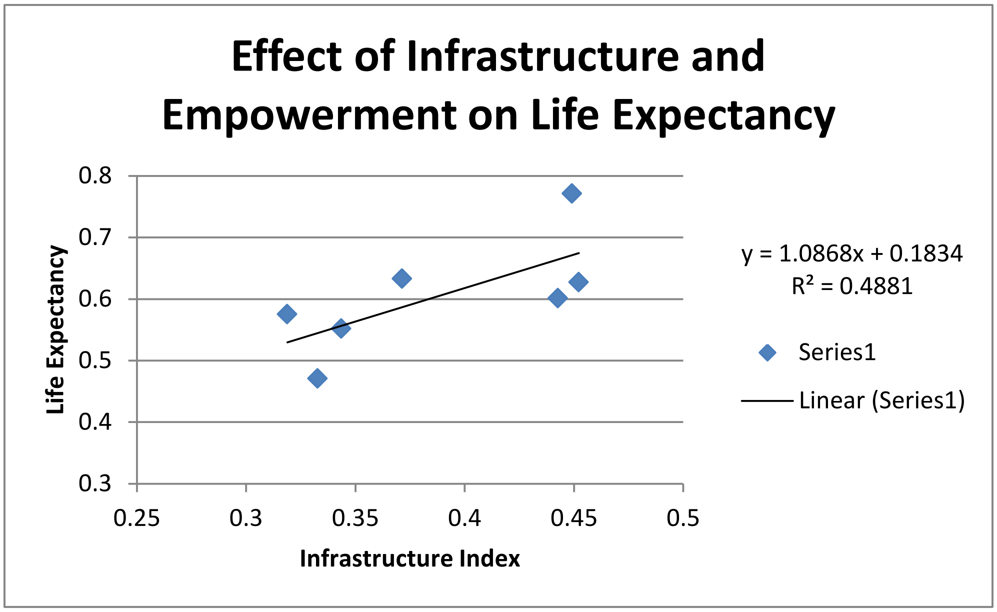

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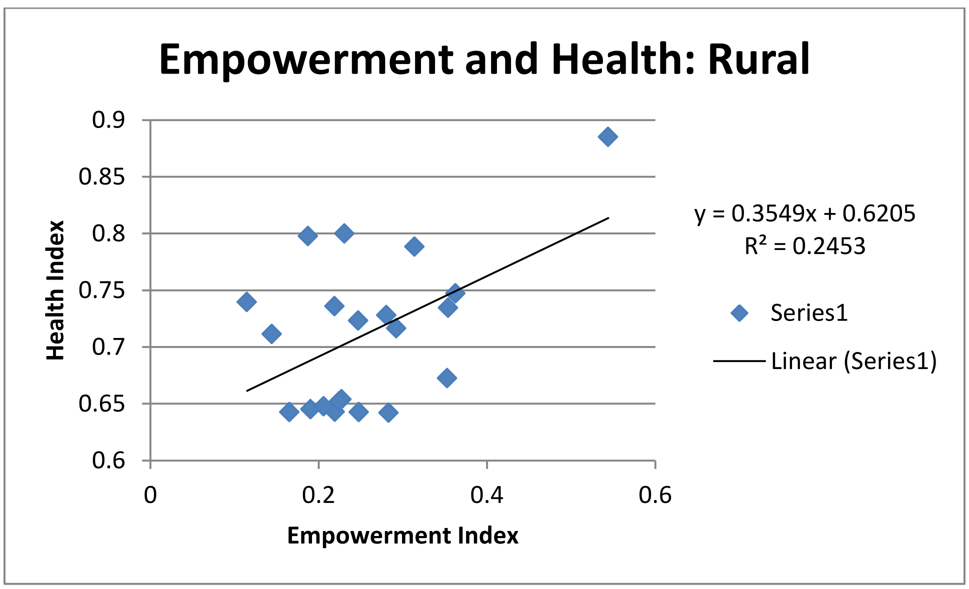


Figure 23.

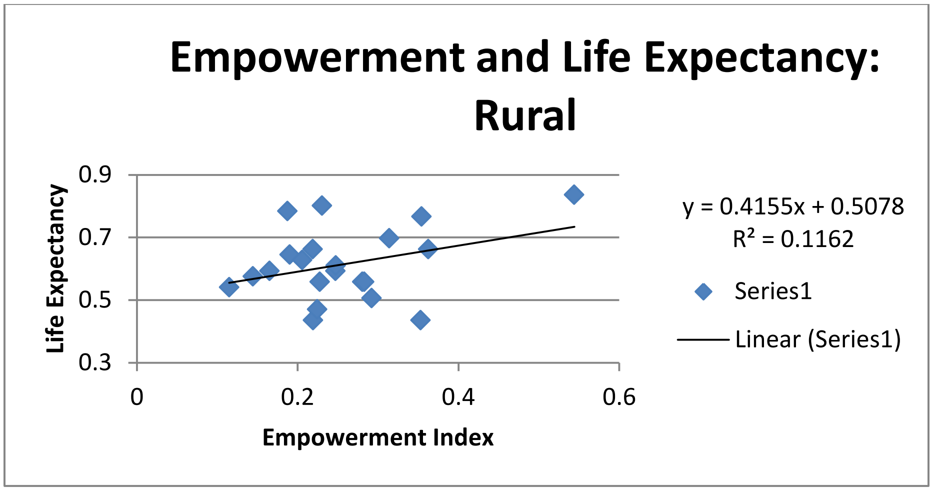


Figure 24.

