Water Utility Journal 13: 3-11, 2016.

Understanding seasonal trend of rainfall for the better planning of water harvesting facilities in the Far-North region, Cameroon

A.E. Cheo
Department of Environmental Geology, Brandenburg University of Technology, Cottbus-Senftenberg, Germany
e-mail: bodiambe@yahoo.com

Abstract: Many studies have been conducted to illustrate changes in annual rainfall but not so often for the seasonal changes. With water harvesting often recommended as an effective adaptation strategy to cope with climate change, the seasonal changes of rainfall might reduce the efficiency of the facility if not well understood. The concern here is that rushing to develop water harvesting facilities as an adaptation strategy for climate change without considering the annual seasonal trend of rainfall might increase the risk of the already vulnerable people by reducing the greater benefit of water availability. This study focuses on evaluating trends in the annual seasonal rainfall data for the Far-North region of Cameroon and to present another perception to consider when planning for water harvesting facilities. Annual data for the dry seasons and rainy seasons between the years of 1957 and 2006 were analysis by performing a Time Series Analysis and the Mann-Kendall test. The rainy season show a decreasing trend and the dry season an increasing trend in rainfall between 1957 and 2006. On the other, the Mann-Kendall test indicated a no statistical significant trend for both seasons. The null hypothesis for the Mann-Kendall test was accepted for both seasons. The study concluded that issues about climate change in the study area necessitates a fundamental rethink on the way water resources, and particularly for water harvesting facilities in the Far-North region, are planned and managed.

Key Words: climate change adaptation, Mann-Kendall test, Time Series Analysis, semi-arid region, water management

1. INTRODUCTION

In recent time, water harvesting is often recommended as a possible source to supplement water supply in both arid and semi-arid regions of the world. According to Braune and Xu (2010), these interventions promote economic growth and help alleviate poverty by reducing risk and making water available when and where it is needed. This means that the amount of rainfall received is very important in determining the amount of water available to meet various demands, such as agricultural, domestic water supply, hydroelectric power generation etc. The uneven distribution of rainfall and the mismatch between water availability and demand has required large storage reservoirs to redistribute the natural flow in accordance with the requirements of specific regions. Increasing threat from climate change might likely worsen the situation in parts of the world that are already experiencing water scarcity.

Climate change is a global problem. Future climate change trend might influence long-term rainfall patterns (duration, intensity and frequency) impacting the availability of water, along with the danger of increasing the occurrence of droughts and floods (Sharad and Vijay 2012). Global Climate Models (GCMs) e.g. General Circulation Models (GCMs) are the primary tools for projecting future changes in the hydrological cycle under GHGs forcing scenarios (Pascale et al. 2014). General Circulation Models (GCMs) have predicted higher frequencies of extreme precipitation events, fewer rainy days, longer drought periods (IPCC 2007) without the concurrent change in total annual rainfall (Knapp et al. 2002). In the last thirty years, GCMs have undergone intense development but a precise representation of the hydrological cycle has not been achieved, particularly at the local and continental scales (Lucarini et al. 2008; Lin 2007; Hasson et al. 2014). This is partly because of the misrepresentation of small-scale hydro-climatic processes (Sabeerali et al. 2014) or the insufficiency in the representation of complex orography (Palazzi et al. 2013). In order to have a more complete description of the precipitation regimes under climate change, it is important to take into account not only the mean total annual amount of precipitation but also more complex statistical properties of intense rainfall events (Sillmann et al. 2013; Mehran et al. 2014) and the seasonality of the annual rainfall (Feng et al. 2013) which often goes unexplored. Furthermore, in Africa, only little systematic analysis has been done on, (1) how climate change might affect existing water storage, (2) how water storage can increase resilience to climate change and (3) how to account for climate change in the planning and management of new water storage schemes (Boelee et al. 2013).

