Unintended Consequences of Dams and Water Security:
An Insight into Women's Vulnerability and the Spread of Malaria in Ethiopia

Romy Buchner, Mridula Nair, and Barbara Pinto[1]

Abstract

The building of hydro-dams as an adaptation strategy for climate change is highly contested due to the environmental, social and economic impacts on the most vulnerable populations. Hydro-dams are highly politicized as they are significantly tied to foreign investment and the hydraulic mission as a path to promote economic growth. Climate change threatens the safety of dams, reducing hydropower and water 'security' with potential to contradict the intended outcomes. This paper will examine the nexus of dams, water security, climate change and vector-borne diseases in Ethiopia and sheds light on the prevalence of malaria due to hydroelectric dams on women's health.

Keywords: Climate Change, Water Security, Ethiopia, Gender, GilGel-gibe dam III, Malaria, Development

[1] Emails: Romy Buchner (rabuchne@uwaterloo.ca), Mridula Nair (m2nair@uwaterloo.ca), and Barbara Pinto (bpintope@uwaterloo.ca)

1. Introduction

In the advent of climate change, hydrological regimes are extremely sensitive to climate variability and as the threat of anthropogenic climate change grows, this increases the variability of precipitation patterns. In response, dams have been used as an adaptation method to enhance water security and provide climate change mitigation. The construction of water resource projects such as dams, irrigation, and canals in Africa is seen as pivotal for food security and alleviating poverty as water security may be threatened in a changing climate. However, the unintended health implications, such as the increase in vector-borne disease transmission, may minimize the intended benefits of securing water through dam construction. This paper will study the effects of climate change, the correlation between dam construction on Malaria transmission, and shed light on the vulnerabilities of women who live in proximity to water management projects such as Ethiopia's largest hydroelectric dam the GilGel-Gibe III.

2. Climate change and its Impacts on Water Security

2.1 Climate Change and Water Security

Rainfall variability and its impact on water security has become a fundamental issue due to the effects of climate change on the hydrologic cycle. Globally, rising temperatures, increased water vapor in the atmosphere, and changes in atmospheric circulation have contributed to increases in daily and seasonal rainfall variability (Huber and Gulledge, 2011). This variability has manifested as changes in location, type, amount, frequency, intensity and duration of rainfall, and increases in extreme events (Trenberth 1998; Allen and Ingram, 2002). Overall, these changes are causing wet regions to become wetter and dry regions to become dryer, which will have disastrous implications for water security (Skliris et al., 2016; IPCC, 2007). Furthermore, in a warmer climate heavy rainfall will increase and be produced by fewer more intense precipitation events (Trenbert, 2005). These extreme events represent an increased risk of droughts and floods.

For eastern Africa, including the Horn of Africa, temperatures will continue to rise and precipitation patterns will become more extreme if actions to slash global greenhouse gas emissions are not taken (IPCC, 2007). Originally, heavier precipitations were predicted to occur during the region's "short rains" season from September to November, but new evidence suggests that these gains in rainfall will be offset by declining rainfall and severe dryness during the "long rains" season from March to May. In addition, increased rainfall during the short rains is expected to result in increased surface runoff, leading to more flooding events. One such event occurred in 2006, where major floods of unprecedented spatial extent and timing occurred across Somalia, Ethiopia, and other parts of East Africa (Tarhule, 2005). Evidence of these trends have been observed in several countries comprising the Horn of Africa, where overall rainfall has been continuously declining, the frequency and duration of drought have increased, and droughts have been interspersed with extreme flood situations (Nicholson, S.E. 2014). The greatest increases in aridity are expected to occur in Djibouti, Ethiopia, and Somalia. This will have dire implications for these regions, which are already grappling with decades of drought and extreme hunger.

Studies have found that rural areas within arid and semi-arid river basins in developing countries are most vulnerable to the effects of climate change (Millennium Ecosystem Assessment, 2005). This raises serious concerns for the 70 million people that are located in areas prone to extreme droughts within the Horn of Africa (Ndaruzaniye, 2011). Many of these inhabitants are affected directly by changes in the volume and timing of river discharge and groundwater recharge. Thus, they can be severely affected by changes in the quantity and distribution of water resources.

Increasing rainfall variability can influence anticipated variations in stream flow, lakes, reservoirs, groundwater levels, and groundwater recharge. For Africa, the predicted decrease in annual precipitation over much of the continent could have severe implications for water availability. According to a study by Wit and Stankiewicz (2006), a 10% decrease in precipitation in regions that receive ~1000 mm of rain per year would reduce surface water supplies by 17%, whereas this same decrease in regions receiving ~500 mm per year would result in a 50% cut. These decreases in surface water supply are projected to affect water access across 25% of Africa by the end of this century. Concerns regarding water scarcity are relevant even in the instances of floods, since moderate rains soak into the soil, benefiting plants and recharging groundwater reserves, while the same rainfall amounts in a short period of time may increase the proportion that is lost through runoff, leaving soils much drier at the end of the day (Kailash et al., 2014). Therefore, regions prone to both or either flooding and droughts may experience water deficits if the extra water is not properly managed and stored.

In the Horn of Africa, increased scarcity and the degradation of water sources are threatening human well-being. The population in the region has increased fourfold in the past 50 years and continues to grow rapidly (United Nations Population Division, 2010). Farmers need more water to feed more people and extended areas are needed for food production. This adds pressure to the region’s land and water resources. Moreover, countries within the Horn that depend strongly on hydropower for electricity generation, such as Ethiopia, will face significant challenges in maintaining their energy supply (Carius, 2008). While Africa in general has a low adaptive capacity (Ndaruzaniye, 2011), the water security situation in the Horn of Africa is particularly severe, and has resulted in decades of periodic water scarcity and food shortages.

While the Horn of Africa has historically grappled with unpredictable, multi-faceted climates, the region's governments, who are tasked with ensuring the survival, livelihood and dignity of their populations, have been unable to develop equitable coping strategies towards the adverse impacts of increasingly extreme climate regimes. It has been estimated that over 600,000 people have died because of drought in the 20th century alone in Ethiopia, Eritrea, and Somalia (ACCES, 2010). Already today, many Eastern African countries are suffering from water stress, with large parts of the population living in poverty and not having access to clean and safe drinking water. As rainfall and surface water become less reliable, demand for groundwater has begun to grow (Calow, 2009). However, as droughts become more intense and frequent in the region and groundwater demand increases, these sources become increasingly prone to failure.

Those regions grappling with water insecurity are also faced with the challenge of growing sufficient quantities of food with limited water resources. A large part of the population within the Horn is engaged in subsistence agriculture and farm marginal lands under rainfed conditions, with relatively limited access to productive assets, inputs, technology, and services. In fact, less than 1% of the cultivable area in the region is under irrigation (UNEP, 2006). Therefore, the scale and duration of rainfall is the main climatic factor determining land productivity. This dependence on rainfall has had major consequences for regional food security. During Ethiopia's 2000 and 2003 production seasons, for example, major drought affected the food security of over 10 million people, leading to episodes of famine (FAO, 2009). Climate models warn of changes in grain yields and the survival of plant and animal species (ACCES, 2011). These changes will have severe social and economic impacts, ultimately hindering economic stability and threatening human security.

While the combination of droughts and dependence on rain-fed subsistence agriculture has impacted the wellbeing and livelihoods of many Ethiopians, the recurrence of extreme weather events cannot adequately explain Ethiopia's food and water crisis. Even in years with adequate rainfall and good weather, there have always been millions of Ethiopians vulnerable to the threat of starvation. In particular, the rural poor have been disproportionately affected by food and water shortages (IFAD, 2016). In an effort to achieve its Millennium Development Goals of attaining middle income status by 2025, government projects and Chinese investments have stimulated economic growth that has translated in a 33% reduction in the share of people living in poverty in the country (World Bank Group, 2015). Despite this achievement, at least 37 million Ethiopians continue to live in poverty and according to recent world bank statistics, the poorest Ethiopians are becoming even poorer. This population segment is caught in the margins of social, economic, and political systems that render them chronically food and water insecure.

Ethiopian governance has historically lacked stability, which has set in motion a perverse political economy in which rules and institutions established to maximize efficiency result in unjust distributive outcomes, exacerbating inequalities (Kennedy, 2012). As Ethiopia becomes economically globalized, multinationals owning significant commercial and economic interests in Africa and domestic elites have managed to appropriate most of the surplus the economy generates. In addition, the government has consistently favored the investment of funds into programs that appease the urban population. For example, in 2005 a program that allowed wheat, sugar, edible-oil and construction of low-cost condominium apartments to be subsidized prompted the government to spend hundreds of dollars on urban infrastructure and the import of luxuries, despite the fact that 81% of the population live in rural areas (The World Bank, 2016). Moreover, under the current regime, land in Ethiopia is under state ownership and farmers are assigned a usufruct right to it. The government claims that that the land policy is a form of social protection because it protects farmers against distress sales, land concentration in the hands of the wealthy and subsequent exploitation of the poor farmers. However, in the last few years the government has been evicting farmers to undertake urban expansion and large-scale private commercial agriculture. As the urban population and powerful corporations reap the benefits, small-scale farmers and the rural poor find themselves increasingly marginalized and struggle to cope with the rising food prices afforded by their wealthier counterparts.