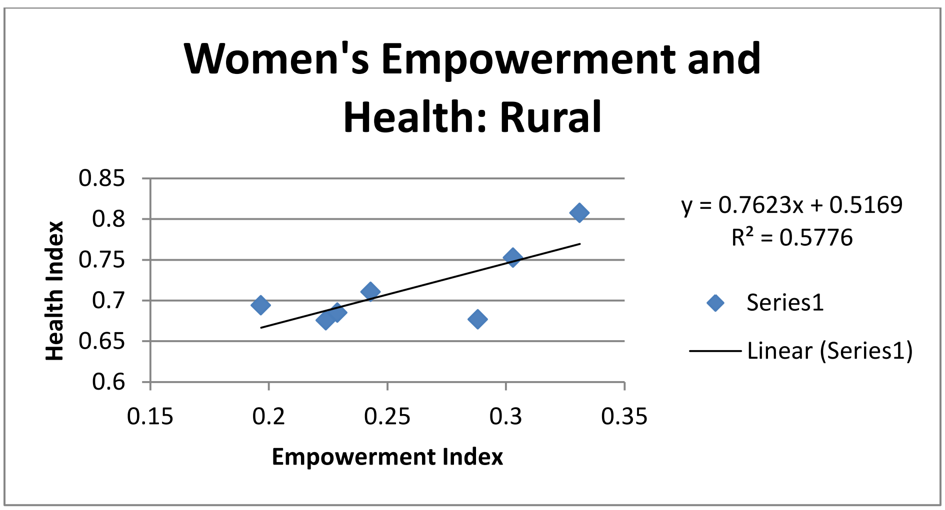


Figure 25.

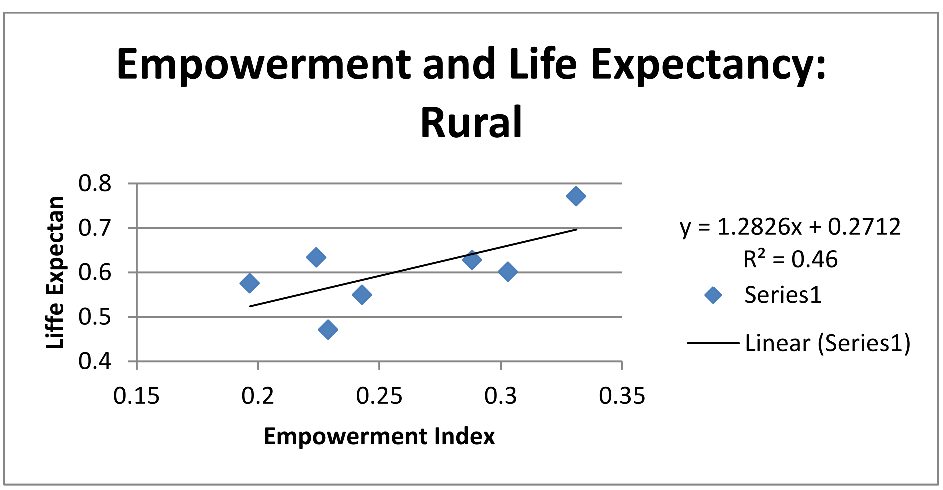


Figure 26.

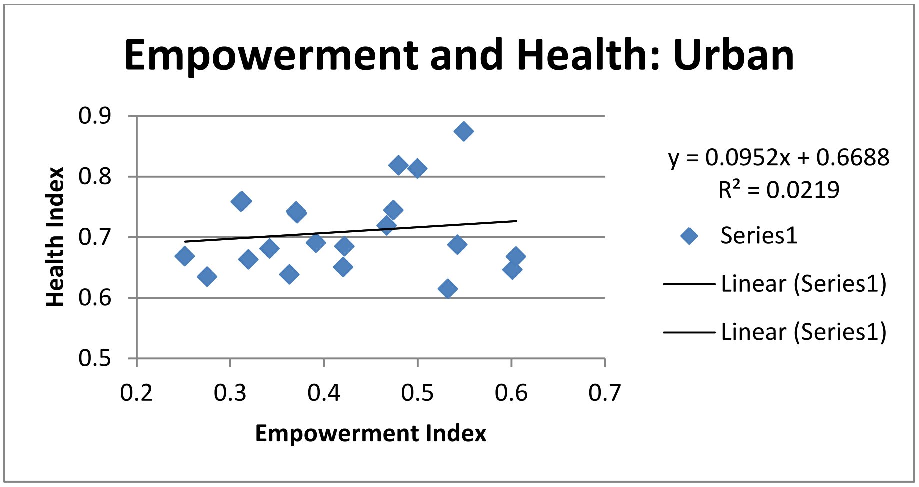


Figure 27.

