Groundwater Use in Climate Change Adaptation in Moshi District, Tanzania

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Abstract

The paper assesses the usability of groundwater in climate change adaptation in Moshi rural district, Tanzania. It examines how groundwater is used as a climate change adaptation strategy as well as the strategy for boosting other adaptation strategies. Data for the study were gathered from five major sources; these include field observation, interviews, household questionnaires and focus group discussions (FGDs). It also reviewed various literature including weather-recorded data. The study found that groundwater is unsurpassed climate change adaptation in the area and it enhances other adaptation mechanisms like planting trees and irrigation. The use of groundwater has thrived to diminish water shortage in the area as a result it helps to increase water for domestic and sanitation usage. It also boosted water use range per person per day and decreased the distances walked by persons in obtaining domestic water. Despite these advantages, groundwater is neglected and less preferred in government planning, a snag that leads to poor groundwater usage and conservation. This paper concludes that, groundwater is among the best climate change options in Moshi rural district as it helped to cover water shortage between rainfall seasons in the area since the area was semi-arid. It provided daily water supply in the area for both agriculture and domestic use hence supporting people's livelihood. Therefore, this paper recommends more research on contributions made by groundwater in climate change adaptation in semi arid regions in Tanzania. This will generate knowledge that can be used by planners in climate change adaptation since groundwater can help to evacuate people's livelihood from climate change vulnerability.

Introduction

Water is necessary for the existence of life on the planet as no any living organism can survive without water (Karanth, 2004: Mwakalila, 2011). Despite the importance of water in human life, climate change has led to decline of both surface and groundwater availability. Therefore, climate change adaptation has become the matter of urgent priority in order to increase life sustenance by reducing the impacts brought by climate change. It is however clear that, adapting to climate change needs many strategies since its impacts cut across all spheres of human life. The use of water in climate change adaptation is necessary since water is central to human life and ecosystem in general. Despite the necessity of water resources in adapting climate change, many parts of the world are experiencing the decline of surface water resources due to increased demand as population grow, economic activities increases and climate change (Kulindwa, 2000).

The decline of surface water makes groundwater becoming more important resource in salvaging the situation. This is so because the freshwater in which terrestrial based living organisms depend is more than 90% and is found underground. Less than 10% only is found on the surfaceof the earth (World Bank, 2005; UNEP, 2008). Therefore, the large proportion of freshwater resources is found underground than on the surface. Furthermore groundwater is less affected by climate change as it has its natural buffer against climate change impacts hence able to support life on the planet than surface water. Moreover, the stock of surface freshwater for supporting terrestrial based is unevenly distributed but groundwater is available almost everywhere on the earth (Karanth, 2004).Given this situation, global climate change adaptation options should be geared toward sustainable groundwater use and management as a way of increasing water availability. This is due to the fact that groundwater use serves not only as a climate

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change adaptation strategies but also as a tool for supporting other adaptation options like afforestation and reforestation programmes.

Yet more the World Bank (2006) reported that its support for groundwater schemes for climate change adaptation had been approximately to be US dollars 50 million over about five years. This is due to incapacity of African government to support its own population against climate change impacts. It also shows that climate change adaptation is a challenge in many African governments especially in sub-Saharan Africa. They have adaptation strategies such as new seeds, Genetically Modified Seeds (GMO) afforestation programmes which are expensive and normally fail due to the natural aridity of many places. This necessitate adoption of groundwater use which is cheap strategy among others as it provides domestic water supplies for industrial use, irrigation and animals in both rural and urban areas and hence boost peoples livelihood and sustainability.

Therefore, this paper focuses on groundwater use as a naturally available climate change adaptation option among others which not only stand by its own but also able to support other climate change adaptation strategies. It discusses groundwater usability in climate change adaptation in the efforts to alleviate poverty, enhancing food security and water availability for domestic use and economic activities in a sustainable development framework.

The Study Area and Methodology

This study was conducted in Moshi rural district, Tanzania which lies between 3^{o} 33' 93'' South and 37^{o} 34' 39''East and it covers an area of 3,054.3 kilometre squares on the southern slopes of Mount Kilimanjaro. The district comprises of three inhabited belts and the study was conducted in the lower belt which is less populated with multi-ethnic when compared to the upper zone which is highly populated by single ethnic group the Chagga. The general climate of the area is semi arid (Sadiki, 2009; Lukio, 2012). The area is lowland and most significant feature is Mount Kilimanjaro to the north. The main vegetation is acacia, baobab trees and other includes bushes, thickets and shrubs. The main economic activities in the area include agriculture, animal husbandry and pastoralism.