The construction of dams as a means of adapting to and mitigating climate change have only worsened the inequalities between the urban rich and the urban poor, with the benefits of these projects being inequitably shared. The water stored within the massive reservoirs are often used as a reliable water source for large and urban communities. However, this is accompanied by water shortages for many of the adjacent rural communities (Tilt et al., 2009). Often, it is the small-scale fishermen and farmers in downstream rural communities whose livelihoods are most severely impacted by river diversion and alterations in streamflow. Meanwhile, the use of dams to improve energy security has also historically benefited the urban-rich. In Ethiopia, dams have been used to increase energy production, yet access to this energy is more readily available in urban areas and largely out of reach for the rural populations. Instead, most rural Ethiopians are highly reliant on biomass for cooking and heating (Virginia Tech, 2014). Therefore, by centralizing power grids, hydropower dams disproportionately benefit industries and higher income groups, widening income disparities.

The Ethiopian government's' interests in economic development and the strides it has made in reducing poverty has ironically come at the expense of the most impoverished. As the rich and urban populations reap the benefits, the rural poor find themselves more vulnerable to external pressures, such as changing rainfall variability. These inequalities represent differential coping capabilities, in which the economic, energy, water, and food security in which Ethiopia's elite indulge better equip them to respond to the impacts of climate change.

2.2 Climate Change and Vector-Borne Disease

Vector-borne diseases continue to contribute significantly to the global burden of disease, and cause epidemics that have wide socioeconomic impacts, increase health inequities, and act as a brake in socioeconomic development. The WHO estimates that one-sixth of the illness and disability suffered worldwide is owing to vector-borne diseases, with more than half of the world's population currently at risk. Every year, more than one billion people are infected, and more than one million people die from vector-borne diseases, including malaria, dengue, schistosomiasis, leishmaniasis, Chagas disease and African trypanosomiasis (WHO, 2014; Lozano et al., 2013). The transmission of many of these diseases is a function of the interaction with the environment, which results in varying spatial distributions and rates of transmission (Githeko et al., 2000). Given the sensitivity of these diseases to weather and climate conditions, the ongoing trends of rising temperatures and increasingly variable rainfall threaten to increase the vector-borne disease risk.

Changing temperature and precipitation may shift the geographic range in which vector-carrying mosquitoes can live and the seasonal period of disease risk. A warming climate and increases in water temperatures could allow the mosquitos to produce more offspring during the transmission period, increase transmission intensity, and increase the proportion of infective vectors (Githeko et al., 2000). Increases in heavy rainfall events and associated flooding has the potential to increase the number and quality of breeding sites for vectors through its influence on standing water (Patz et al., 2003). In addition to changes in transmission rates and characteristics, higher temperatures, changes in precipitation, and climate variability will alter the geographic range and seasonality of many vector-borne diseases, which could lead to the introduction of these diseases into new non-endemic regions (Hunter, 2003). Higher temperatures in combination with increasingly variable rainfall patterns will expand the geographic range of malaria transmission to higher altitudes and latitudes and extend the transmission season in some locations (Githeko et al., 2000).

Developed and developing countries have an equal probability of being struck by the effects of climate change, although, limited-resource countries are often less able to cope with the associated disease outbreaks. In poor countries in particular, the impacts of major vector-borne diseases can limit or even reverse improvements in social development. The burden of climate-sensitive diseases is already greatest for these populations owing to poorer environmental and social conditions (Wu et al., 2016). The effects of climate change on these diseases will only intensify this burden.

2.3 Motivations for Dams

Dams have been used to manipulate water flows for thousands of years. Originally, dams were built for a single purpose for water supply or irrigation. As civilizations developed, there was a greater need for dams multi-purpose use: for water supply, irrigation, flood control, navigation, water quality, sediment control, and energy. By 1900, several hundred large dams had been built in different parts of the world, mostly for water supply and irrigation. The century that followed saw a rapid increase in large dam building, and by the end of the 20th century there were over 45,000 large dams in over 140 countries; representing over $2 trillion in investments (Terrascope, 2013). According to the International Commission on Large Dams (ICOLD), an international organization that sets the standards for dams, 50% of today's large dams are used for irrigation, 18% for hydropower, 12% for water supply and 10% for flood control, and the rest for other functions, including navigation, debris control, and recreation (SIWI, 2012).

Irrigation and Electricity are among the main purposes of dams due to their global demand and economic ties. The agricultural sector in general places the greatest demand on water resources, accounting for 70% of freshwater withdrawal globally (WWAP, 2012). The vast quantities of water in reservoirs allow them to act as effective and steady sources of water for irrigation with minimal seasonal fluctuations. As of 2013, 30 to 40% of the 271 million hectares that are irrigated worldwide rely on irrigation dams (Terrascope, 2013). Electricity generated from dams is the largest renewable energy source in the world. World hydroelectric power plants produce over 2.3 trillion kilowatt-hours of electricity each year; generating approximately 16% of the electricity consumed globally and represents 86% of all electricity from renewable sources (IPCC, 2011). This energy has been promoted as 'green energy' due to its clean, renewable, non-emitting nature that provides low-cost electricity and helps reduce carbon emissions. Compared with conventional coal power plants, hydropower prevents the emission of about 3 GT CO_2 per year, which represents about 9% of global annual CO_2 emissions (Berga, 2016). As the world rushes into implementing the commitments enshrined in the historic climate deal in Paris, the use of large dams to mitigate climate change is becoming increasingly popular across the world.

With increasingly extreme rainfall patterns, the use of dams for water supply and flood control will continue to serve as a tool to buffer against climate change. Properly planned, designed, constructed, and maintained dams contribute significantly toward fulfilling our water supply requirements. One third of the countries in water-stressed regions of the world are expected to face severe water shortages this century (World Commission on Dams, 2000). Furthermore, the uneven distribution of water supply accompanying increasingly variable rainfall patterns means that countries may have water surplus and water deficits at different temporal and spatial scales. To accommodate the variations in the hydrologic cycle, dams and reservoirs are needed to store and balance flows during different weather conditions, such as by holding flow during major flood events to prevent flooding downstream and releasing more during dry seasons to increase downstream water supply (SIWI, 2012). This ability to regulate river levels can serve as an adaptation strategy towards the increasingly frequent and severe rainfall extremes following climate change.

Although, dams have many uses in the human community, they also have large impacts on the environment and populations living close to them. These impacts have both environmental and social dimensions, and encompass significant land use changes, infrastructure development, and socio-economic changes. Environmental impacts from dams can include the inundation of valuable land: habitats, productive landscapes, infrastructure, and settlements; changes to river flows, water quality, evaporation rates, and sediment transport; and fragmentation of terrestrial and aquatic habitats (WWF, 2013). The primary social impacts include displacement as a result of flooding of the area used as a reservoir; loss of livelihoods, access to resources, and cultural heritage by altered river flows and ecosystem fragmentation; and threats to human health through the creation of potential breeding sites for parasites (SIWI, 2012).

A growing body of science is also increasingly suggesting that one of the dams' most attractive features –its potential to move economies towards a low-carbon future- may, in fact, be false. These studies have identified a number of features of dams that may ultimately be contributing to, rather than mitigating, climate change. The main concern is in regards to the organic material that flows into the reservoirs, decomposes, and emits methane and carbon dioxide into the water. Through this process, dams can end up emitting more greenhouse gases that coal-fired power plants (Washington State University, 2012). Dams also contribute to greenhouse gas emissions through the enormous amounts of energy needed to create them, as well through the massive deforestation the precludes the flooding of the reservoir (Houghton, 2005). In addition, dams that divert water out of rivers may drain and dry up downstream wetlands that would otherwise store carbon (Kayranli, 2010). With this in consideration, the rapid construction of dams in the coming years will have a larger negative impact on global emissions than was previously hoped.

Their utility as both a climate change mitigation and adaptation tool has continued to be supported by the world's most elite and powerful, who are set to reap the benefits from their construction, yet challenged by the scientific community and environmental advocacy groups. Despite the environmental and social costs of these engineering marvels and their associated uncertainties and contestations, their ability to propel economic growth has and will continue to lead to their growing use worldwide. However, sustainable approaches to water and energy planning are required if the large-scale environmental and social impacts are to be minimized.

3. Dams and Vector-Borne diseases: Overview

3.1 Dams and vector-borne diseases

Large dams are among the most potent symbols of economic development. The construction of large dams has been seen as a mechanism for promoting economic growth, ensuring food security, alleviating poverty, and increasing resilience in the face of climate variability and change in sub-Saharan Africa (SSA) (Kibret, 2015). There is an estimated 40,000 large dams, defined as impoundments more than 15 meters high or storing more than 3 million m3 of water, and 800,000 small dams have been built, and 272 million hectares of land are currently under irrigation worldwide (Keiser, et al., 2005).

