Impact of Climate Change on Groundwater in Dhamar Basin (Yemen)

Hefdhallah Al-Aizari[1]*, Abdelaziz Achaouch[1], Mohamed Fadli[2], Mohammed Al-Mashreki[3]
[1]Laboratory of Biotechnology, Environment and Quality - UFR of process Engineering, Faculty of Sciences, Ibn Tofail University, BP 133, Kenitra, 14000, Morocco
[2]Laboratory of health Nutrition and Environment, Faculty of Science, Ibn Tofail University, BP. 133, Morocco
[3]Renewable Natural Resources Research Center (RNRRC), Dhamar, Republic of Yemen
***Corresponding author: E-Mail: alaizari2@gmail.com**

ABSTRACT

The change of climate is the most important for environmental issues that require study and evaluation because of its significant impact in several sectors such as water, agriculture and others. The aim of this paper is to study climate change and its impact on the water resources in Dhamar basin, by studying the climatic data observed in the governorate during 18 years (1999 – 2016). The results showed an increase of temperature in recent years in the summer and decrease its in the winter as well as decrease the amount of rain falling with Its delay and increased frequency of the dry cycle in addition to increased loss of evaporation. After calculating the potential evapotranspiration (PE) values by thornthwait method then derive values of water deficit (WD), where it found a water deficit throughout the year. According to the climatic data analysis of the basin Dhamar show that semi-arid area study.

KEY WORDS: Dhamar Basin, Climate date, Thornthwait Method.

1. INTRODUCTION

The subject of climate change, of the most important environmental issues that require study and evaluation because of its significant impact in several sectors such as water, agriculture and others, climate changes can cause the intensity of seizures drought, increased risk of flooding, increased salinity of the soil, declining groundwater levels and others. It has the impact of climate change on water resources in particular is of great interest to many international organizations and scientific and research institutions in many countries of the world for their great impact on the food security of citizens. The climate of the globe changes from century to century and sometimes from year to year. This change may be caused by several causes beyond the terrestrial system, such as the change of solar radiation or as a result of the spread of ash after volcanic eruptions or for reasons within the terrestrial system as a result of human activities, such as the release of some greenhouse gases, as these concentrations have increased in comparison to pre-industrial (World Bank, 2006). The climate change is closely linked to the issue of food security. Climate changes are affected by greenhouse derivatives, whether they are population, economic, political, and technological or cultural. Leading to climatic changes, the main features of which are increasing CO_2 emissions, increasing temperatures, whether large or small and increasing climatic changes and weather events. All these changes in climate are performed has led to a change in the assets of the diet, which is one of the most important indicators of change in food production assets and change in storage, transport, marketing and livestock assets (FAO, 2008). According to reports from the Intergovernmental Panel on Climate Change (Adam, 2007) indicate that the climate change of the planet and its associated acceleration and change in temperature rise, the average rose by 0.76^0C during the twentieth century, as sea level rose to 17 cm during the same period, and that a temperature rise of 2^0C constitutes a critical phase, on-temperature the land continues to rise on a regular basis and the last 15 years since the year 1985 until 2010 the hottest since 1850. The challenges of water resources development in Yemen in general and in the study area in particular will be exacerbated by the sequel of climate change, with severe consequences for socio-economic growth. Therefore, (Bates, 2008) states that these challenges include population pressure and problems associated with soil erosion, sediment deposition and the potential environmental consequences of land-use change on the hydrological cycle. This climate change, especially changes in climate variability such as drought and floods, will make these problems more complex. However, the major impact will continue to include poor people with limited access to water resources. Current droughts also go into critical water-deficit periods for sectors urban water supply and supply (Mutasa, 2010). The importance of the study is that climate change is a reality imposed as a global phenomenon happening in the world, and this phenomenon is affected Yemen, like other countries of the world and this effect is evident in agriculture, natural resources in general and water resources in particular. Hence, the importance of conserving water resources and the need to rationalize their use and good management in order to sustain them must be sufficiently studied, researched, evaluated and strategically planned. The Dhamar Basin is one of the largest water basins in the Yemeni governorates. The best of these is the depletion of water wells due to the excessive pumping of the numerous artesian wells scattered throughout the area to irrigate various agricultural crops during the winter and summer seasons.