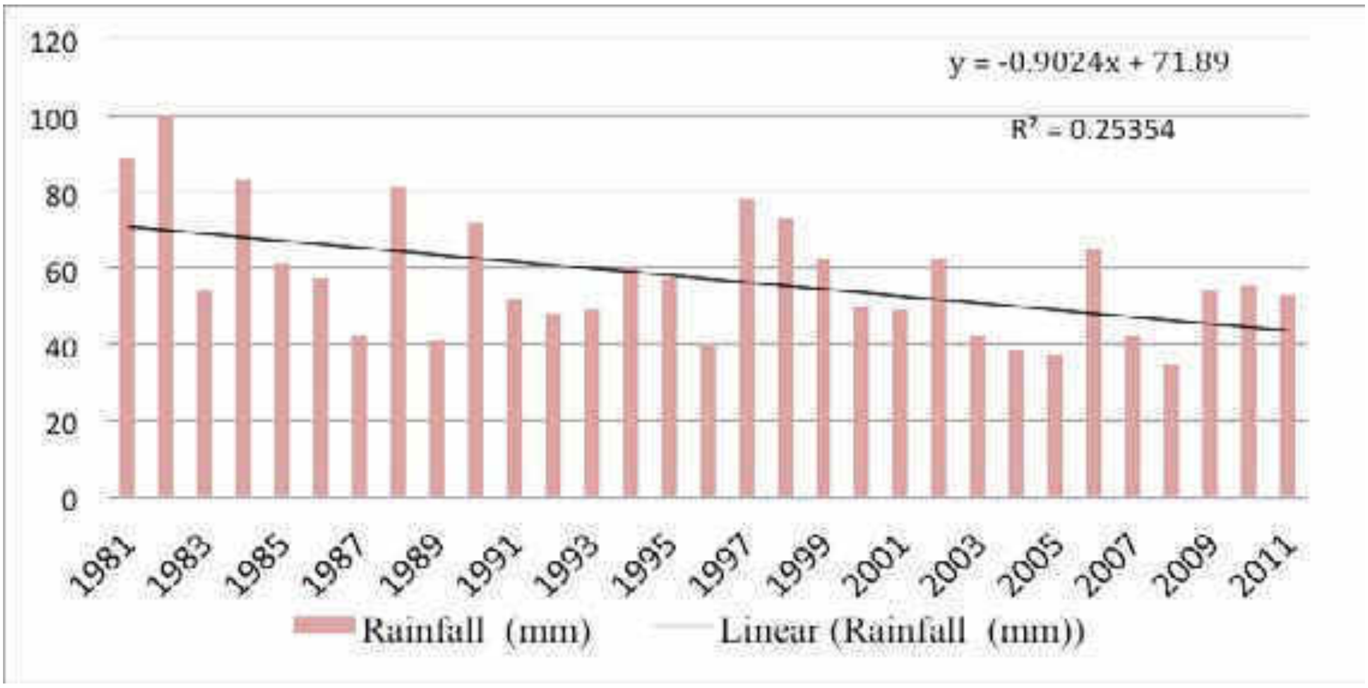
Three villages were involved in this study which included Ghona, Uchira and Oria villages. These villages were selected from different wards to get enough chance for a comparative study on the use of groundwater in climate change adaptation. Also these villages were selected purposely because they are arid and hence depended on groundwater. The presence of groundwater schemes and multiethnic nature of inhabitants performing different economic activities together enabled to gather enough reliable data.

Data were collected by using five methods which included field observation, interview with key informants and Focus Group Discussions (FGDs) with elders and leaders. Also household questionnaires were administered in the three villages whereby 99 households were randomly selected and visited. In attaining the objectives the study discussed and made direct observation to cross-check information given and reviewed in various literature and from various sources. Data collected were compiled and analysed by using the SPSS program to generate various statistics such as percentages, averages and listings. Also Microsoft excel was used in making figures, tables and charts for presentation.

Manifestations of Climate Change in Moshi Rural District

There are many ways in which climate change can be manifested in a given locality. However, this paper discusses climate change signs based on two major climatic facets such as rainfall and temperature variability and change.By observing rainfall and temperature trends in the area it is clearly seen that, climate of Moshi rural district has changed. There ischange inrainfall regime in the area and the community is aware of these changes. Climate change has also led to fluctuation of rainfall and variability in terms of time and amount per year. It has led also to the shift in rainfall patterns whereby nowadays rainfall season delay and it is becoming more unpredictable than before.