As the climate changes, natural mosquito habitats in many areas of Africa are abundant even without human environmental modification. Any human alteration such as clearing land for agriculture or construction of dams risk exacerbating existing mosquito-associated problems by expanding habitats, creating new habitats, or altering habitats in such a way that limited mosquito populations may explode with the availability of new habitats (Norris, 2004). All mosquitoes share essentially the same pattern of biological development. Eggs are deposited on or near the surface of an existing or expected water source. Mosquitoes can develop in just a few millimetres of water ranging from near freezing to temperatures in excess of 40°C. Habitat may include, for example, fresh or brackish water in ponds, stagnant pools, slow-moving streams, including dam reservoirs (Norris, 2004). Water resources developments coupled with demographic changes alters human-vector-parasite contact patterns and individuals living in proximity to infested waters have higher risk of exposure to infected mosquitoes. Mosquito-transmitted vector-borne diseases include dengue fever, rift valley fever, yellow fever, chikungunya, malaria, japanese encephalitis, lymphatic filariasis, and west nile fever (WHO, 2014, Factsheet).

As dams continue being constructed as an adaption method for water insecurity, critical questions must be asked, first, are the benefits of large scale dams out weighed by the costs of reservoirs as breeding grounds for vector-borne diseases? Second, are these projects undermining the overall attempt at creating water security? Third, who is water secure and who has an increased vulnerability? The unintended consequences in health costs related to dams built in a precarious climate may indicate that dams are not the method in which water security can be achieved. More than one million people die every year from the direct causes of malaria. The additional costs can be measured in an estimated loss of 46.5 million disability adjusted life years (DALYs) with almost 90% currently concentrated in sub- Saharan Africa (Keiser et al., 2005). As dams and irrigation schemes transform ecosystems and can substantially change the nature of malaria risk in proximity to their location. These factors are particularly important in the establishment and operation of resource development projects. In Africa alone, 9.4 million people live near to large dams. Studies have indicated the correlation of proximity to dams between 3-5 kms as an indicator of higher risk factors for transmission of malaria (Kibret, 2015).

There is strong correlation between large dams and the transmission of vector-borne illness, particularly malaria. In a research review conducted by Kibret (2015), in areas of unstable transmission within Sub-Saharan Africa, approximately 919,000 malaria cases per year were associated with the presence of 416 dams. The concluded research included a total of 15 studies on 11 dams, and investigated the impact of dams on malaria in semi-arid areas and highland fringes with seasonal malaria transmission in Africa. These studies outline that malaria prevalence was higher in dam villages than non-dam villages. In areas of stable malaria transmission, 204,000 malaria cases per year were associated with the presence of 307 dams. The data also suggest that malaria cases in areas of unstable malaria transmission were on average 3.2

times greater in communities living close to existing reservoirs than those living more than 5 km from them. Overall, the reservoirs investigated account for 0.6 % of the total malaria burden in the SSA. However, in the vicinity of the reservoirs in stable and unstable areas, reservoirs associated with large dams contribute to 47% of malaria cases on average in communities living within 5 km (Kibret et al., 2015).

4. Ethiopia's Hydropower the Gilgel-Gibe dam III

4.1 Ethiopia: Hydro-dams Politicized

As previously discussed, dams have negative ecological implications which largely impact livelihoods of vulnerable populations. The promise of economic growth through export potential is an justification in Ethiopia, which has one of the world's lowest rates of access to modern energy services (Hathaway, 2008). Ethiopia is one of the enthusiastic participants in massive dam building. There are three overarching goals for Ethiopia's dam projects: to boost domestic electricity production and consumption, both by extending the grid to hydro-scarce regions; to reduce Ethiopia's vulnerability to climate and hydrology, weakening its dependence on erratic rain-fed cultivation, enabling irrigated production for both internal consumption and international exports. Finally, by exporting hydro, economic benefits and foreign exchange relationships can be increased (Verhoeven, 2013). In 2005, the Ethiopian Power System Expansion Master Plan (EPSEMP) 2006-2030, was motivated to increase hydro domestic demand in five years to nine countries to become potential buyers of electricity generated in Ethiopia: Djibouti, Egypt, Eritrea, Kenya, Somalia, Somaliland, South Sudan, Sudan and Yemen (Cuesta-fernández, 2015).

Eight hydropower dams account for over 85% of Ethiopia's existing 767 MW generating capacity and five additional hydropower sites with a combined capacity of 3,125 MW are currently under construction (Yewhalaw et.al,2009). An audacious $4.8 billion gigantic Grand Ethiopian Renaissance Dam project is in progress that is funded from local taxes, donations and government bonds (UN Africa Renewal, 2014). Ethiopians abroad and at home contributed the first $350 million, with government workers contributing amounts equivalent to a month of their salaries (UN Africa Renewal, 2014).

Ethiopia's current generation facilities, including the Grand Renaissance dam and the series of Gilgel-gibe dams, have increased Ethiopia's production capacity to a level more than three times above that of the country's domestic demand. Ethiopia is conveying a contradictory message dams are being justified as a development tool to alleviate poverty; only 17 per cent of the population is living with electricity, with an even greater disparity among rural populations (Hathaway, 2008).

Dams as pathways for development is a highly contested topic as dams for hydropower is highly politicized in Ethiopia for a number of reasons. Dam creation is often tied with land access and large-scale foreign land acquisitions, or 'land grabbing'. Populations living on the banks of the Omo river will no longer benefit from flood retreat cultivation which is essential to their livelihoods. Water located in the lake reservoirs behind the Gibe III dam (and the future Gibe IV dam) is advertised to be used for large-scale irrigation on lands to be given out to foreign investors (Abbink, 2012). This is a clear example of 'land grabbing' or more accurately 'water grabbing' on the site of the Gilgel-gibe III. As water is intrinsically interwoven with land, energy and minerals and therefore in this context can be categorized as a distinct 'material' which is crucial to the context of agricultural use 'land grabbing' (Franco et al., 2013).

The desire for rapid construction of hydro-dams is argued to be deeply rooted in the modernized development ideology, as well as a mechanism to increase state-building. Through the power and prestige of stimulating private sector and smallholder initiatives, the political inner circle is increasingly positioned to firmly control the development process (Verhoeven, 2013). This benefits select key players and boosts national prestige simultaneously as it deepens the model of formal and informal power at the state level. The Ethiopian government, led by the Ethiopian People's Revolutionary Democratic Front (EPRDF) view dams as necessary, and the most proactive way to attain energy self-sufficiency and the capacity to boost governmental power and empower Ethiopia (Abbink, 2012). Ethiopia's pursuit to construct multiple dam-building schemes as hydro-agricultural state-building projects highlight how dynamic and contradictory Africa's changing politics of water security and energy development are at the national, local and regional level (Verhoeven, 2013).

3.2 Case study Gilgel- Gibe hydroelectric dam

As part of the East African Power Pool (EAPP) initiative that was launched in 2005 to facilitate the trade of electricity between countries (International Rivers, 2011), Ethiopia built the Gibe III hydroelectric dam on the Omo River, which supplies more than 80% of the inflows to Lake Turkana (Velpuri and. Senay, 2012). Investment of the project was estimated to be about US$2.11 billion, of which the Ethiopian government provided US$572 million from its national budget (International Rivers, 2011). The remaining funds were secured from Industrial and Commercial Bank of China (ICBC), which supports the Ethiopian Electric Power Corporation through a USD$500 million loan. This loan was essential for Gibe III after the World Bank, African Development Bank and European Investment Bank withdrew, due to social and environmental concerns (Verhoeven, 2013).

The Gilgel-gibe dam III has as much to do with agriculture as it does with hydro power. Ethiopia's dams on the Omo River, and the irrigation projects, enable the country to illustrate that the competing logics of water and food security, energy development and climate change adaptation are political struggles as the paradigms of water security of local, national and global actors prioritize their different interests (Verhoeven, 2013). China has taken a particular interest in investing in Africa, particularly Ethiopia. By 2006, China's investments in Africa reached almost US$8 billion. China is considered to be one of Africa's top three FDI providers; their loans, typically at near-zero interest, are often repaid in natural resources, if they are not canceled entirely (Brautigam, 2007; Sautman et al., 2007). China's relations with many African countries is based on a infrastructure for natural resources, in contrast, the Sino–Ethiopian relationship infrastructure for diplomatic support (Adem, 2012). As Ethiopia's hydro potential is underutilized, Chinese banks regard Ethiopia as an excellent credit risk and have provided finance to rural electricity distribution systems, rural telecoms, and rural power generation (Brautigam, 2012).

As with most foreign investments, the Ethiopia-China relations appear to be mutually beneficial; they provide political and economic alliances through options of bilateral trade. Trade between Ethiopia and China have increased since 2000. In 2009 the value of Ethiopia's exports to China reached $243 million, and the value of Ethiopia's imports from China amounted to $1.25 billion. Although, Ethiopia does not produce industrially critical raw materials such as oil and strategic minerals, Ethiopia is an untapped resource, approximately 9% of global tantalum production came from Ethiopia. This is a crucial input for the manufacturing of electronic equipment, metal alloys, and explosives (Yager 2010, Adem, 2012).

China's involvement in the development of Ethiopia is crucial in facilitating the goals of industrial modernization in Ethiopia, through the development of hydropower, energy production and infrastructure such as the Gilgel-gibe III. However, the potential negative impacts of China's involvement are apparent. First, the Chinese dam industry has yet to demonstrate that it can be socially and environmentally responsible. Second, a primary focus of Chinese investors is to make previously inaccessible resources accessible. Third, major Chinese investors, financiers and equipment suppliers developing dams overseas have so far not adopted environmental or human rights policies; or the developed policies do not meet international standards (McDonald et al, 2009).