The aim of this study is to determine the impact of climate change on the water basin of Dhamar Governorate, being one of the most important water basins in Yemen.

Study area: Dhamar Basin is located between latitude 1580000, 1660000N, and longitude 420000, 500000E with an area of approximately 5000 km^2, and it is also of varies surface with varying degrees of elevation from sea level 2573 m to the south of Maram east of the basin and 2570 m to the west of the basin to the north-west of the basin as the highest value of the rise 2252 m for the lower floor as the lowest value for the other bottoms. This variation in height between bottoms directly affects the relationship between rainfall and groundwater levels of secondary basins, bounded by one side, the north is the Sana'a basin, and the eastern part is the eastern part of Wadi Uthana and the south is Wadi Bani west and Dyan Siham, Rama and Zubaid. The study area of Dhamar basin is shown in figure.1 (William, 1985; Van Buitenlandse, 2007).

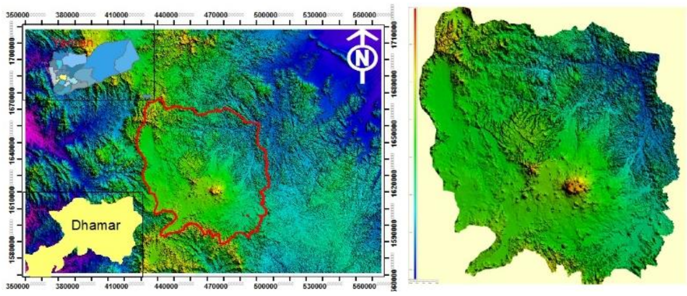

Figure.1. Location of Dhamar basin

Topographically, Dhamar plain occupies a high land area consisting of a series of broad plains and valleys bounded by larger complexes of hills and volcanic cones. Qa's in Dhamar basin are plain area surrounded by hills and valleys, due to higher altitude of Dhamar plain as a whole, the water level is relatively deep and as a result, wells generally have depth of 100 m or more.

Geology and Hydrogeology:

Geology: The geology of the study area is very complex. The major outcrops in the Dhamar basin are those of quaternary basaltic lavas and ignimbrite ash flows. There are also volcanic cones of basalt and rhyolite. The western and northern part of Dhamar basaltic plateau is marked with obscured normal fault. Towards north, the outcrop of Tawilah sandstones and Amran limestone are found. Rocks of Tawilah groups are best seen in the steep cliffs at Bani Amar, south west of Beynun. These rocks also occur in steep valley sides beneath a cap of Tertiary volcanic rock. The eastern and north-eastern parts of the Dhamar basin are dominated by Pre-Cambrian metamorphic rocks along with presence of post tectonic granite and diorites outcrops. The central part of Dhamar basin is dominated by Quaternary basaltic lava flows having prominent older volcanic features with radial obscured Thrust-Faults near Jabal-Isbil (Chiesa, 1985; Overstreet, 1985; Al-Kohlani, 2009; Minissale, 2013).

Table.1. The stratigraphy in the Dhamar baisn is as follows

Age	Group
Quaternary	Quaternary Deposits, Quaternary Basalts
Tertiary	Tertiary intrusive, Yemen Volcanics
Cretaceous	Tawilah Group
Jurassic	Amran Group
Pre-Cambrian	Precambrian Basement

Hydrological Characteristics: Can be described of geological formations and their natural characteristics and their relation to groundwater in Dhamar basin as follows:

Ground reservoirs in sediments and volcanoes of quaternary: These sediments are composed of gravel and sand with primary permeability and are located on solid rocks that help to prevent groundwater infiltration through them. In general, they are excellent underground water reservoirs.