Figure 1: Annual Mean Rainfall Time Series from 1981 to 2011 as recorded by TMA at Moshi Weather Station

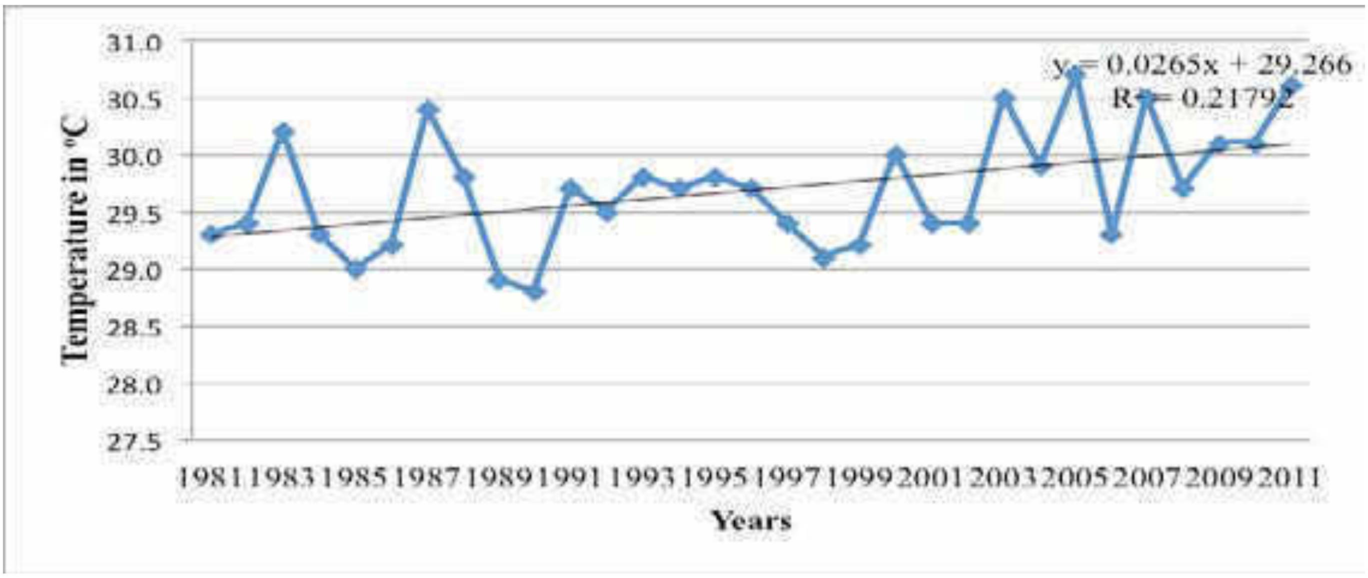


Source: TMA, (2012)

Therefore, general trend of rainfall in Moshi rural district show that, the amount of rainfall is decreasing except in times of extreme events such as *El Nino* in 1997/1998. According to the TMA data the decrease in rainfall amount is statistically insignificant at $R^2 = 0.2535$. Despite the fact that this decrease is statistically insignificant it has large effects to people's livelihood.

About 88 out of 99 (89%) of the households reported that there was an increase in temperature in the area especially from the mid-1990s to present. According to UNEP (2009) climate change has not only decrease the amount of rainfall and surface water resources but also increases temperature in which it is declared the decade of 1998-2007 the warmest on records. Also Statistical records from TMA show general increase in temperature in the area thus, corresponding to the reports from farmers in Moshi rural district.

Figure 2: Annual Mean Maximum Temperature from 1981 to 2011 at Moshi Weather Station



Source: TMA, 2012

The observed climate change influence on rainfall and temperature intensity has brought many effects to the sustainable development of the community. These include floods and droughts which lead to crop failure and health problems. These climate change events have led to various impacts in the study area, simply because they disturb ecosystems and general well being of the people.

The area is highly affected by drought and famine. It should also be noted that a large part of the area is semi arid; therefore, periods of drought are those periods where there were extreme droughts that led to completely loss of crop production hence hunger and famine in the area. Also drought trends in Moshi rural area show that from 1980 drought occurred at a 10 years interval, for example in 1985, 1995 and 2005. But from 2005 to date there is re-occurrence of drought, for instance 2005, 2008, 2009, 2011 and 2012. Therefore, this trend attest that the area is moving towards more dry days in the future something which will affect people's livelihood and environmental sustainability at large.