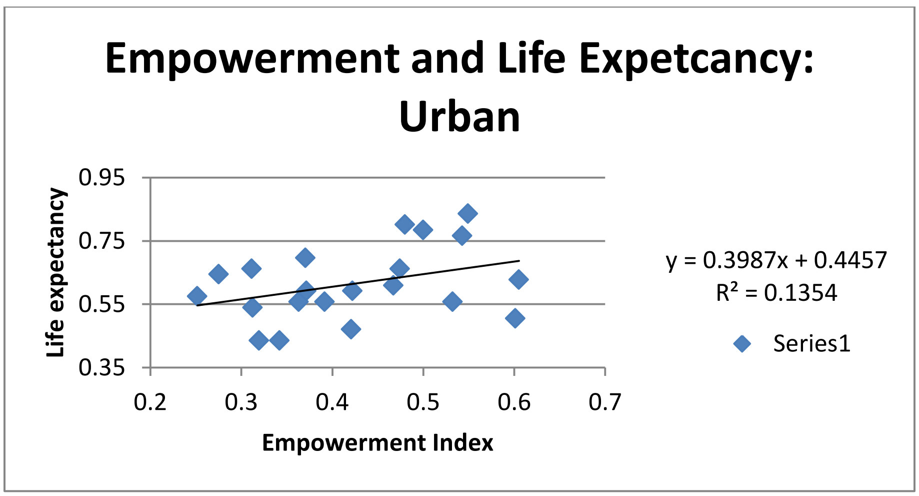


Figure 28.

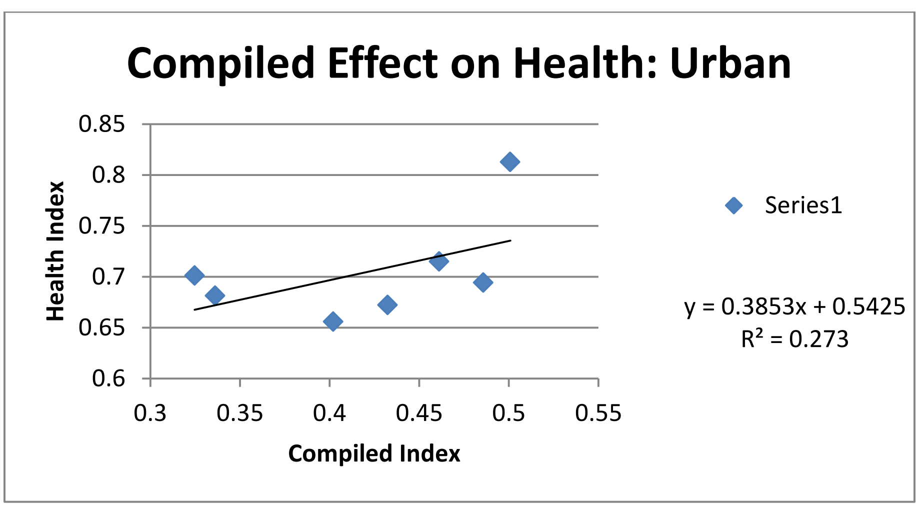


Figure 29.

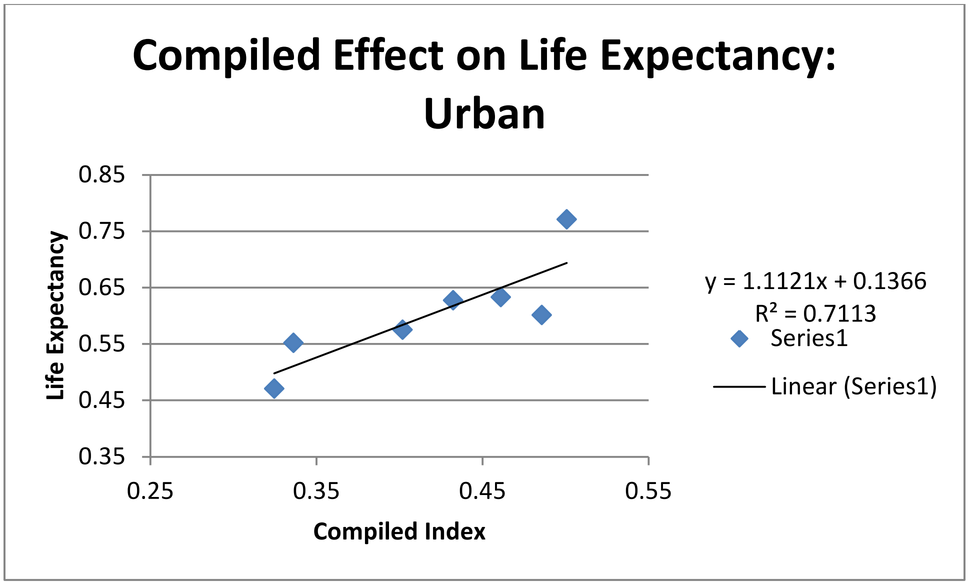


Figure 30.