Reservoirs underground in volcanoes tertiary: Contain layers medium to good groundwater aquifers in fractions and cracks, especially in the fractured volcanic basalt rocks of the Quaternary (Ground Water Resources, 1995), groundwater wells are abundant in ponds the quaternary sediments such as the bottom of Jahran and most of the Dhamar rocks of basalt rocks, which are characterized by their permeability and are carrying water.

Climatic Characteristics: According to a recent study (Bruggeman, 1997) Dhamar basin is located in agroclimatic zone 6A and 7A, which has two representative rainfall stations, viz. Dhamar at 2100 in and Risaba at 2300 in altitude. These zone 6A and 7A it is characterized by mild summers and cold winters. Where average rainfall during 1999-2016 is about 407.8mm /year, the mean annual rainfall over the surface water catchment of Dhamar depression is found to be 200- 400 mm and The monthly rainfall distribution shows that most of the rainfall amounts precipitate within five months of which most part occurs in March, April and May and the other higher amount occurs in July and August. Dhamar area is affected by moderate weather, while the average maximum annual temperature is during 1999-2016 about 24.4°C, as much as the surface water potential relay by direct mean on the rainy season, and while most of the rain water Evapotranspiration (about 90%) to the atmosphere, only 10% of the total rainfall infiltrate into groundwater recharge and forms the run-off portion, according to the Agricultural Research Center in Dhamar, 2016.

2. MATERIALS AND METHODS

We have Visited the Agriculture Office of Dhamar for the purpose of obtaining data on water levels available for some ponds with high control and succession and visit to the Office of the General Authority for Water Resources Dhamar, the Library of the University of Dhamar and the National Information Center Sana'a for the purpose of obtaining available studies on the Dhamar water basin climate data for the last 18 years (1999-2016) of all climatic elements. Using the program SPSS 22 and reversing the results of the different analysis in the form of tables and graphic formats and then scientifically interpreted to achieve the objectives of the study. Where the following equations were used in calculating the climatic water Budget:

- Potential Evapotranspiration (PEx) is calculated in many statistical ways, but the most common is Thornthoit method (Thornthwaite, 1948):

$$PEx = 16(10T/I)a$$

The potential evapotranspiration value can be extracted for all months of the year.

$$PE = PEx(D*T/360)$$

- The calculation of the total Evapotranspiration can be calculated by Ivanovich's relationship as follows (Ivanov, 1957):

$$ETO = 0.0018(T+25)^2 (100-Rh)$$

- Thornthoite coefficient for drought calculation can be calculated as follows (Thornthwaite, 1963);

$$D = 1.65 (r/ (t+12.2))^{10/9}$$

3. RESULTS AND DISCUSSION

Impact of climate elements: In order to determine the impact of any climate change, it was necessary to analyze the climate data for a number of years of available data so as to determine whether any changes have been made to elements. The climate in the study area and the extent of those changes, if any, and thus these variables can be linked to the subject of the deterioration of the water resources of the basin of Dhamar. Based on the above, the most important climatic factors (temperature and rainfall) are for to determine the extent of the change and the impact on the quantity and quality of water in the Damar Basin. The following table summarizes the annual rates for both temperature and annual rainfall and the amount of annual evaporation in the city of Dhamar for the period 1999-2016 and the rate of change in the three elements.