The environmental and social predictive outcomes from the Gilgel-gibe III have indicated that the highest 'costs' in ecological degradation, loss of livelihoods, local displacement, and health impacts are paid by the most vulnerable. To aid in the assessment of potential impacts, as required by Ethiopian and international law, the building of dams require an Environmental and social impact assessments (ESIA) to evaluate the potential harm of implementing the infrastructure. In the case of the Gilgel-gibe III, the assessments were not conducted in a responsible time-frame to fully evaluate the potential challenges that will face the ecology and social livelihoods of the area's communities. Controversially, the results of the assessment were released two years after the construction of the dam had started and with all plans already determined and approved by the state authorities (Abbink, 2012).

The Gilgel-gibe III will bring major hydrological changes to a very fragile ecosystem, by eliminating the Omo River's natural flood cycle, and putting the Dassanech, Mursi, Nyangatom, and other indigenous peoples at great risk (International Rivers, 2011). At least 100,000 people depend on food cultivated in the river's flooded banks, a practice known as flood-retreat cultivation and the river's harvest helps support an additional 100,000 people through local trading practices between farmers and herders (International Rivers, 2011). This traditional food system is crucial for these communities because they live in one of the poorest, most remote parts of Ethiopia and have long been politically marginalized (International Rivers, 2011).

4.3 Unintended Consequences

The problem of malaria is very severe in Ethiopia, where it has been the major cause of illness and death for many years. According to records from the Ethiopian Federal Ministry of Health, 75% of the country is malarious with about 68% of the total population, or over 54 million people, living in areas at risk of malaria (Campbell-Lendrum, 2017; Adhanom et al., 2006). This population experiences major epidemics every 5-8 years, but focal epidemics occur every year. The transmission risk of malaria is dependent on a range of environmental and socioeconomic factors. In Ethiopia, malarial transmission is unstable, seasonal, and depends primarily on altitude and rainfall. Exposure typically peaks from September to December and April to May, which coincide with the harvesting season for farmers (Alemu et al., 2012). Due to the unstable and seasonal pattern of transmission, the protective immunity of the population is generally low, and all age groups are at risk of infection and disease (Ayele et al., 2012). However, individuals with poor socio-economic conditions, particularly children and women, are at greater risk of infection (Legesse et al., 2007).

The region surrounding the Gilgel-Gibe III dam encompasses a range of altitudes, and is subsequently subject to distinct malarial distributions. The highest peaks are affected by occasional transmission, while the highland fringes range from high to low transmission and the lowlands with intense transmission (Alelign et al., 2016). Regional studies have shown that at the Gilgel-Gibe III site, rainfall and relative humidity are driving forces behind malaria (Sena et al., 2015). This is of concern given the anticipated changes in these variables as a result of climate change. As with the rest of Eastern Africa, temperatures are expected to warm in Ethiopia, increasing by up to 5.1°C by the 2090s (McWeeney et al., 2010). Rainfall, however, has been more difficult to project. Attempts to model future changes in rainfall show large ranges relative to the baseline, alluding to possible increases and decreases in annual amounts (Ababa, 2007). However, it is generally expected that there will be an increase in the intensity of extreme precipitation events, which will increase flood risk and mosquito breeding sites.

Through the changes in temperature and rainfall patterns and the subsequent effects on the distribution and seasonal transmission of malaria, an overall increase in malarial transmission is anticipated across the Ethiopian landscape. The disease is projected to show increases of more than 100% in person-months of exposure in Ethiopia towards the end of the 21st century (Tanser et al., 2003). In addition, parts of the highlands are expected to become newly suitable for malaria by 2050 (Rogers et al., 2000). As a result, more than 122 million Ethiopians will be exposed to the disease (Tanser et al., 2003). These projections compound the concerns regarding the regional effect of the Gilgel-Gibe III dam on malarial transmission and must be considered when planning for the potential impacts of future water resource development projects.

Due to recent Gilgel-Gibe III dam construction, large numbers of people living in villages in proximity are at potentially greater risk of malaria transmission in this area. For example, a high number of Anopheline arabiensis (the major malaria vector) was recorded in the Gilgel-Gibe area (Yewhalaw et al., 2014). Studies conducted on malaria transmission patterns reveal that increased risks of exposure to Malaria is correlated with village proximity (within 3-5 kms) to the dam reservoir. A two-year study indicated that among children less than 10 years living in 16 study villages around the Gilgel-Gibe indicated that Mosquito density decreased by 53% at 6-7 km from the dam, compared with localities close to the dam reservoir (Yewhalaw et al., 2013). The findings also indicated that malaria prevalence was 7.7% in communities within 3 km as compared to 4.4% in those living more than 3 km from the dam (Yewhalaw et al., 2013).

4.4 Women's Vulnerabilities

Women's vulnerability to vector-borne diseases may be evident; however, limited information on *why* women and their children have increased rates of malaria is often less discussed. It is argued here that there are biological, social and environmental determinants which increase women's risk for transmission of vector-borne diseases. Since women carry the high burden of vector-borne infections, it is important to investigate why women are more vulnerable than men.

A gender analysis is encouraged when analyzing the epidemiology of vector-borne diseases as the understanding of transmission is governed by epidemiology, however, prevention and treatment are affected by gender stratification in societies. The biological determinants are specific to pregnant women, making them more at risk. Studies have indicated that pregnant women have lowered immunity to malaria, which leads to anemia, miscarriages, low-birth rates, neonatal deaths and maternal deaths. Extreme poverty only heightens the vulnerability for this segment of the population. Approximately 125 million pregnant women are infected by malaria each year. Malaria is known to cause 75,000-200,000 infant deaths yearly in sub-Saharan Africa, and a large proportion of maternal deaths (37%) during pregnancy are attributable to Malaria in several African countries. In endemic areas, malaria can cause placental malaria and severe, malaria anemia. Maternal anemia infection might lead to intrauterine growth restriction and prematurity among newborn, which in turn may lead to low birth weight (Austin et al., 2013).

Pregnant women living near the Gilgel-Gibe III are particularly at risk. A high prevalence of anaemia indicates it is currently a serious health problem of pregnant women living in Gilgel - Gibe dam area. In a study conducted to assess risk factors of living in proximity to the dam reservoir, anemia was found in 53. 9% of the 388 pregnant women tested (Getachew, et al., 2012). It has been suspected that nutrition might influence susceptibility to infection by the malaria parasite or modify the course of disease. There have been relatively few efforts to examine such interactions, in most countries in sub- Saharan Africa, more than 20% of the women are classified as being malnourished. Malnourished pregnant women are more likely to give birth to underweight babies who then in turn are more susceptible to infectious disease including malaria (Rylander et al., 2013).

Social indicators, which include economic and cultural circumstances in which men and women live, contribute to women's vulnerabilities by influencing her access to preventative measures and treatment services. A gender perspective framework is important in recognizing health seeking behaviours, both at prevention and treatment levels. Early recognition of symptoms can be the key to addressing women's vulnerability to adverse outcomes. When the limited gender analysis literature is examined, the common theme expressed in understanding women's vulnerabilities is the overarching socio-cultural indicator of women's lack of autonomy. This has some of the largest consequences on women's health status. Gender inequalities, including economic, health and education, can have an impact on women's malaria rates. Women's socio-health status has the strongest direct correlation with malaria rates and overall health outcomes measured by women's legal economic status, formal access to land, access to loans, and access to property for women. With increased social status being correlated with lower rates of malaria (Austin et al., 2013).

In rural areas, women's gendered domestic roles increase their vulnerabilities, as women carry the major of the responsibility for the well-being of the household. Although, this responsibility is rarely matched by autonomy to make decisions or by access to the necessary resources (Tanner et al., 1998). In both health prevention and treatment seeking behaviours, women may have to ask permission from their husbands, mothers-in-law, or senior household males before being permitted to seek care. In some cultures, women cannot visit health centres unaccompanied. This may add additional barriers for women to act upon their desire to seek treatment. Women's lack of financial autonomy suggest that women have an inability to make decisions about how money is spent in the household, therefore they are limited in the ability to prioritize preventive measures, such as ensuring use of bed nets within their household. Revenues earned by women are more often used to meet basic needs that improve quality of life, such as education fees, health care costs, clean water and sanitation services, and clothing for children, in comparison to earnings made by men (Austin et al., 2013). Although women carry the largest burden of malaria, whether confronted with a child with the disease or herself, women in most societies tend to be the ones that are often poorly informed about disease risks and possibilities for prevention and cure (Tanner et al., 1998). The lack of knowledge of exposure, symptoms and treatment may correlate with women's inequalities in education. In rural Ethiopia the literacy rates for rural women are just 19%, compared with 43% for men (Jones et al., 2010).

Domestic and reproductive gender roles such as child care, domestic chores and subsistence agriculture link women to water resources for domestic needs. Since women and girls often cook, clean, farm, and provide health care and hygiene for their households, they are on the front line of their communities' and countries' water issues. Women also play a crucial role in ensuring the availability of water for the household survival (Fonjong, et al., 2015). Therefore, environmental challenges due to climate change also increase women's vulnerabilities as they are directly related to the water scarcity. With livelihoods being directly related to natural resources, women are particularly at risk from the predicted impacts of climate change on water resources (Baker et al., 2015).