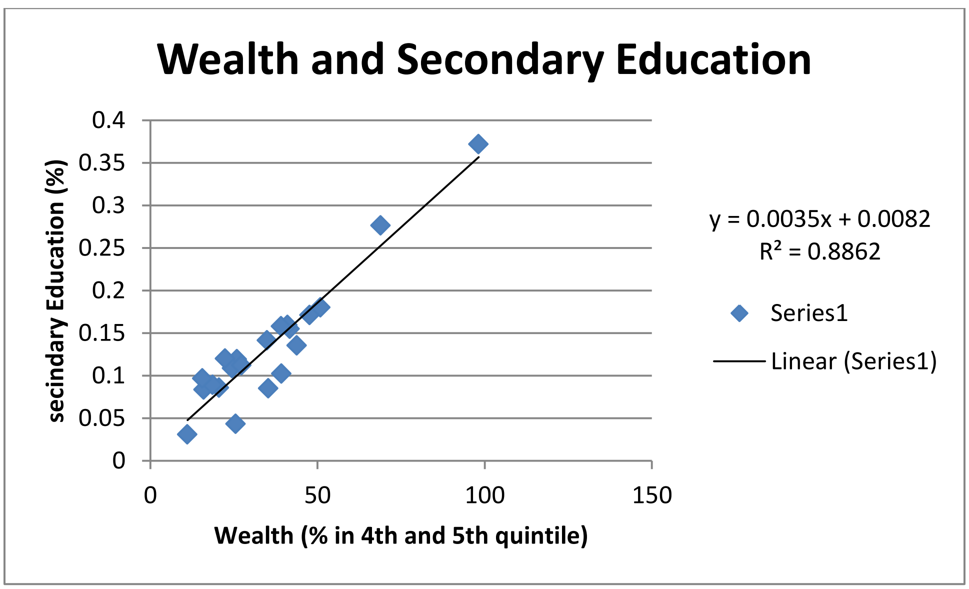


Figure 31.

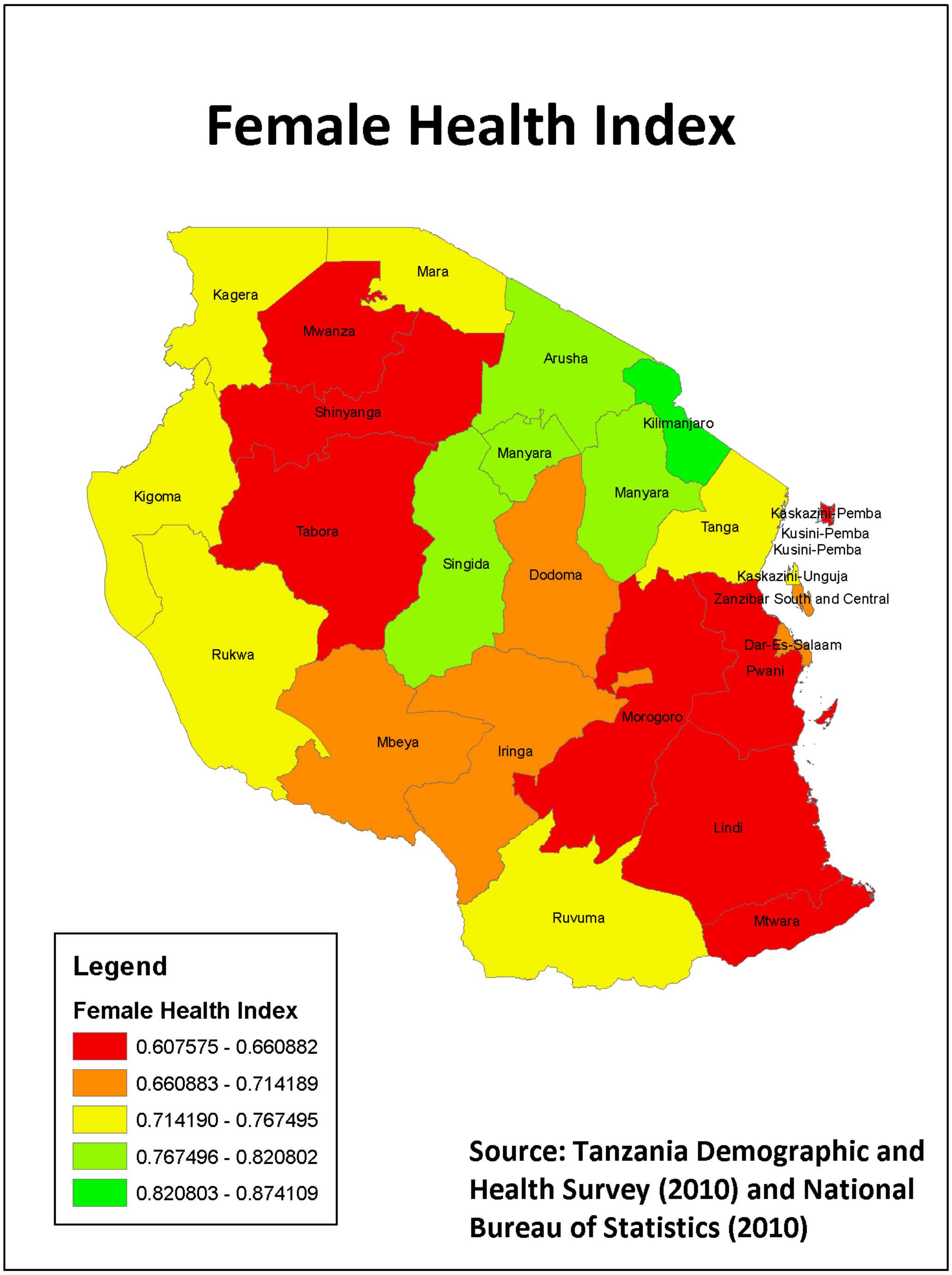

Female Health Index
Kagera
Mara
Mwanza
Arusha
Kilimanjaro
Shinyanga
Manyara
Kigoma
Manyara
Tanga
Kaskazini-Pemba
Kusini-Pemba
Kusini-Pemba
Tabora
Singida
Dodoma
Kaskazini-Unguja
Zanzibar South and Central
Dar-Es-Salaam
Pwani
Rukwa
Morogoro
Mbeya
Iringa
Lindi
Ruvuma
Mtwara
Legend
Female Health Index
0.607575 - 0.660882
0.660883 - 0.714189
0.714190 - 0.767495
0.767496 - 0.820802
0.820803 - 0.874109
Source: Tanzania Demographic and Health Survey (2010) and National Bureau of Statistics (2010)

Figure 32.