Table.2. Determination of the rates of release, the amount of evaporation and the amount of rain falling on the city of Dhamar and the rates of change for the period (1999-2016)

annual	Tmax ^{0}C	RC Tmax ^{0}C	Tmin ^{0}C	RC Tmin ^{0}C	EV	MoyEV.	Pr (mm /annual)	RC Pr mm / annual
1999	25.6	0	7.5	0	1812.63	382.77	194	-215.77
2000	27.2	1.6	7.7	0.2	1791.87	362.01	276.3	-133.47
2001	25.4	-0.2	7.4	-0.1	1573.72	143.86	375.9	-33.87
2002	25.7	0.1	8.1	0.6	1565.84	135.98	194.7	-215.07
2003	25.8	0.2	7.1	-0.4	1609.43	179.57	328	-81.77
2004	24.6	-1	6.1	-1.4	1481.07	51.21	339.1	-70.67
2005	23.5	-2.1	4.9	-2.6	1215.74	-214.12	664.2	254.43
2006	23.6	-2	7.7	0.2	1197.51	-232.35	578	168.23
2007	23.3	-2.3	7.8	0.3	1325.50	-104.36	747	337.23
2008	22.9	-2.7	7.1	-0.4	1323.42	-106.44	315	-94.77
2009	23.7	-1.9	8.5	1	1355.41	-74.45	237.6	-172.17
2010	21.5	-4.1	6.9	-0.6	1256.03	-173.83	641	231.23
2011	24	-1.6	8.5	1	1327.98	-101.88	387.8	-21.97
2012	24.1	-1.5	8.7	1.2	1394.35	-35.51	417.2	7.43
2013	23.3	-2.3	8	0.5	1313.98	-115.88	490.1	80.33
2014	24.7	-0.9	7.47	-0.03	1351.55	-78.31	260.6	-149.17
2015	25.3	-0.3	8.7	1.2	1438.58	8.72	335	-74.77
2016	25.2	-0.4	4.9	-2.6	1402.95	-26.91	594.3	184.53

Maximum of temperature (TMax ^{0}C), Rate of change in maximum temperature (RC Tmax ^{0}C), Minimum of temperature (TMin ^{0}C), Rate of change in minimum temperature (RC Tmin ^{0}C), Evapotranspiration (EV) Moyenne of Evapotranspiration (MoyEV). The amount of precipitation (Pr mm / annual) and Rate of change in the amount of precipitation (RC Pr mm / annual)

Through the contents of the previous table we obtained the following result.

Temperature: Temperature is the most important climate element because its degree of difference affects other elements such as atmospheric pressure, wind, humidity, condensation and therefore rainfall.

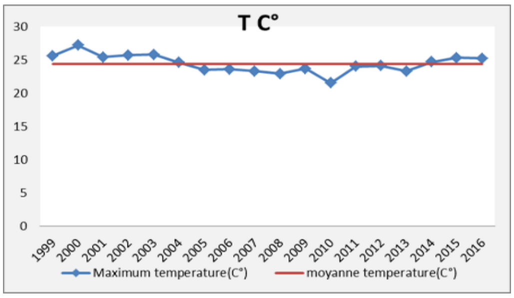

Figure.2. Annual average temperature of Dhamar basin for the period (1999-2016)

The temperature was found through the readings recorded in the table.2 and figure.2, that the average annual maximum temperature for a period of 18 years according to the data available for years (1999-2016) that the highest rate of temperature was in (2000) where it reached (27.3) and the lowest rate to the point the maximum temperature was (21.3) in (2010) a difference of -4.1 compared to the year (1999) and the overall rate of maximum temperature during the period the study tends to decrease by about (-1.2), (figure.3).

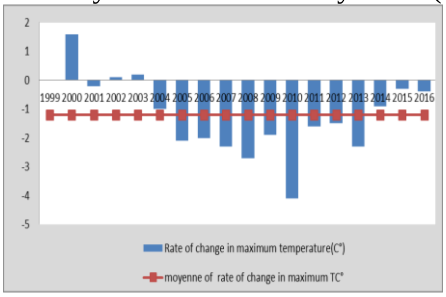

Figure.3. Rate of change in maximum temperature of Dhamar basin for the period (1999-2016)