Ramifications of Climate Change on Water Resources and Peoples Livelihood

Environment for Development (EfD), (2012) and Mwakalila et al., (2011) observed that climate change has led to shortage of water due to increased evapo-transpiration and evaporation of surface flow in rivers and drying of wetlands. Also World Bank, (2006) and United Nations, (2009) pointed out that there will be increasing water stress to over a hundred million people due to the decrease of freshwater availability and increased water stress. In this study 89 (89.9%) out of 99 households reported great decline of water resources in rivers, water channels and springs (surface water) which is accompanied by drying up of the river valley throughout the year.

The climate change effects on water resources have many results to people's existence in the area. It has brought many socio-economic sufferings in all sectors which put both marine and terrestrial based organisms in danger hence retarding sustainable development.The agricultural sector is among the sectors that form the basic human needs for survival. However, agricultural production is severely compromised due to unreliable rainfall and dryness of water for irrigation (Orindi and Murray, 2005; Kangalawe *et al.*, 2011).In this study 86(86.9%) out of 99 households in the area have reported the incidence of total crop failure in some seasons due to drought. The health and sanitation sector is affected as there is alteration of spatial and temporal transmission of disease vectors (Boko *et al.*, 2007). Also in this study, 27(27.7%) out of 99 households reported pollution of water due to floods from highlands thus, polluting water sources like open boreholes and springs. This has become the sources of cholera and increased typhoid in the area. Climate change has not left domestic sector unwavering, according to United Nations (2009) climate change has led in many places the lack of surface water resources which lead in rural areas not only decreases in water use range per day but also long walks in obtaining water for domestic use. However, in this study this case was reported by only 10 (10.1%) out of 99 households which have no access to groundwater sources.

It is therefore clear that, climate change has and will continue to have many far reaching effects on human socio-economic wellbeing(Perez, 2009 as cited in Hepworth, 2010). The economic costs of climate change for Tanzania have been estimated at between 1.5 to 2% of GDP by 2030, a total of US dollars 270 million each year. Major new studies are ongoing to refine these figures (IIED, UNEP, 2010).

The impacts are likely to be significant for the future development of Tanzania and economic valuations of climate change impacts can be useful in setting the political priority afforded to adaptation planning (Mwakalila, 2011). Since adaptation to climate change is costly and this cost cannot be escaped rather minimize, there is a need to find appropriate adaptation strategy which will help to reduce these costs.

Groundwater distribution, quality and quantity in the study area

Groundwater influences environmental ecosystems and survival of human beings on the earth's surface thus forms the basic unit of life (Karanth, 2004). However, to save its purpose groundwater should qualify some two fundamentals, the quality and the quantity components. This is basically because; water quality determines its usability and quantity determines life extent of its use (Karanth, 2004; Shah, 2007). In this study the quantification of groundwater was done by compiling existing boreholes log data and the field survey made by the study. The study found that the water table is close to the surface whereby it is possible to construct shallow wells up to 5 metres deep and yields a large amount of water throughout the year and this differed from place to place. The study area is rich in groundwater resources and it is the chief source of water in the surveyed villages

This study went further to assess quality of groundwater resources in the area because quality of groundwater water affects its usability. According to Shah (2007) and Karanth (2004) the quality of groundwater is as much as the usability of it. In assessing the quality of groundwater in the area this study paid attention in physical chemical and biological/bacteriological parameters. These parameters affects groundwater use since groundwater can be available but of poor quality hence not usable, as a result, it offers no valuable contribution to people's livelihood in their daily struggle to adapt climate change. Therefore, groundwater uses do not only depend on its availability but also is determined by its chemical, physical and bacteriological properties.

Physically, it was found that, groundwater in the area is relatively clean, colorless, and odourless with little or no suspended matter and relatively constant temperature. Also found that groundwater is safe free from suspended impurities and pollution and have constant temperature and it is superior to surface water supplies in the area. This concurs with Karanth (2004) assertion that, unless the water supply points are located close to impurities, the physical quality of groundwater remains good. It is clean and odourless hence can be put in to different uses such as irrigation, drinking, sanitation as well as for livestock. Thus, this makes groundwater in the area to be the primary source of water for domestic and sanitation.