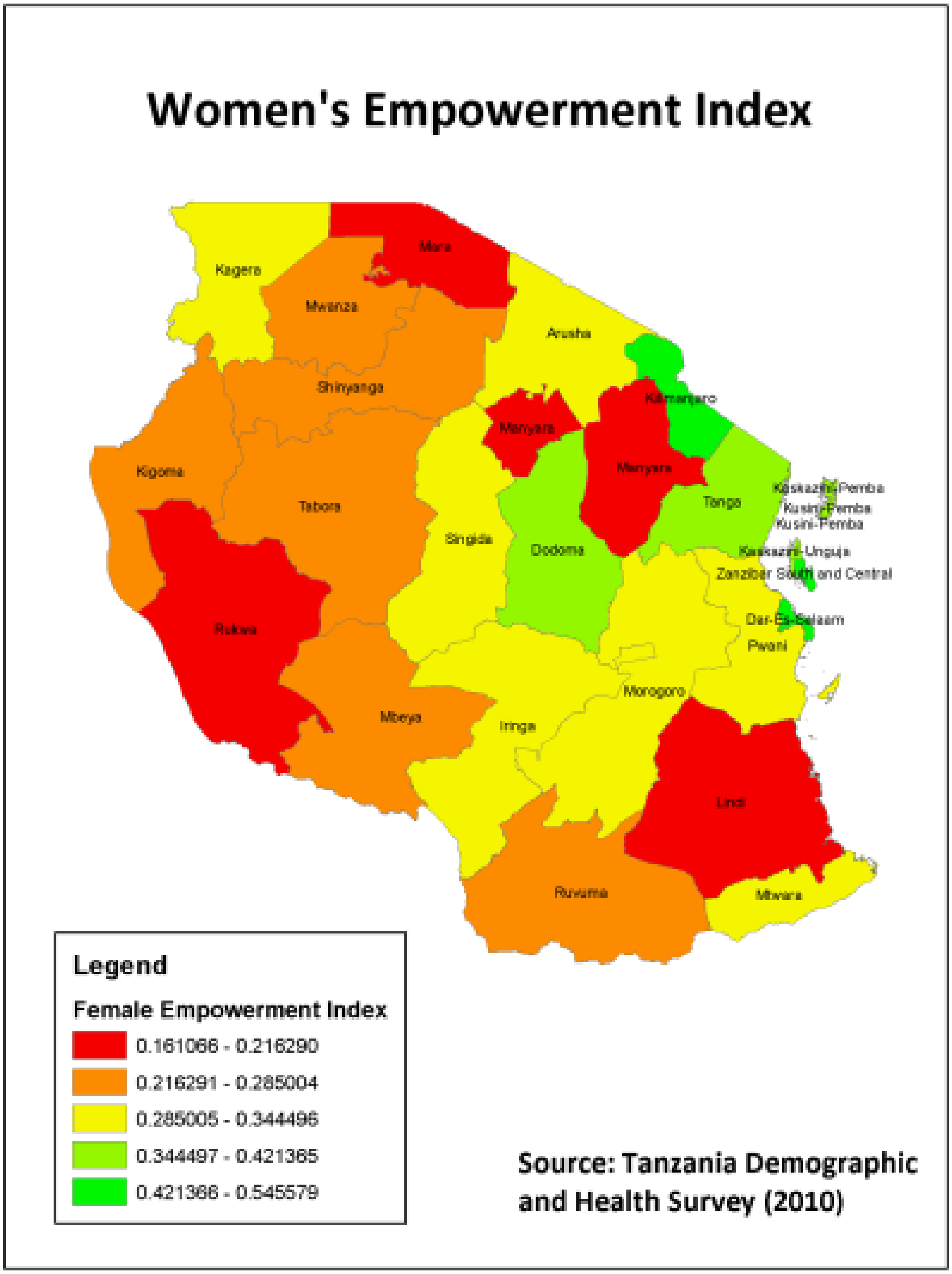

Women's Empowerment Index
Kagera
Mara
Mwanza
Arusha
Shinyanga
Kilimanjaro
Manyara
Manyara
Kigoma
Tabora
Tanga
Kaskazini-Pemba
Kusini-Pemba
Kusini-Pemba
Singida
Dodoma
Kaskazini-Unguja
Zanzibar South and Central
Rukwa
Dar-Es-Salaam
Pwani
Morogoro
Mbeya
Iringa
Lindi
Ruvuma
Mtwara
Legend
Female Empowerment Index
0.161066 - 0.216290
0.216291 - 0.285004
0.285005 - 0.344496
0.344497 - 0.421365
0.421366 - 0.545579
Source: Tanzania Demographic and Health Survey (2010)

Figure 33.