Women's domestic water use may also be challenged by global water-related issues such as over- consumption, population growth, water privatization and climate change, all of which affect the quality and accessibility of water. As women are primarily responsible for securing water for domestic use, they will be forced to adjust to such changes (Fonjong, et al., 2015). In addition, water scarcity and contamination disproportionately impact low-income women, and their health seeking opportunities are further jeopardized for many who must walk miles to access clean water. Clean water shortages and man-made infrastructures such as dams may require women to walk further distances in order to access water resources. Access to water, sanitation and hygiene are indicators of good health outcomes; as it is primarily a woman's domestic chore to gather water. The ability to adequately implement these practices may be threatened not only by inadequate accessible sources of clean water due to rainfall variability, but also the risk of exposure to high densities of vector-borne carriers in her attempt to secure water as she is forced to walk near mosquito habitats.

5. Effective interventions for water security and malaria

The Way Forward

Reduced access to natural resources for remote communities after dam construction such as land, water and forests often negatively impacts their livelihoods, since natural resources represent, for the majority of those people, the main capital asset (Velpuri et al., 2012). Not only are large dams costly and prone to systematic and severe budget overruns, they also take a long time, on average 8.6 years, to be built (Ansar, et al., 2014). Climate change is believed to further exacerbate existing vulnerability to disease and food insecurity for remote populations since they are more reliant on agriculture, are more vulnerable to droughts, and have a lower adaptive capacity relative to their urban-rich counterparts (Huynen, et al., 2013).

The key to successful governance and overcoming the threats to water security is institutional change that brings together key stakeholders in ways that ensure long-term, sustainable futures for the environment, water users, and their communities (Connell and Grafton, 2011). This section will shed light on the preventative measures that can be implemented to combat malaria and water security in Ethiopia.

5.1 Potential Solutions

As discussed, the use of dams for climate change mitigation will likely continue to grow despite the negative outcomes, as witnessed in Ethiopia. Alternative solutions are difficult to integrate into the dam-for-development debate, which rationalizes the negative social and ecological outcomes under the veil of economic growth. There are few realistic or conceivable approaches to address both the adaptation and mitigation strategies of climate change as they relate to water security. The following solutions may not be effective in Ethiopia's context as the government is determined to bring growth and "power" to Ethiopia through the state-building multi-dam schemes. However, they may shed light on alternative ways to move forward.

Alternative Energy

Ethiopia's dependence on hydropower creates potential risks as their water security method is highly vulnerable to droughts. Firstly, alternative green energy sources need to be further investigated for the country's domestic energy demand. Ethiopia needs to diversify its energy generation methods. Solar power has significant potential in Ethiopia. There may be great potential for Ethiopia to convert their dependency on hydropower to innovative solar water heating and large-scale grid plants. There is also the possibility of at least 30 MW of power from cogeneration in some of the country's sugar factories (Hathaway, 2008).

Rainwater harvesting

Rainwater harvesting creates synergies by upgrading rain-fed agriculture and enhancing productive landscapes. The rainwater use by crops and natural vegetation is in many cases by-passed in integrated water resource management (UNEP, 2009). Consequently, the rainwater harvesting interventions are not widely recognized in water policy or in investment plans, despite the broad base of cases identifying multiple benefits for development and sustainability (UNEP, 2009). By introducing policies recognizing the value of ecosystem services and the role of rainfall to support these systems, rainwater harvesting emerges as a set of interventions addressing multiple issues on human well-being and improved ecosystems services. Governments and communities should jointly make efforts in enabling policies and legislation, together with cost sharing and subsidies for rainwater harvesting interventions.

Linking Multiple Dam Operations

If the proposed dams are used for irrigation and alternative irrigation strategies such as drip irrigation, artificial groundwater recharge and water harvesting cannot be implemented, reducing dam water use therefore ensuring optimal efficiency should be a priority. This can potentially be accomplished in multi-dam schemes. By linking the operations of multiple dams arranged in a cascade, water can be transferred between reservoirs. This minimize evaporation losses by storing water in the most upstream reservoir and transferring water to reservoirs downstream for water supply only when it is needed in the irrigation season, thus minimizing the need for unnecessary water transfers and subsequent water losses (Watts et al., 2011).

Mitigation Measures

Aside from alternative green energy sources, potential solutions must also focus on alternative mitigation measures to address the adverse effects of large scale dams. There are many mitigation options for the environmental impacts of dams, although they are rarely implemented primarily due to financial restrictions. As discussed, one of the major concerns with large scale dams is the potential downriver hydrological changes. These impacts can be minimized by managing the water releases from the turbines or ‘reoperation’. Hydro-dams which generate baseload electricity, such as the Gilgel-gibe III, are potentially capable of mimicking downriver flows to provide adequate downriver water supply though off-channel pumped storage. Alternatively, coordinated operations within a cascade of dams can address extreme daily fluctuations in flow and assist in restoring the natural seasonal patterns (Watts et al., 2011). This water-flow management can help offset the impacts of the dam on riparian ecosystems, reservoir and downriver water quality, and aquatic weed and disease vector control (Ledec, et al., 2003).

Highly eutrophic dam reservoirs are potentially challenged by floating aquatic vegetation, which can cause problems such as a loss of habitat for fish and other aquatic species which may lead to extinction. Floating vegetation has also been linked to the creation of breeding grounds for mosquitos and other disease vectors. Therefore, pollution control and pre-impoundment selective forest clearing and the occasional drawdown of reservoir water levels may be used to kill aquatic weeds (Ledec, et al., 2003). As an innovative way to reduce the eutrophication in dam reservoirs, an Artificial Floating Island (AFI) can be added to the reservoir. This mechanism uses a small buoyant frame on which plants grow, they act to compete with algae for excess nutrients in the water. They can also reduce biochemical and chemical oxygen demands by the water up to 60% (Kamble et al., 2012), although further research on this method is needed to support its potential to mitigate the adverse effects on the ecosystem.

Conclusive and timely Environmental and Social Impact Assessments (ESIA) must be conducted for each new proposed large scale dam or irrigation scheme. Although with the siting of the Gilgel-gibe III, this was not the case. Each proposed dam should also include an implementation of mitigation measures for cumulative impacts of multi-dam schemes. These should be completed prior to the construction of any additional dams. Increased research on gender analysis as it relates to climate change is needed to fully understand how this increases women's risks for life-threatening diseases. Women's domestic relationship with water management may also increase their risk to exposure, as a consequence to climate change, these effects, such as the depletion of natural resources lead men and women to interact with natural resources and landscapes in different ways. It is imperative that the Environmental and social impact assessments (ESIA) include women's specific vulnerabilities as a criteria for potential negative outcomes.

5.2 Integrated Water Resource Management (IWRM)

Water managers are assisted in making rational and balanced decisions on the water use, conservation and protection. Control of stagnant water for instance in reservoirs and irrigation systems as well as enhancing the quality of water for domestic use is important for prevention of malaria and other diseases (GWP, 2004). Environmental flows as an Ecosystem Approach provides benefits for people and nature by integrating the environment in decision-making, strengthening investment in ecosystems and social inclusion and catalyzing good governance.

Environmental flows have conventionally been used to provide nature with an equitable share of water to keep rivers alive and flowing. The flow regime includes many components that are critical to ecosystem health, including flow magnitude, flood frequency, duration, timing, depth and velocity. The management of river basins plays a key role in the conservation and improvement of the general state of water bodies world-wide because it allows for the consideration of resource protection while meeting social and ecological need the consideration of improvement of the ecosystem status as the unique objective in the design and prioritization of management actions may lead to undesired negative consequences for human well-being as a result of a decrease in the level of certain ecosystem services (Terrado et al., 2016).

5.3 Polycentric Governance

As the natural boundaries of water resources do not coincide with political boundaries, water has to be dealt with by multiple organizations through systems of 'polycentric governance' that enable interaction to occur between different institutions (Mueller, 2012). Effective organizations are built by users with common long-term interests who can invest in monitoring and building trust, often at a relatively small and local level that are supported by national governments and guides efforts by local water users and stakeholders to create effective management mechanisms for their local resources (Mueller, 2012). Governance is shared between national and local actors to preserve local user groups' ability to devise local rules and establish systems for coordination creating complementary, overlapping systems that are adapted to the unique social and biophysical conditions at subnational scales (Baldwin et al., 2016).