Biologically, the laboratory test from Pangani Basin Water Office shows that, groundwater in the area is free from bacteriological parameters such as faecal and total coliforms, bacteria, viruses and protozoa and other diseases causing organisms. Also 92%of the households reported that, groundwater there were just few cases of8% of the households reported on diseases caused by the use of groundwater but this was especially due to use of water from shallow open boreholes during floods where water become contaminated by polluted water from highlands areas

In those covered boreholes local community reported that water was good biologically and free from pathogenic organisms since they face no disease due to its usage. This was possibly right because the areas lack industries, compacted settlements as well as poor sewerage systems which are mostly the agents for pollution of groundwater in many places. These results correspond to the contention by Arturo and Mira (2010) that groundwater in areas which are highly industrialized are also highly polluted than the area with less industrial development. Therefore, this study found that, groundwater in the area is free from these pathogenic micro-organisms as a result it is recommended for various uses both for human beings and ecosystem (Table 1).

Chemically, this study discovered that groundwater in the area is free from excessive chemical compositions. However, the chemical quality of groundwater in the area differed from one place to another in the area according to the environment and geological composition. Some properties like pH, temperature, chemical and bacteriological were recorded from existing data in the field. These properties were measured and cross checked against the standards of the World Health Organization (WHO) of 1971and Tanzania's Standards of 1983 for water quality (Table 1).

Table 1: Results of Laboratory Water Quality Test against WHO and Tanzania Standards

S/N	Chemical Parameters	Units	Results	WHO Standard	TZ Standards	Remarks
	pH		7.3	6.5-8.5	6.5-9.20	Acceptable
	Turbidity	NTU	0.0	5.00	5.00	Acceptable
	Alkalinity ($CaCo_3$	Mg/l	100.00	nm	nm	Acceptable
	Total Diss. Solids	Mg/l	104.8	1000	nm	Acceptable
	Hardness ($CaCo_3$)	Mg/l	53.00	400.00	600.00	Acceptable
	Electrical cond.	us/cm	-	219.00	nm	Acceptable
	Fluoride (F^-)	Mg/l	0.85	1.50	4.00	Acceptable
	Sulphate (SO_4^{2-})	Mg/l	0.00	250.00	450.00	Acceptable
	Iron (Fe^{2+})	Mg/l	0.02	0.03	1.00	Acceptable
	Manganese (Mn^{2+})	Mg/l	0.00	0.10	0.50	Acceptable
	Nitrate (NO_3^-)	Mg/l	5.63	50.00	75.00	Acceptable
	Nitrite (NO_2^-)	Mg/l	0.06	3.00	nm	Acceptable
	Calcium (Ca^{2+})	Mg/l	11.20	200.00	200.00	Acceptable
	Magnesium (Mg^{2+}	Mg/l	6.07	150.00	150.00	Acceptable
	Chloride (Cl^-)	Mg/l	1.42	250.00	800.00	Acceptable
	Bacteriological					
	Faecal Coliform	Count/100ml	0.00	0.00	0.00	Acceptable
	Total Coliform	Count/100ml	0.00	0.00	0.00	Acceptable

nm = not mentioned

Sources; PBWO, 2012; MUWSA, 2012

In this case, the groundwater in the study area meet the World Health Organization (WHO) and Tanzania's standards for water quality, physical, biological and chemical. Groundwater in the area has low TDS, turbidity, total hardness, colourless and odourless as well as balanced chemical properties hence suitable for both human consumption and other uses which help in adapting the impacts of climate change and hence improving people's livelihood.

Climate Change Adaptation and Groundwater Use in Moshi District

Climate change adaptation is very important to sustain human since climate change impacts create a big burden to people's livelihoods. It forces people to adjust their live in a given ways that suit their environmental and climatic pressures in the area. Therefore, people have adopted different adaptation strategies in the area to adapt climate change and related events such as water shortages, prolonged drought, food shortage and income, floods and increased pests/parasites and diseases. These adaptation strategies vary according to sector. In curbing shortage of domestic water in Moshi rural district, the community adapted through, constructing large deep boreholes, harvesting rainwater, buying water from vendors and others decided to walk long distances for fetching water

In adapting to food and income shortage, about 37 (37.7%) out of 99 households use new improved seeds which are drought resistant and high yield crops. Although large percent of the households grow drought resistant crops, they have blamed the district officer for delay of these seeds and only few people succeed to get them due to political issues. This hinders their efforts in adapting climate change through this method. This study also found that 33 (33.3%) out of 99 households have responded to drought and shortage of water conditions in the area by drilling their own boreholes. This study discovered that, irrigation through boreholes was the major adaptation mechanism to cope with shortage of water for irrigation. However this was done by those households who were economically able or supported by charitable organizations. Since prolonged drought has led to food shortage, soil conservation and agricultural techniques were also used by 9 (9.9%) out of 99households. They mostly apply mulch materials to conserve soil moistures in the area. However, 12 (12.2%) out of 99 households did nothing to adapt to drought impacts and they are mostly poor and affected. The most and far most option used by many farmers is irrigation through the use of boreholes groundwater.