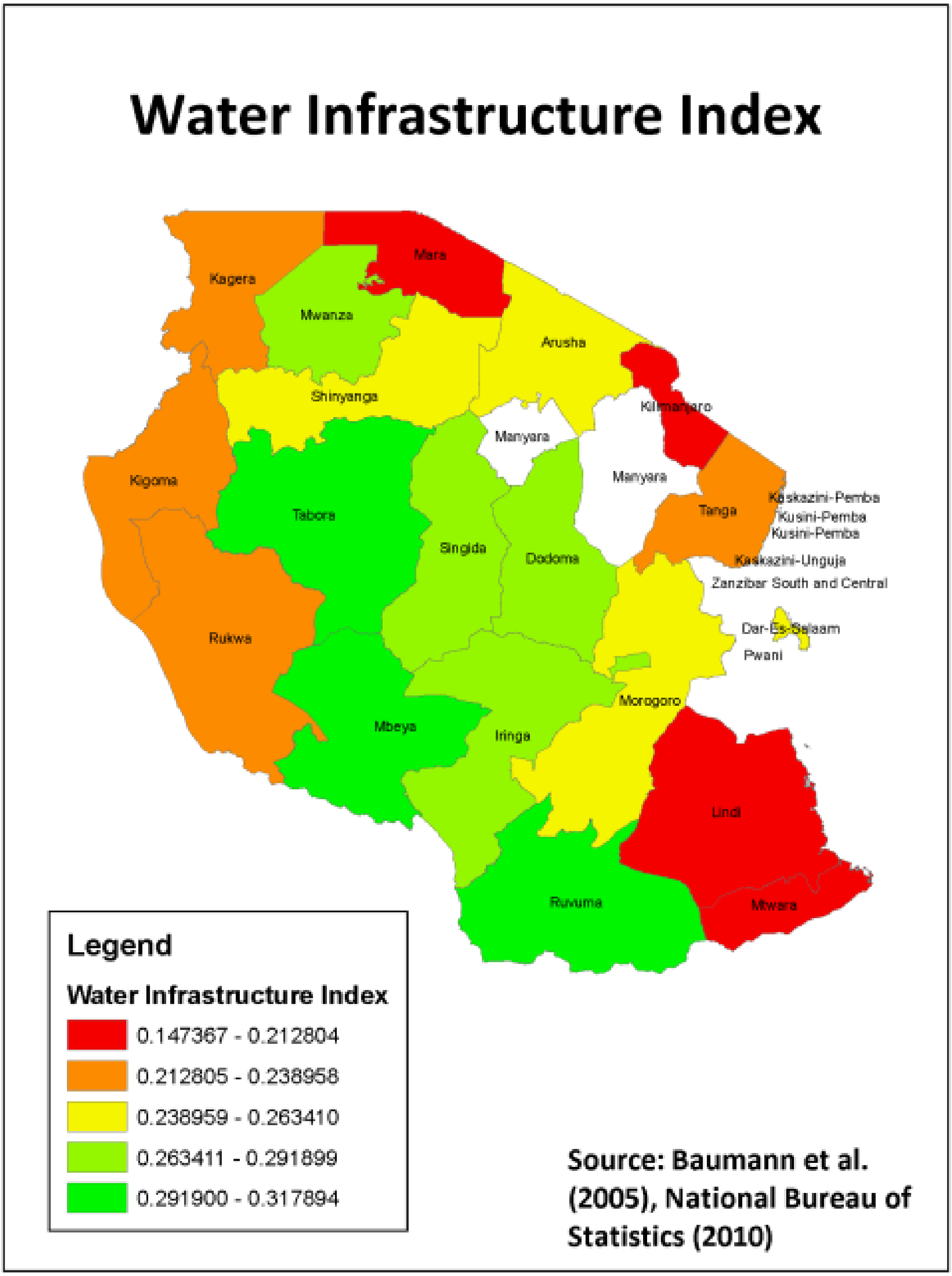
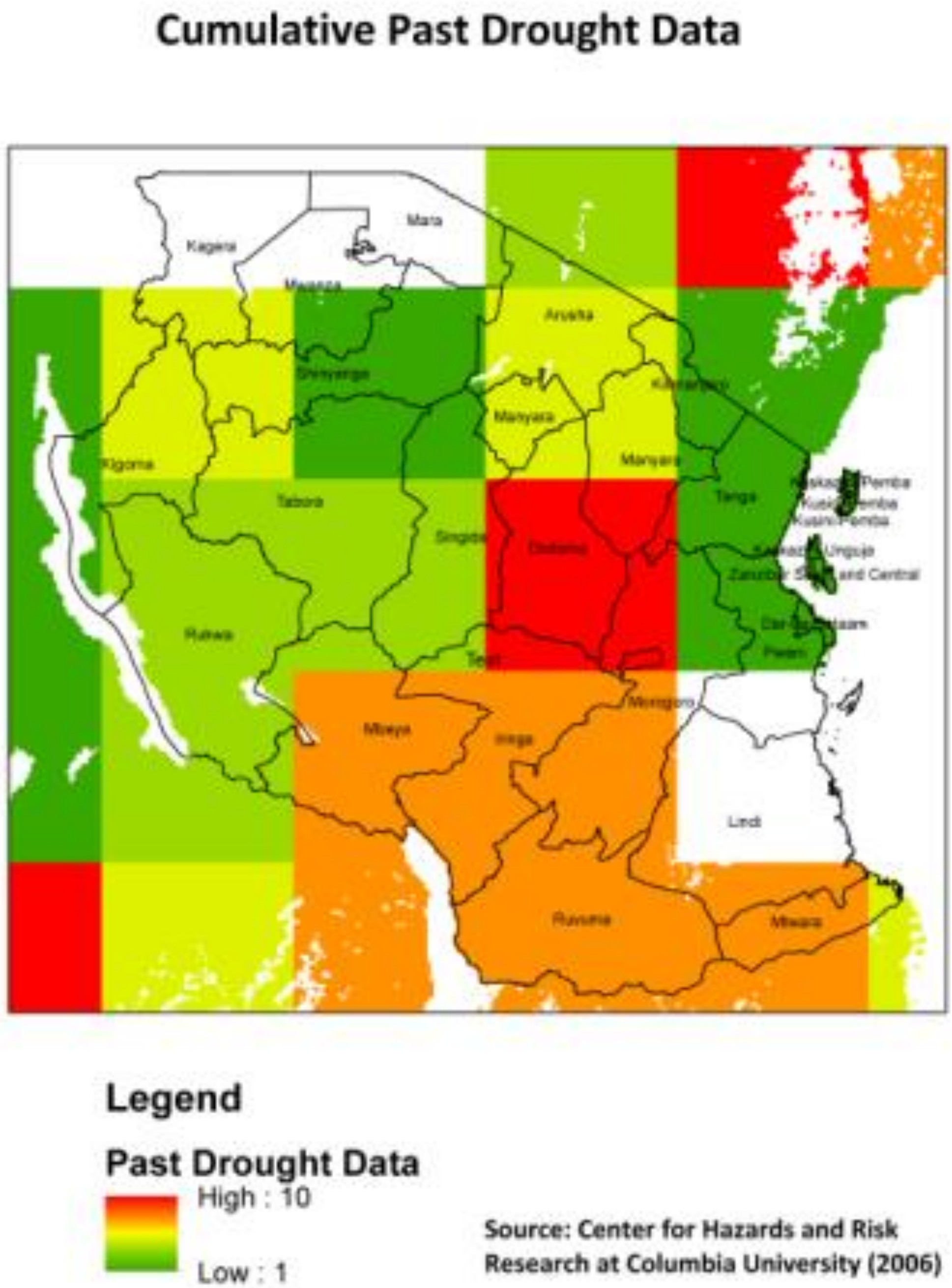