Kenya, for example, has embarked on a series of reforms that create a polycentric approach to water governance in which decision making about water resources is shared among multiple, overlapping local, regional, and national authorities. In the Likii River subcatchment, poor irrigation conditions in the 1980s and 1990s prompted NGOs, research centers, government authorities, and farmers to form a collaborative group to solve the region's chronic water shortages that propelled upstream users to adjust the timing and quantity of their water use, particularly during times of water scarcity (Baldwin, et.al, 2016). The group promoted the formation of Water Users' Associations—groups of water users and other stakeholders who would meet to discuss conditions, share information, and anticipate and resolve problems that included the key aspects of resource governance: resource allocation, monitoring of compliance with allocation rules, sanctioning of improper rules, and resolution of conflicts (Baldwin, et.al, 2016). Polycentric connotes many centers of decision making that are formally independent of each other that can overcome collective action challenges by focusing on optimal scales of implementation that minimize governance costs and recognize spatially varying catchments for benefits (Ostrom, 2010; Bixler, 2014)

5.4. Role of women in polycentric governance

A disproportionate share of the labour and health burden of household water and sanitation inadequacies falls on women. Reducing the distance to a water source from 30 to 15 min increased girls' school attendance by 12% according to a study in Tanzania (UN Water, 2013). Social networking and political participatory aspects of women who are almost secondary in relation to water have garnered substantially less attention (Sorenson et al., 2011). From a public health and psychological perspective, it is these gender-based inequities and disparities in expectations that generate the exposures, or acquired risks, and the risk factors that adversely influence women's health (Dasgupta, 2013). Prioritizing their needs, interests and perspectives could lead to greater privacy, personal dignity, better all-round health, increased educational opportunities, better personal safety and more possibilities for earning income. In 2003, the Ugandan Directorate of Water Development (DWD) published an explicit Water Sector Gender Strategy (WSGS) to help mainstream gender into its plans and activities. This study uses the to enhance gender equity, participation of both women and men in water management, and equal access to and control over water resources in order to alleviate poverty (UN, 2006). The strategy sets out clear aims, rationales and targets and is designed to provide guidelines to water sector stakeholders on how to mainstream gender in their work plans and for the planning and implementation of water and sanitation programmes (UN, 2006).

5.5 Management for malaria/ vector borne diseases

In the era of sustainable development across diverse sectors; water, sanitation and hygiene (WASH) forms the core and needs to be prioritized. Despite the progress seen in Ethiopia, 43% of the population does not have access to an improved water source and 28% practice open defecation while the majority of health facilities lack access to clean water and only about 32% have access to safe water (WHO, 2017). The disease burden related to insufficient and inadequate WASH facilities is evident, with deaths every year attributed specifically to these health determinants (Bartram, Lewis, Lenton and Wright, 2005). The economic liabilities associated with mortality and malnutrition due to unsafe WaSH, time lost in collecting water, and seeking somewhere to defecate is of major concern (Bartram and Cairncross, 2010). Combating health related issues in accordance with WaSH in rural communities calls for local solutions that includes participatory approaches. Community level knowledge and practices related to the ecology and environmental management for disease control could result in lasting sustainable reductions of vector-borne diseases such as malaria (Randell et al., 2010).

Community health workers (CHWs) as an intervention in the health and WaSH sectors play a crucial role in broadening access and coverage of health services in remote areas and can undertake actions that lead to improved health outcomes (WHO, 2007). Environmental management practices for disease control can be implemented at the community level by mobilizing local resources through financial aid and educational aid to community health workers (Randell et al., 2010). Governments, NGO's and foundations need to strengthen their engagement to accelerate the provision of WaSH amenities to rural remote communities. Inclusion and participation of women in stakeholder decision-making processes at all levels should be one of the top key objectives of global health national and international leaders and practitioners. CHWs with adequate training and support offer simple and effective ways to increase uptake of malaria prevention and effectively deliver essential healthcare (IPTp and ITN services) to women of reproductive age, as well as counseling to communities (Okeibunor et al., 2011). CHWs play an important role in the redistribution of health service provision to less specialized health workers in order to bring essential health services closer to populations with limited or no access to essential public health services (Buchner et al., 2014).

There is good evidence that insecticide treated nets (ITNs) are a cost-effective and successful method of reducing malaria morbidity and mortality and their use provides a protective efficacy against malaria of up to 60%, and in areas with stable malaria they reduce the incidence of uncomplicated malarial episodes by 50% (Williams et al., 2009). Furthermore, ITNs can avert more than just malarial deaths—in children, their use has been shown to significantly reduce under-five childhood mortality due to all causes (Williams et.al, 2009). Mass, free ITN distribution campaigns and subsidized voucher programs for ITNs targeting pregnant women and children <5 years have been successful at increasing the proportion of households that own and use an ITN (Sangaré et al., 2012).

Despite the considerable increase in funds over the recent years to control malaria in Ethiopia, the disease has been the most frequently reported cause of morbidity and mortality as intermittent preventive treatment (IPT) for malaria prevention during pregnancy has not been adopted completely (Ali and Deressa, 2009). The availability and affordability of IPT for community-based malaria control interventions carried out by village-based community health workers (CHWs) and home-based management of malaria is a major concern (Ali and Deressa, 2009). IPT prevents the adverse consequences of malaria on maternal and fetal outcomes, such as placental infection, clinical malaria, maternal anaemia, fetal anaemia, low birth weight and neonatal mortality and has been shown to be highly cost-effective for both prevention of maternal malaria and reduction of neonatal mortality in areas with moderate or high malaria transmission (WHO, 2014).

Scaling up the interventions of sustainable distribution of ITN’s and educating women in rural communities through outreach programs on the benefits of ITN’s and IPT is crucial for the prevention and cure of the disease. Malaria control programmes should strive to achieve full protection in pregnant women by both IPTp and ITNs to maximize their benefits.

6. Conclusion

Hydro-dams as a mechanism to enhance state-building and economic growth masked under ‘development’ for agriculture and foreign trade indicate that in the building of dams there are clear winners and losers. Gilgel-gibe III may pave the way for development in Ethiopia, by supplying to other hydro-scarce African countries; however, the case of the Gilgel-gibe III is evident of the intersection between large scale water security measures, climate change adaptation, and the burden of vector-borne diseases. ‘Land grabbing’ and ‘water grabbing’ by foreign entities indicate that Ethiopia’s impoverished populations, particularly women as the most vulnerable affected by the building of the Gilgel-gibe III are not a priority in the ‘development’ plan of Ethiopia. The loss of capacity to ensure healthy, safe and thriving livelihoods has been threatened as Ethiopia exploits hydro potential. This paper discussed climate change as a major contributor of spread of malaria and dams as an instrument that is intrinsically tied to water security, yet threatens health. Although the spread of vector-borne diseases may be addressed by preventative measures such as WASH and the use of treated bed nets, truly preventative and equitable solutions lie in the role of Ethiopia’s governance and priority to seek-out alternative options to ‘green energy’ and climate change mitigation which are clearly entrenched in water politics.

References

Ababa, A. (2007). Climate change national adaptation programme of action (Napa) of Ethiopia. *Nationa lMeteorological Services Agency, Ministry of Water Resources, Federal Democratic Republic of Ethiopia.*

Abbink, J. (2012). Dam controversies: contested governance and developmental discourse on the Ethiopian Omo River dam. *Social Anthropology*, *20*(2), 125-144.

Adhanom, T.D.W., H.K. Witten, A. Getachew, T. Seboxa. (2006). The Epidemiology and Ecology of Health and Disease in Ethiopia 1st edition. Ababa Addis, Ethiopia: Shama PLC, 556-576.

Adem, S. (2012). China in Ethiopia: Diplomacy and economics of Sino-optimism. *African Studies Review*, *55*(01), 143-160.

Africa, Climate Change, Environment and Security (ACCES). (2010). Climate change and security in Africa: Vulnerability Report. Retrieved on March 31st 2017 from http://www.gwiwater.org/sites/default/files/pub/ACCES%20Vulnerability%20Report_1.pdf

Africa, Climate Change, Environment and Security (ACCES). (2011). Climate change and security in Africa: Vulnerability discussion paper. Retrieved on March 31st 2017 from http://www.africa-eupartnership.org/sites/default/files/documents/doc_climate_vulnerability_discussion_paper.pdf

Alelign, A, and T. Dejene. (2016). Current status of malaria in Ethiopia: Evaluation of the burden, factors for transmission and prevention methods. *Acta Parasitologica Globalis*. 7(1):01-06.

Alemu, A., D. Muluye, M. Mihret, M. Adugna and M. Gebeyaw, (2012). Ten year trend analysis Of malaria prevalence in Kola Diba, North Gondar, Northwest Ethiopia. *Parasites & Vectors.* 5:173.

Allen M.R. and Ingram W.J. (2002) Constraints on future changes in climate and the hydrologic cycle. *Nature*. 419, 224–232.

Ansar, A. Flyvbjerg,B., Budzier, A. and Lunn,D.(2014). Should we build more large dams? The actual costs of hydropower mega project development. *Energy policy*, 69, 43-56.

Austin, Kelly F., Mark D. Noble, and Maria Theresa Mejia. "Gendered vulnerabilities to a neglected disease: A comparative investigation of the effect of women's legal economic rights and social status on malaria rates." *International Journal of Comparative Sociology* 55.3 (2014): 204-228.

Ayele, D. G., T.T. Zewotir, and H.G. Mwambi. (2012). Prevalence and risk factors of malaria in

Ethiopia. *Malaria Journal*. 11(1), 195.

Baker, Tracy J., et al. "A socio-hydrological approach for incorporating gender into biophysical models and implications for water resources research." *Applied Geography* 62 (2015): 325-338.

Baldwin, E., Washington-Ottombre, C.,Dell'Angelo, J., Cole, D., and Evans, T. (2016). Polycentric Governance and Irrigation Reform in Kenya. *Governance*, 29(2), 207-225.