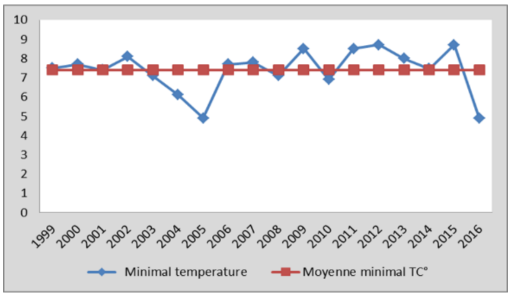

Figure.4. Annual average minimum temperature in Dhamar basin for the period (1999-2016)

During the period (1999-2016), the table.2 and figue.4, the data was showed that lowest average minimum temperature was (4.9^{0}C) in 2005 and 2016 the year while the highest rate of minimum temperature in the same period was 7.8^{0}C for the year 2012 and the average mean that the change during the period mentioned to the minimum temperature was 7.4.

Rainfall: Rain is the main source of water, it is estimated at an average of 216 mm / year, rain is fluctuated from year to year and varies from one region to another because of the difference in soil formation and rise above sea level. Climate change is increasing demand for water in most regions of the world due to the combination of low precipitation and increased evaporation from high temperatures, which in turn will affect production systems and water resources in the coming decades through interactions associated with social, and climate change, therefore, increased demand for water in agriculture will depend on changing climatic conditions and increased demand for food due to growing population growth.

Climate change will have a significant impact on agricultural and food security activities, changes in evaporation rates for rainfall will modify the demand for plant water for a baseline without climate change. On the other hand, modified patterns of the watershed and watershed cycle will change the seasonal and annual rates, inter-annual rates of water availability for terrestrial and aquatic ecosystems (Parry, 2004).

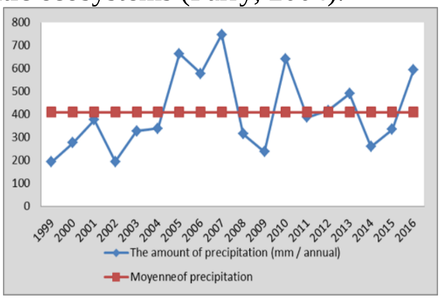

Figure.5. Annual average precipitation in the city of Dhamar for the period (1999-2016)

Through the table.1 and figure.5, showed data of the amount of rain falling on Dhamar basin during the period (1999-2016), it is a change in the average amount of rainfall and the minimum rainfall in the year 1999 of 194 mm/year, while recording the highest amount in the year 2007, where it arrived 774 mm/year at a change rate from the base year calculated by 110 mm. overall rainfall rate during the same period is estimated at about 409.8 mm/year and the rate of change tends to increase by-2.4 (figure.6).

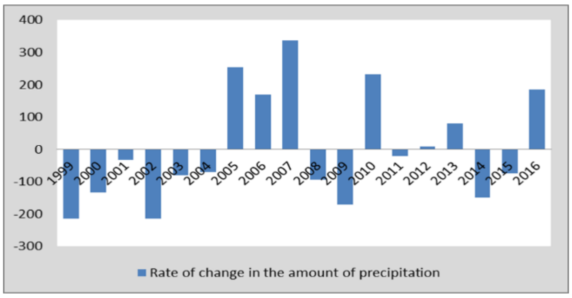

Figure.6. Rate of change in the amount of precipitation in the city of Dhamar for the period (1999-2016)

Evaporation: The evaporation is a process of water from the water bodies and from the surface of the soil and vegetation and their transfer to the atmosphere.

This is done through two processes: The first is the evaporation of the water bodies and the water in the soil granules called the evaporation process, the second is the loss of the plant to the quantities of water through the gaps of leaves and called the process of transpiration. Evaporation processes have significant impacts on the growth of agricultural crops. Knowing how much water is lost by the evaporation process is therefore very important for the plant environment. Dangerous effects increase on the life of plants, the greater the amount of water lost by evaporation, the greater the loss, especially when the amount of rain is low (less than half the amount of evaporation). If the water loss compensation exceeds half the amount of evaporation - whether it is through rainwater or through supplementary irrigation - thereby eliminating any risk that the plant may be dehydrated, During the period (1999-2016), the table.1 and figue.7, the data was showed that lowest average evaporation was (1198mm) in 2006 the year while the highest of evaporation in the same period was 1800mm for the year 2016 and the average mean that the change during the period mentioned to the evaporation was 1450mm.