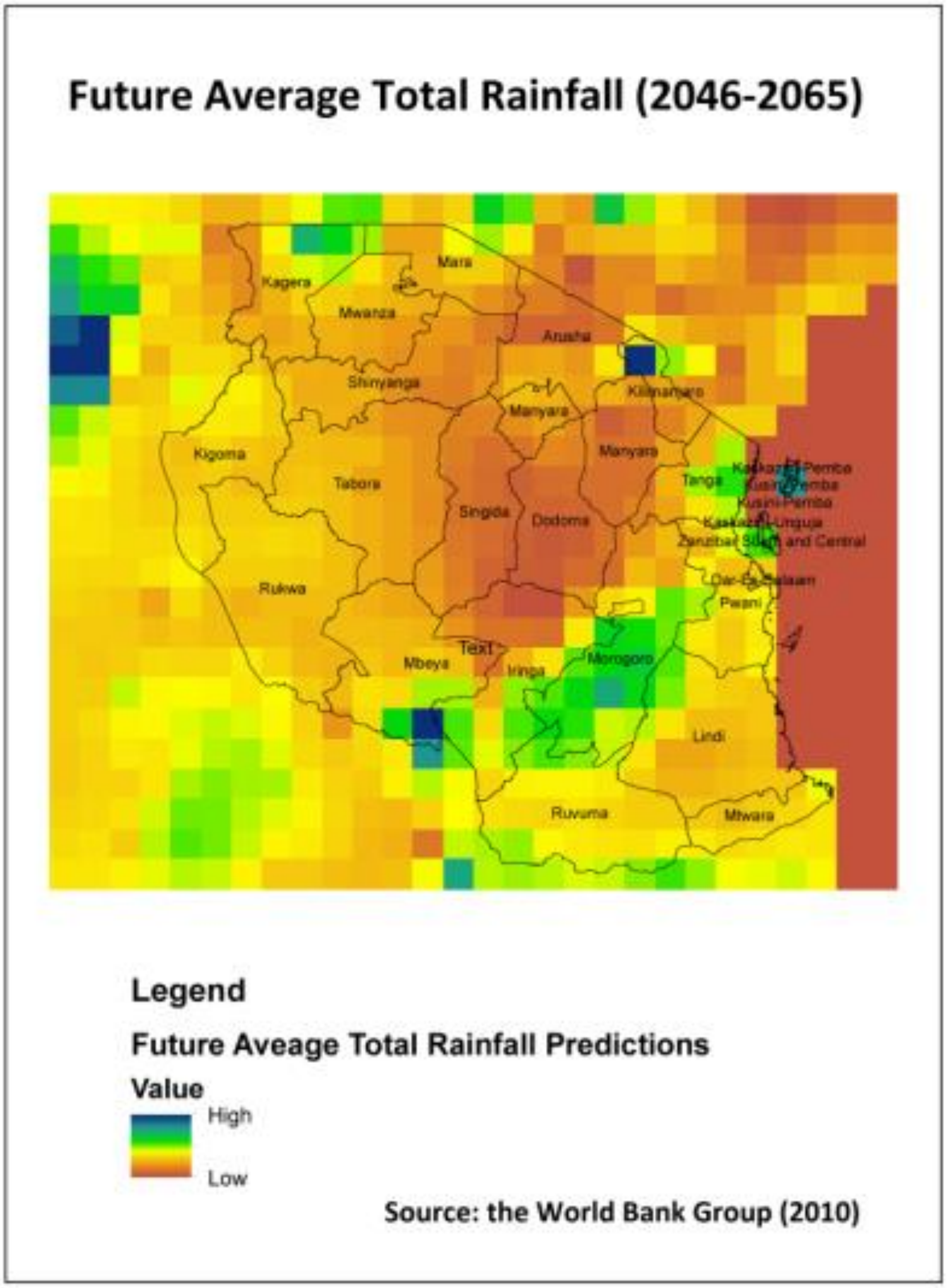