Bartram, J., Lewis,K., Lenton, R. and Wright, A. (2005). Focusing on improved water and sanitation for health. *The Lancet*. 365(9461), 810-812.

Bartram, J. and Cairncross, S.(2010). Hygiene, Sanitation, and Water: Forgotten Foundations of Health. *PLoS Medicine*, 7(11), e1000367.

Berga, L. (2016). The Role of Hydropower in Climate Change Mitigation and Adaptation: A Review. *Engineering*, *2*(3), 313-318.

Bixler, R. (2014). From Community Forest Management to Polycentric Governance: Assessing Evidence from the Bottom Up. *Society & natural resources*. 27(2), 155-169.

Brautigam, D., & Tang, X. (2012). *An overview of Chinese agricultural and rural engagement in Ethiopia*. IFPRI Working Paper, May.

Buchner, D. L. Brenner, J.L., Kabakyenga, J., Teddy, K., Maling, S.,Barigye, C.,Nettel-Aguirre, A. and Singhal, N. (2014). Stakeholders' Perceptions of Integrated Community Case Management by Community Health Workers: A Post-Intervention Qualitative Study. *PLoS One*, 9(6)

Calow, R. C., A.M. MacDonald, A.L. Nicol, and N.S. Robins. (2009) Groundwater security and Drought in Africa: linking availability access and demand. *Ground water*, *48*(2), 246-256.

Campbell-Lendrum, D., L. Manga, M. Bagayoko, and J. Sommerfeld. (2017). Climate change And vector-borne diseases: what are the implications for public health research and policy? *Philosophical Transactions Research Society*. 370:20130552.

Carius, A., D. Tänzler, and A. Maas. (2008). *Climate change and security: challenges for German development cooperation*. Eschborn: GTZ. Retrieved on March 31st from http://www.preventionweb.net/files/8023_enclimatesecurity1.pdf

Carr, C. J. (2017). At Stake with River Basin Development in Eastern Africa. In *River Basin Development and Human Rights in Eastern Africa—A Policy Crossroads* (pp. 1-21). Springer International Publishing.

Connell, D. and Grafton, Q.(2011). Water reform in the Murray-Darling Basin. Water Resources Research, 47(12)

Cuesta-Fernández, I. (2016). mammoth dams, lean Neighbours: Assessing the bid to Turn Ethiopia into East Africa's powerhouse1. *A New Scramble for Africa?: The Rush for Energy Resources in Sub-Saharan Africa*, 93.

Dasgupta, S. (2013). Poverty as a Contextual Factor Affecting Sexual Health Behavior Among Female Sex Workers in India. *Qualitative health research*, 23(6), 825-833.

Deressa, W. and Ali, A. (2009). Malaria-related perceptions and practices of women with children under the age of five years in rural Ethiopia. *BMC Public Health*, 9, 259-259.

De Wit, M., & Stankiewicz, J. (2006). Changes in surface water supply across Africa with Predicted climate change. *Science*. 311(5769), 1917-1921.

Edenhofer, O., R. Pichs-Madruga, Y. Sokona, K. Seyboth, S. Kadner, T. Zwickel, T., ... and P. Matschoss. (Eds.). (2011). *Renewable energy sources and climate change mitigation: Special report of the intergovernmental panel on climate change*. Cambridge University Press. Retrieved on March 31st 2017 from https://www.ipcc.ch/pdf/special-reports/srren/SRREN_FD_SPM_final.pdf

Food and Agriculture Organization of the United Nations (FAO). (2009). The State of Food Insecurity in the World 2009: Economic Crises – Impacts and Lessons Learned, (Rome, 2009). Retrieved on March 31st 2017 from ftp://ftp.fao.org/docrep/fao/012/i0876e/i0876e.pdf

Franco, J., Mehta, L., & Veldwisch, G. J. (2013). The global politics of water grabbing. *Third World Quarterly*, *34*(9), 1651-1675.

Fonjong, L. N., & Fokum, V. Y. (2015). Rethinking the water dimension of large scale land acquisitions in sub-Saharan Africa. *Journal of African Studies and Development*, *7*(4), 112-120.

Getachew, Million, et al. (2012). Anaemia and associated risk factors among pregnant women in Gilgel Gibe dam area, Southwest Ethiopia." *Parasites & vectors* 5.1: 296.

Githeko, A.K., S.W. Lindsay, U.E. Confalonieri, and J.A. Patz. (2000). Climate change and vector- borne diseases: a regional analysis. *Bulletin of the World Health Organization*. 78(9).

GWP. (2004). GWP in Action. https://issuu.com/gwp-publ/docs/gwp_in_action__annual_report_2004

Haithcox Dennis, M. (2013). Rethinking the Factors of Success: Social Support and Community

Coalitions. American Journal of Health Education, 44(2), 110-118.

Hathaway, T. (2008). What cost Ethiopia's dam boom. *A look inside the expansion of Ethiopia's energy sector. International Rivers, People. Water. Life.* Retrieved from httpn'fwwwinternationalriversorg/files: r EthioReport06Feb08. pdf.

Houghton, R. A. (2005). Tropical deforestation as a source of greenhouse gas emissions. *Tropical deforestation and climate change*, *13*.

Huber, D., and J. Gulledge. (2011). Extreme weather and climate change. Centre for climate and energy solutions. Retrieved on March 31st 2017 from https://www.c2es.org/publications/extreme-weather-and-climate-change

Hunter, P.R. (2003). Climate change and waterborne and vector-borne disease. *Journal of Applied microbiology*. 94(s1), 37-46.

Huynen, M.M.T.E., Martens, P., and Akin, S.-M.(2013). Climate change: an amplifier of existing health risks in developing countries. Environment, Development and Sustainability, 1-18.

Intergovernmental Panel on Climate Change (IPCC). (2007). Fourth Assessment Report: The

Physical Science Basis. Chapter 11, p 868. Retrieved on March 23rd from http://www.ipcc.ch/pdf/assessmentreport/ar4/wg1/ar4-wg1-chapter11.pdf

International Fund for Agricultural Development (IFAD). (2016). Investing in rural people in Ethiopia. Retrieved on April 17th 2017 from https://www.ifad.org/documents/10180/d030748c-44d6-455e-a35b-5f35ac8893e0

Jones, Nicola, Yisak Tafere, and Tassew Woldehanna. (2010). Gendered risks, poverty and vulnerability in Ethiopia: To what extent is the Productive Safety Net Programme (PSNP) making a difference. *London: Overseas Development Institute. http://www. odi. org/sites/odi. org. uk/files/odiassets/publications-opinion-files/6250. pdf* .

Joseph, S. (2010). Tackling Informality: Why HIV/AIDS Needs to be a Critical Component of Urban Development Policies. Urban Forum, 21(2), 85-105.

Kailash, R., T. O'Leary, A. Turner, G. Petrakis, M. Leonard, and S. Westra. (2014). Changes to The temporal distribution of daily precipitation. *Geophysical Research Letters*. 41:8887–8894.

Kamble, R., & Patil, D. (2012). Artificial floating island: solution to river water pollution in India. Case study: rivers in Pune City. In *International Conference on Environmental, Biomedical and Biotechnology IPCBEE* (Vol. 41).

Kayranli, B., Scholz, M., Mustafa, A., & Hedmark, Å. (2010). Carbon storage and fluxes within freshwater wetlands: a critical review. *Wetlands*, *30*(1), 111-124.

Keiser, Jennifer, et al. (2005). Effect of irrigation and large dams on the burden of malaria on a global and regional scale. *The American journal of tropical medicine and hygiene* 72.4: 392-406.

Kennedy, D. (2012). African poverty. *Washington Law Review*. *87*, 205.

Kibret, Solomon, et al. "Malaria impact of large dams in sub-Saharan Africa: maps, estimates and predictions." *Malaria journal* 14.1 (2015): 339.

Ledec, G., & Quintero, J. D. (2003). Good Dams and Bad Dams: Environmental Criteria for Site Selection of Hydroelectric Projects The World Bank. *Latin America and Caribbean Region, Environmentally and Socially Sustainable Development Department (LCSES)*.

Legesse, Y., A. Tegegn and T. Belachew, (2007). Knowledge, attitude and practice about Malaria transmission and Its preventive measures among households in urban areas of Assosa Zone, Western Ethiopia. *Ethiopian Journal of Health Development*. 21:157-65.

Lozano, R., M. Naghavi, K. Foreman, S. Lim, K. Shibuya, V. Aboyans, ... and M.A. AlMazroa.

(2013). Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*. 380(9859), 2095-2128.

Norris, Douglas E. (2004). Mosquito-borne diseases as a consequence of land use change. *EcoHealth* 1.1: 19-24.

Mao, H. (2013). Water insecurity in the Horn of Africa: Scarcity or institutional failure. Retrieved on March 31st 2017 from https://www.hiiraan.com/op4/2013/oct/41759/water_insecurity_in_the_horn_of_africa_scarcity_or_institutional_failure.aspx

McDonald, K., Bosshard, P., & Brewer, N. (2009). Exporting dams: China's hydropower industry goes global. *Journal of environmental management*, *90*, S294-S302.