Also economic diversification is another climate change adaptation option used by 21 (21.1%) out of 99 households in the studied villages. These householders engaged in various activities to increase their livelihood since the livestock and crop cultivation were not enough. The field survey disclosed that 4 (4.4 %) out of 99 householders were selling their labour in other peoples' farms to earn their family income for buying food or in exchange for food.

Boko et al., (2007) and Hepworth, (2010) observed that groundwater is an effective adaptation strategy for climate change as it increases domestic water supply in both urban and rural areas, as would be shifting from shallow wells to deeper boreholes. The report on the assessment of groundwater availability and its potential use by Kashaigili (2010) portrays the potential use of groundwater in Climate Change Adaptation. The groundwater use offer potential contribution in this changing climate (Kashaigili, 2011; Mato, 2002). Groundwater is the preferred for domestic water supply in rural areas and many other urban areas exploit groundwater to supplement supply from surface water sources (Noel, 2010; World Bank, 2010). This is because it is easy and cheap to develop as compared to surface water and it can be developed where it is required. Furthermore, it is associated with low operation and maintenance costs and not much affected by drought and climate change unlike surface water resources. World Bank(2010) noted that groundwater, from water wells (boreholes and hand-dug wells), now supplies one-fourth of urban dwellers and is the fastest-growing source of improved water supply in African cities by far. With utility coverage rates falling in urban Africa, groundwater has essentially stepped into the breach, and the rapid growth of boreholes shows the appetite for lower cost solutions.

These adaptation options enabled the community to survive the impacts of climate change in the area. These options include planting trees, protection of water catchment to reduce aridity, diversifying the economies and improving soil nutrients. Other options include selling labour, mixed farming, harvesting rain water and using modern agricultural inputs like drought resistant crops, early maturing and high yield crops. .However, it was not possible for these adaptation options to be feasible without groundwater in the area. This is particularly because of the arid nature and the decline of surface water resources in the study area, groundwater has become the solution to salvage people's livelihood in the area and many other arid and semi arid regions (Kashaigili, 2011; World Bank, 2010).

However, groundwater being the main source of water in the area, communities has constructed their own boreholes; this was confirmed by 32 (32.2%)out of 99 households. These boreholes were either for individual farmers or under a given irrigation scheme in the area. In shortage of water for domestic use, 14 (14.4%) out of 99 households survived by buying water from vendors, 2 (2.2%)out of 99 households adapt by harvesting rain water and 4 (4.4%) out of 99 households did nothing rather than walking long distance to get water sources. 47 (47.7%) out of 99 households used water from groundwater projects as the effort made by the government to increase supply of domestic water in rural area which faces acute water shortage.

Efficiency of Groundwater in CC Adaptation in the Area

Morris *et al*., (2003) affirmed that, groundwater is a key source for drinking water supply for two billions of people, or approximately one third of the global population in today's changing climate. Also Villholth and Sharma (2006) added that, groundwater provides irrigation livelihoods to billions of people around the globe, and to more than one billion poor farmers in rural area. Therefore, groundwater use is thus key to ensuring that agricultural production and peoples livelihoods withstand the stresses caused by climate in the area. As observed in the study area, there were different groundwater uses such as irrigation, livestock, domestic supply and ecosystems. Therefore, this study reveals that people's livelihoods in the study area largely depend on groundwater.

In domestic water supply; households need water supply for domestic uses and sanitation. Boko et al. (2007) and Christensen et al. (2007) stated that climate change will lead to acute water shortage of domestic and sanitation water in Africa. There will be increasing water stress whereby 75 to 220 million people will face more severe water shortages by 2020. Water use ranges of people in rural and semi arid area will consecutively drop from 30 litres per capita per day in areas of average supply to less than 5 litres per capita per day in acutely water scarce areas.