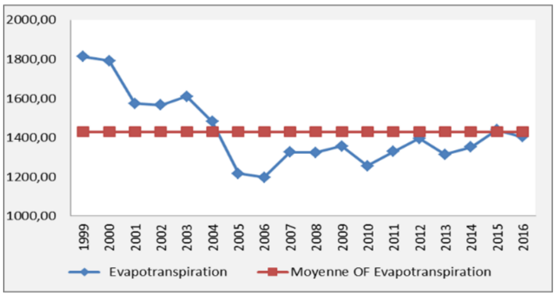

Figure.7. Annual average evaporation in the city of Dhamar for the period (1999-2016)

Water Balance climate: The water balance in the basin is the relationship between the falling rain and the total loss of the basin of water in various forms (Domenico & Schwartz, 1998). The calculated water balance of any basin is one of the methods used to determine the increase or decrease of water in hydrological systems, but it is one of the most difficult to apply when determining the levels of natural recharge of aquifers because of the difficulty of measuring all elements of the water balance accurately. The basic assumption in the water budget is based on inputs and outputs of the system are equal and in the event of any change resulting from an increase or decrease in one or both, the difference will generate a change in the basin stock of surface or groundwater water Level of time period (Domenico & Schwartz, 1998).

The water budget climate depends primarily on the elements of the climate as temperature And rainfall and evaporation measurements (latent and real) to reach the results of the deficit and surplus water - basin so the calculation of evaporation statistics are as follows in table (1.1): Climate water balance in the study area.

Table.3. Climate water balance in the study area

	Jan	Feb	Mar	Apr	May	Jun	July	Aog	Sep	Oct	Nov	Dec
T ^{0}C	12.4	14.0	15.9	16.9	18.4	19.5	19.2	18.8	18.0	15.2	13.3	12.1
Precipitation (mm/month)	2.5	4.3	35.1	64.7	43.5	16.3	92.2	115.2	14.1	3.8	10.1	5.9
PEx (mm/month)	48.5	55.0	62.4	66.3	72.1	76.5	75.5	73.9	70.8	59.7	52.1	47.4
PE (mm/month)	20.0	25.7	33.1	37.3	44.1	49.8	48.4	46.3	42.6	30.3	23.0	19.0
Eto (mm/month)	118.8	129.7	142.4	149.4	160.1	168.6	166.5	163.5	157.7	137.6	124.7	117.0
WS (mm/month)	0	0	0	0	0	0	0	0	0	0	0	0
WD (mm/month)	-36.1	-41.0	-46.5	-49.4	-53.7	-57.0	-56.2	-55.0	-52.7	-44.5	-38.8	-35.3

Potential Evapotranspiration (PEx), Evapotranspiration (PE), total Evapotranspiration (eto), Water surplus (WD), Water deficit (WD).

From table, the results of the calculation of the elements of the water budget in the region of the following study are shown below:

- The region suffers from water deficit through out the year.
- The period of water deficit suggests increased reliance on irrigation water, which increases ground water recharge, this lowers the water level of the pond and makes water vulnerable to salinity in the near term Because of the high water consumption and not compensated in any way because the only source is rain.
- The calculation of drought

$D=1.65*(407.8/(16.1+12.2))^{10/9}$; D = Drought factor (mm/m); R = rainfall for the total months of the year (mm) T = annual temperature (m).

D= 31.9. According to Thorn Thwaite for the calculation of drought, the study area is semi - dry according to climate data analysis.