Water Infrastructure Index
Mara
Kagera
Mwanza
Arusha
Shinyanga
Kilimanjaro
Manyara
Manyara
Kigoma
Tabora
Tanga
Kaskazini-Pemba
Kusini-Pemba
Kusini-Pemba
Singida
Dodoma
Kaskazini-Unguja
Zanzibar South and Central
Dar-Es-Salaam
Pwani
Rukwa
Morogoro
Mbeya
Iringa
Lindi
Ruvuma
Mtwara
Legend
Water Infrastructure Index
0.147367 - 0.212804
0.212805 - 0.238958
0.238959 - 0.263410
0.263411 - 0.291899
0.291900 - 0.317894
Source: Baumann et al. (2005), National Bureau of Statistics (2010)

Figure 34.



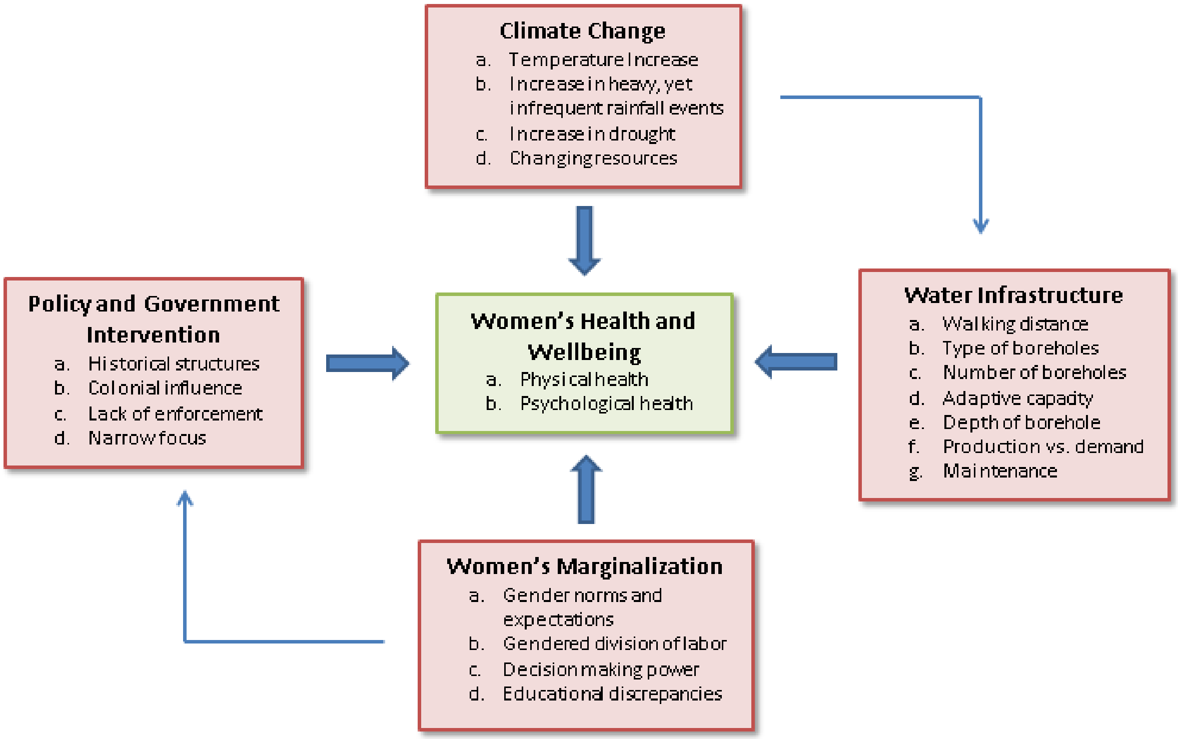
Cumulative Past Drought Data
Mara
Kagera
Mwanza
Arusha
Shinyanga
Manyara
Kigoma
Tabora
Tanga
Dodoma
Rukwa
Mbeya
Iringa
Lindi
Ruvuma
Mtwara
Legend
Past Drought Data
High : 10
Low : 1
Source: Center for Hazards and Risk Research at Columbia University (2006)

Figure 35.



Future Average Total Rainfall (2046-2065)
Mara
Kagera
Mwanza
Arusha
Shinyanga
Kilimanjaro
Manyara
Kigoma
Tabora
Manyara
Tanga
Singida
Dodoma
Rukwa
Pwani
Text
Mbeya
Iringa
Morogoro
Lindi
Ruvuma
Mtwara
Legend
Future Aveage Total Rainfall Predictions
Value
High
Low
Source: the World Bank Group (2010)

Figure 36.


Climate Change
a. Temperature Increase
b. Increase in heavy, yet infrequent rainfall events
c. Increase in drought
d. Changing resources
Policy and Government Intervention
a. Historical structures
b. Colonial influence
c. Lack of enforcement
d. Narrow focus
Women's Health and Wellbeing
a. Physical health
b. Psychological health
Water Infrastructure
a. Walking distance
b. Type of boreholes
c. Number of boreholes
d. Adaptive capacity
e. Depth of borehole
f. Production vs. demand
g. Maintenance
Women's Marginalization
a. Gender norms and expectations
b. Gendered division of labor
c. Decision making power
d. Educational discrepancies