However, it was found that, 79 (79.8%) out of 99 households which were surveyed depend on groundwater for their daily domestic and sanitation use. They obtained groundwater from springs and boreholes/ wells which were found in the area. Therefore, this study found out that despite the decreased in surface water sources, the area obtain its reliable domestic water supply for cooking, drinking and sanitation from groundwater resources. In the studied villages groundwater water supply meet the government basic level of service for domestic water supply in rural areas which is protected, year-round supply of 25 litres of potable water per capita per day through water points located within 400 meters from the furthest homestead and serving 250 persons per outlet (URT, 2002; Hepworth, 2010).

Table 2: Contribution of Groundwater Use in Domestic Water in the Area

Scenarios	Supply Before the Groundwater Project	Supply After the Groundwater Project
Distance	0.5-1 Km	0-0.25 Km
Quality	Not assured	Assured
No. of Person Per Outlet	800-1000	50 -100
Water use Range person/day	10 to 20 litres	40 to 50 litres

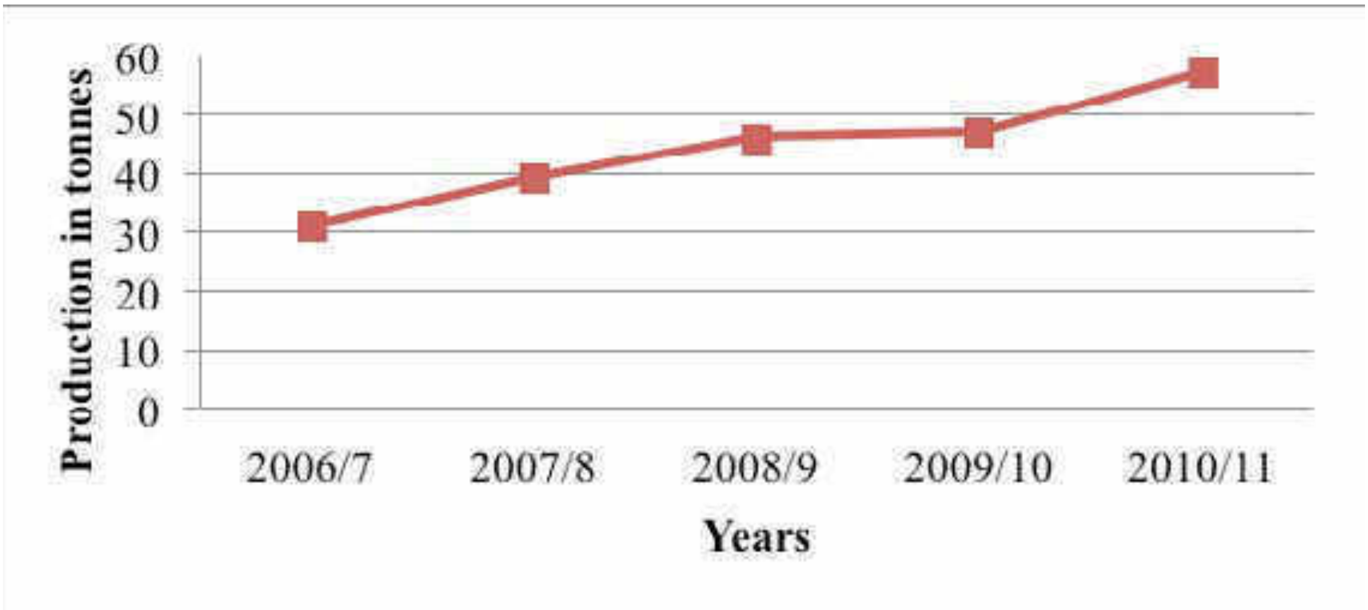
Source: Field Survey, (2012)

It is therefore clear that groundwater is the efficient source of domestic water supply in the area which has advocated people from shortage of domestic water due to climate change. Thus, groundwater use is the main strategy toward decreasing domestic water shortage by many families in the study area. Also it display that, groundwater helps to reduce distance walked by people in fetching water for domestic use from one kilometre to a quarter and zero kilometre in the study area. But also increases the water use range per person per day. People accessed water at low cost of 25 TShs per 20litres bucket. Therefore, groundwater use has succeeded to reduce the climate change impacts in domestic water supply in the area by increasing water supply, reducing distance walked in obtaining domestic water as well as water safety (Table 2)

In agricultural production;this study depict that groundwater is also used in agricultural activities and it is among sources of water for irrigation. The area has three major sources of water for agriculture which include rainfall, rivers and groundwater. According to Villholth and Sharma (2006) groundwater irrigation provide livelihoods to billions of people around the globe, and to more than one billion poor farmers in rural areas of Africa South of Sahara and Asia alone. In addition, according to IGRAC (2006) about 60 percent of withdrawn groundwater is used to support agriculture in arid and semi-arid climate. This study revealed that, there is increased use of groundwater in agricultural production in the area due to decrease in surface water caused by climate change. Therefore, some farmers use groundwater to curb water shortage caused by climate change in the area. There is no enough runoff and river flow for irrigation through river water and direct rainfall and above all the area receives little amount of rainfall (less than 500mm) per year. Therefore, this makes groundwater be the major efficient and effective source of water for agricultural production and major adaptation strategy in the area.