4. CONCLUSION

- The Annual and monthly averages of rainfall of the Dhamar basin meteorological stations showed that the general annual rainfall is (407.8) mm, the maximum rainfall is 148.2mm in Juin and the minimum is (88.2) mm in janvier during 1999-2016.
- The Annual and monthly averages of rainfall and temperature of the Dhamar basin meteorological stations showed that the general annual rainfall is (407.8) mm. The maximum rainfall is 148.2mm in Juin and the minimum is (88.2) mm in janvier.
- while the general monthly averages of temperature ranging between (21.4^0C in December - 27.7^0C in June).
- The region suffers from water deficit throughout the year.
- The period of water deficit suggests increased reliance on irrigation water, which increases groundwater recharge, this lowers the water level of the pond and makes water vulnerable to salinity in the near term because of the high water consumption and not compensated in any way because the only source is rain.
- The study area is semi - dry according to climate data analysis.

REFERENCES

Adam D, Worse than we thought, The Guardian Castany G, Traite pratique des eaux souterraines, Paris, 2007, 661.

Al-Kohlani, Taha Ahmed M, Geochemistry of thermal waters from Al-Lisi-Isbil geothermal field, Dhamar Governorate, Yemen, 2009.

Bates BC, Kundzewicz ZW and Palutikof JP, (eds.) Climate Change and Water, Technical Paper of the Intergovernmental Panel on Climate Change, Geneva, IPCC, 2008.

Bruggeman H Y, Agro-climatic Resources of Yemen, Part I, Agro climatic Inventory, Field document I I, FAO Proie (A GCNYEM/021/RIET. AREA, Man mi, 1997.

Chiesa S, La Volpe L, Lirer L & Orsi G, Geology of the Dhamar-Rada Volcanic Field, Yemen Arab Republic. N. Jahrbuch Geol. Palaont. Mh, 8, 1983, 481-494.

Domemico PA and Schwartz FW, Physical and chemical hydrogeology, John Wiley and Sons. Inc., New York, 1998, 506.

FAO, Food and Agricultural organization of the United Nation, Climate change and Food Security a framework Document, Rome, 2008.

Ivanov NN, Mirovaya karta isparyaemosti (World map of evaporation), Leningrad, Gidropmeteoizdat, in Russian, 1957.

Minissale A, Vaselli O, Mattash M, Montegrossi G , Tassi F, Ad-Dukhain A, & Al-Kohlani T, Geothermal prospecting by geochemical methods in the Quaternary volcanic province of Dhamar (central Yemen), Journal of Volcanology and Geothermal Research, 249, 2013, 95-108.

Mutasa, African Environmentalists Discuss Climate Change Adaptation Strategies, The Climate Change Action Africa 2007 Conference (August 28-30, 2007), Southern African News Features (SANF), SANF 07 No 35, July 2007.

Overstreet WC, Kiilsgaard TH, Grolier MJ, Schmidt DL, Domenico MM, Donato, Theodore Botinelly and Harms TF, Contributions to the geochemistry, economic geology and geochronology of the Yemen Arab Republic, U.S. Geological Survey, 1985, 85-755.

Parry ML, (Ed.). Climate change 2007-impacts, adaptation and vulnerability, Working group II contribution to the fourth assessment report of the IPCC, Cambridge University Press, 4, 2007.

Thornthwaite, Charles Warren, An approach toward a rational classification of climate, Geographical review, 38 (1), 1948, 55-94.

Van Buitenlandse Zaken, Ministerie, Support to rural water supply and sanitation in Dhamar and Hodeidah Governorates, Republic of Yemen, 2007.

William C, Overstreet, Thor H, Kiilsgaard, Maurice J, Grolier, Dwight L, Schmidt, James A, Domenico, Mary M, Donato, Theodore BotinelTy and Thelma Harms F, Contributions To The Geochemistry, Economic Geology And Geochronology Of The Yemen Arab Republic, 1985, 85-755.

World bank, Making the Most of Scarcity Accountability for Better Water Management in the Middle East and North Africa, 2007.