McSweeney, C., M., New, and G. Lizcano. (2010). The UNDP Climate Change Country Profiles:Improving the accessibility of observed and projected climate information for studies of climate change in developing countries. American Meteorological Society. DOI:10.1175/2009BAMS2826.1

Millennium Ecosystem Assessment. (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, District of Columbia, 155 pp. Retrieved on March 23rd from http://www.millenniumassessment.org/documents/document.356.aspx.pdf

Mueller, M. (2012). Polycentric governance: water management in South Africa. Proceedings of the ICE - Management, procurement and law, 165(3): 193-193.

Ndaruzaniye, V. (2011). Water Security in Ethiopia: Risks and Vulnerabilities' Assessment. *Global Water Institute for Africa Climate Change, Environment and Security*.

Nicholson, S.E. (2014). A detailed look at the recent drought situation in the Greater Horn of Africa. *Journal of Arid Environments*. 103: 71-79.

Okeibunor, J. C. Orji, B.C., Brieger, W., Ishola, G., Otolorin, E.D., Rawlins, B., Ndekhedehe, E. U., Onyeneho, N. and Fink, G. (2011). Preventing malaria in pregnancy through community-directed interventions: evidence from Akwa Ibom State, Nigeria. Malaria journal, 10, 227-227.

Ostrom, E. (2010). Beyond Markets and States: Polycentric Governance of Complex Economic Systems. The American Economic Review, 100(3), 641-672.

Patz, J. A., A.K. Githeko, J.P. McCarty, S. Hussein, U. Confalonieri, and N. De Wet (2003). Climate change and infectious diseases. *Climate change and human health: risks and responses*. 103-132.

Randell, H.,Dickinson, K., Shayo, E., Mboera, L. and Kramer, R.(2010). Environmental Management for Malaria Control: Knowledge and Practices in Mvomero, Tanzania. EcoHealth, 7(4), 507-516.

Rogers, D.J., and S.E. Randolph. (2000). The global spread of malaria in a future, warmer world. *Science*. 289:1763–1766.

Rylander, Charlotta, Jon Øyvind Odland, and Torkjel Manning Sandanger. (2013). Climate change and the potential effects on maternal and pregnancy outcomes: an assessment of the most vulnerable—the mother, fetus, and newborn child. *Global health action.* 6.

Sangare, L. R., Weiss, N.S., Brentlinger, P.E., Richardson, B.A., Staedke, S.G.,Kiwuwa, M.S. and Stergachis, A.(2012). Determinants of Use of Insecticide Treated Nets for the Prevention of Malaria in Pregnancy: Jinja, Uganda. PLoS One, 7(6), e39712.

Sautman, B., & Yan, H. (2007). Friends and interests: China's distinctive links with Africa. *African Studies Review*, *50*(3), 75-114.

Sena, L., D. Wakgari, A. Ahmed. (2015). Correlation of climate variability and malaria: A retrospective comparative study, Southwest Ethiopia. *Ethiopian Journal of Health Sciences*. 25(2): 129–138.

Skliris, N., J.D. Zika, G. Nurser, S.A. Josey, and R. Marsh. (2016). Global water cycle amplifying at less than the Clausius-Clapeyron rate. *Scientific Reports*. 6:38752.

Sorenson, S. B. (2011). Safe access to safe water in low income countries: Water fetching in current times. Social science & medicine, 72(9), 1522-1526.

Stockholm International Water Institute (SIWI). (2012). Large-Scale water storage in the water, energy and food nexus: Perspectives on benefits, risks and best Practices. Retrieved on March 23rd 2017 from http://www.siwi.org/documents/Resources/Papers/Water_Storage_Paper_21.pdf

Tanner, Marcel, and Carol Vlassoff. (1998). Treatment-seeking behaviour for malaria: a typology based on endemicity and gender. *Social science & medicine* 46.4-5: 523-532.

Tanser, F.C., B. Sharp, D. le Sueur. (2003). Potential effect of climate change on malaria Transmission in Africa. *The Lancet*. 362(9398): 1792-1798.

Tarhule, A. (2005). Damaging rainfall and flooding: the other Sahel hazards. *Climatic change*, *72*(3), 355-377.

Terrascope. (2013). Dams and Reservoirs. Retrieved on March 31st 2017 from http://12.000.scripts.mit.edu/mission2017/dams-and-reservoirs/

The World Bank. (2016). Rural population (% of total population). Retrieved on April 17th 2017 from http://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=ET

Tilt, B., Y. Braun, and D. He. (2009). Social impacts of large dam projects: A comparison of international case studies and implications for best practice. *Journal of environmental management*, *90*, S249-S257.

Trenberth K.E. (1998) Atmospheric moisture residence times and cycling: Implications for Rainfall rates and climate change. *Climatic Change*. 39, 667–694.

Trenberth, K. E. (2005). The impact of climate change and variability on heavy precipitation, floods, and droughts. *Encyclopedia of hydrological sciences*.

United Nations Environment Programme (UNEP). (2006). Africa environment outlook 2: Our environment, our wealth. ISBN: 92 807 2691 9

United Nations.(2006).Gender, Water and Sanitation. Case studies on Best Practices. http://www.un.org/esa/sustdev/sdissues/water/casestudies_bestpractices.pdf

UN Water. (2013). Water and Gender. http://www.unwater.org/fileadmin/user_upload/unwater_new/docs/water_and_gender.pdf

UN Africa Renewal. (2014). Financing Africa's Massive Projects.

http://www.un.org/africarenewal/magazine/december-2014/financing-africa%E2%80%99s-massive-projects

UNEP. (2009). Rainwater Harvesting: A lifeline for human well-being http://www.unwater.org/downloads/Rainwater_Harvesting_090310b.pdf

UNICEF. (2017). Water, Sanitation and Hygiene. https://www.unicef.org/wash/

Velpuri, N. M. and Senay, G.B. (2012). Corrigendum to "Assessing the potential hydrological impact of the Gibe III Dam on Lake Turkana water level using multi-source satellite data" published in Hydrol. Earth Syst. Sci., 16, 3561-3578, 2012. Hydrology and earth system sciences, 16(10), 3645.

Verhoeven, H. (2013). The politics of African energy development: Ethiopia's hydro-agricultural state-building strategy and clashing paradigms of water security. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, *371*(2002), 20120411.

Virginia Tech. (2014). The grand Ethiopian renaissance dam: Sustainable development of not? Retrieved on April 17th 2017 from https://scholar.vt.edu/access/content/group/5b95dc6f-a3ef-4ce5-8e1a-875819148663/Web/Student%20Publications/ASwanson.GERD_final.pdf

Washington State University. (2012). New global warming culprit: Methane emissions jump dramatically during dam drawdowns. *ScienceDaily*. Retrieved April 17, 2017 from www.sciencedaily.com/releases/2012/08/120808081420.htm

Watts, R. J., Richter, B. D., Opperman, J. J., & Bowmer, K. H. (2011). Dam reoperation in an era of climate change. *Marine and Freshwater Research*, *62*(3), 321-327.

Williams, P., Martina, A., Cumming, R. and Hall, J. (2009). Malaria Prevention in Sub-Saharan Africa: A Field Study in Rural Uganda. Journal of Community Health, 34(4), 288-294.

World Bank Group. (2015). Ethiopia poverty assessment 2014. Washington, DC. © World Bank. Retrieved on April 17th 2017 from https://openknowledge.worldbank.org/handle/10986/21323 License: CC BY 3.0 IGO

World Commission on Dams. (2000). *Dams and Development: A New Framework for Decision-making: the Report of the World Commission on Dams*. Earthscan. Retrieved on March 31st 2017 from https://www.internationalrivers.org/sites/default/files/attached-files/world_commission_on_dams_final_report.pdf

World Health Organization (WHO). (2014). A global brief on vector-borne diseases. Geneva, Switzerland: World Health Organization. Retrieved on March 31st 2017 from http://apps.who.int/iris/bitstream/10665/111008/1/WHO_DCO_WHD_2014.1_eng.pdf

World Health Organization (WHO). (2014). Fact Sheet Vector-Borne Diseases.Retrieved from: http://www.who.int/kobe_centre/mediacentre/vbdfactsheet.pdf

World Water Assessment Programme (WWAP). (2012). The United Nations World water development report 4: Managing water under uncertainty and risk. Paris, UNESCO. Retrieved on March 31st 2017 from http://unesdoc.unesco.org/images/0021/002171/217175e.pdf

World Wildlife Fund (WWF). (2013). Seven sins of dam building. Germany. Retrieved from http://awsassets.panda.org/downloads/wwf_seven_sins_of_dam_building.pdf

Wu, X., Y, Lu, S. Zhou, L. Chen, and B. Xu. (2016). Impact of climate change on human Infectious diseases: Empirical evidence and human adaptation. *Environment international*. *86*:14-23.

Yewhalaw, D, et al. (2009). Malaria and water resource development: the case of Gilgel-Gibe hydroelectric dam in Ethiopia. *Malaria journal* 8.1: 21.

Yewhalaw, D, et al. (2013). The effect of dams and seasons on malaria incidence and anopheles abundance in Ethiopia. *BMC infectious diseases* 13.1: 161.

Yewhalaw, D., et al. (2014). Blood meal sources and sporozoite rates of Anophelines in Gilgel-Gibe dam area, Southwestern Ethiopia. *African Journal of Vector Biology*.