According to Pangani Basin Water Office (2012) and Moshi District Agricultural Officer, irrigation by using groundwater has raised agricultural production in the area especially of vegetables production. This can be evidenced from various groundwater irrigation projects in the area. There is doubling of production of vegetables in the area due to the use of groundwater from 2006 to 2011 since it is possible for farmers to grow and harvest two or three seasons per year. Compiled data of vegetable production from Moshi district show that, those farmers who use groundwater doubles their production each year when compared to those who depend on rainfall only. This is observed not only in vegetables but in all seasonal crops like maize where those who depend on rainfall and river flow most of their crops dries before maturity due to shortage of water.

Figure 3:Vegetables Production by Groundwater Schemes in Moshi district 2006-2011



Source: Moshi Agricultural Office, (2012)

In livestock production; livestock has potential contribution in the food supply, family nutrition, incomes, employment, soil fertility and livelihoods. Therefore livestock keeping helps in reducing impacts of climate change as it helps in food security and economic diversification. This study found that, groundwater is also used in livestock production since livestock keeping is among the economic activities practiced in the area. Major livestock kept includes cattle, sheep, donkeys, goats and poultry. Groundwater is used for livestock drinking, washing and production of livestock fodders. Hence, there is increase in livestock production in the area, according to Moshi district livestock statistics (2012) in the year 2005 the study villages had 5021 livestock (cattle, goats and sheep) in 2011 was 11413. Also groundwater use has increased animal fodder and zero grazing that helps to conserve the environment.

Therefore, this study discovered that, groundwater use has been played a great role in raising livestock production in the area. It provides fresh drinking water for livestock whereby despite the aridity in the area there is no death of livestock due to shortage of water. Not only that it provides fresh drinking water but also is used in production of fodder for livestock. Generally, the rise of agricultural production by those farmers who irrigates by using groundwater assures fodder to livestock by supplying crop remains hence reducing impacts of climate change.

Conclusion and Recommendations

Water is the basic unit of life on the planet earth (Karanth, 2004; Mwakalila *et al*., 2011). In Tanzania, groundwater is an important water source supplying more than 25 % of the domestic water consumption (JICA, 2002; Hepworth, 2010; Kashaigili, 2010). In addition, groundwater is a viable source of irrigation for many areas in the country. In other places which have persistent water shortages it is a better and secure alternative to surface water. It is estimated that at about 88% of groundwater extracted from the Pangani river basin is used for irrigation, 4% for industrial use and 8% for domestic use (Mato, 2002; Kongola, 2008). Moreover, the tapping of groundwater is regarded as simple task by pastoralists than moving elsewhere with the livestock for a surface source. In this fact, groundwater has always been considered a secondary priority to pastoralist and livestock keeping. Groundwater resources in Moshi district is used not only to bridge the rainfall seasons but in most cases as the only source of water in the studied villages due to their arid nature. In this case, it has succeeded to boost domestic water supply, agricultural and livestock production in the area hence salvaging people's livelihood and sustainable development. There is no doubt that, groundwater in Tanzania is a key resource to improve the water supply coverage for many activities, adapting climate change as an option but also as supporter of other climate change adaptation strategies in vulnerable areas especially arid and semi arid regions.

Despite its valuable contributions in climate change adaptation and sustainable development in arid and semi arid regions, groundwater is neglected in planning and there is little knowledge and emphasis on its use in Tanzania. Water Sector Development Strategy (WSDS) plan reveals absence of robust prioritization of groundwater use in mainstreaming and increasing water supply instead it stresses on recycling waste water that is not cost-effective especially to less developed country. Without increasing water supply to the urban and rural areas by exploiting groundwater the vulnerability to climate variability and change through water based impacts will persist, particular within poor communities, and that inequitable resource access will continue. Therefore, there is a great need to boost groundwater use in addressing water related impacts from climate change. This will increase community resilience and hence sustainable development will be realized in many parts of the country.

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