Precipitation changes and how the changes will propagate to various terrestrial ecosystems remain unclear. In the Far-North region of Cameroon, the uneven rainfall pattern naturally creates highly variable flows over time and space causing uncertainty in water availability for both domestic users and farmers (Ngounou et al. 2008). Furthermore, rainfall seasonality, the related drought and flood risks makes agricultural activities and the sustainable management of water resources very challenging for local communities. The availability of water over the year depends on the seasonal peaks of rainfall, river flow and lake level that succeed each other from July to January (Ngounou, 2009). Local water management interventions are often based on very little understanding of the local hydrological regimes, which govern the potential supplies of water for harvesting. For example, the Maga dam in the Far-North region of Cameroon has reduced the flow of the Logone River and seasonal inundation of the Yaere floodplain (Ngounou, 2009). Many of the traditional water harvesting systems are no more in used (Agarwal and Narain 1997), or have lost their relevance in the modern day context due to their inability to satisfy the needs of communities because their designed are often based on the assumption that climatic conditions are static (Kumar et al. 2008).

For runoff harvesting, rainfall has to exceed a certain threshold to generate runoff, however thresholds varies greatly with the nature of the soil and land cover of the area (Kumar et al. 2008). For examples, observation in the Hathmati sub-basin of the Sabarmati basin shows that for runoff to cross 100 mm, the minimum rainfall required is 682 mm whereas in the case of the Kabani sub-basin of the Cauvery Basin, runoff starts when the rainfall crosses 366 mm (Kumar et al. 2008). Changes in rainfall as a result of climate change will influence the hydrological cycle, the pattern of stream-flows and demands (e.g. in agriculture) and this will require the review of hydrologic designs and management practices of communities (Sharad and Vijay 2012).

Water harvesting has a vital role to play in the management of water variability, ensuring global food security and building resilience for adaptation to climate change (Smakhtin et al. 2014). However, open water storage facilities such as reservoirs, ponds, and tanks might also provide ideal breeding conditions for mosquitoes, flies, or snails (Keiser et al. 2005; Steinmann et al. 2006) which are health risk to the local population. To meet the Sustainable Development Goals (SDGs), countries with low per-capita water storage, especially those in sub-Saharan Africa, will have to invest in new water storage facilities (Smakhtin et al. 2014). According to Mbomba (2010), to determine the volume of the required storage tanks to ensure sufficient water supply to the set population is dependent on the duration of the water-stressed period, the targeted per capita consumption during that period and finally, a suitable turnover rate that guarantee a steady renewal of the stored water within the tanks.

Water resources in drier climates are more sensitive to climate change due to increasing temperature resulting to high evaporation, low river flow, a decline in lakes and groundwater levels (Philander 2008). Majority of the local population in the Far-North region are made up of poor rural households, who survive on subsistence farming. According to Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (2015), climate change has an acute impact on crop production, cattle farming and fisheries in the region. The high level of rainfall variability poses a risk to crop production on land that is traditionally farmed through rain fed agriculture, irrigation and flood recession farming, as well as from pastureland and fishing (GIZ 2015). Changes in climatic conditions result in increased food insecurity, social tensions and poverty, and cause a rise in the number of refugees among the affected population (GIZ 2015). This study is focus on evaluating trends in the annual seasonal rainfall data so as to provide insights into the potential climate change impacts on the seasonal water supply and demand. The study also seeks to present another perception to be considered when planning for water harvesting facilities which will help to enhance the resilience of the already vulnerable population against climate change.

2. MATERIAL AND METHODS

2.1 Site description

The Far-North region is located within the coordinates of latitude 10^o 34´55´´North and longitude 14^o 19´39´´East (Cheo et al. 2014). This region has a Sahel type tropical climate (Neba 1987) with temperature ranging between 28°C and 45°C. The climatic condition greatly varies according to the different months of the year, with some months being very hot (January to May) and others being cooler (June to September) with reasonable rainfall. Rainfall and evapotranspiration data indicate that there is a water deficit in the region during the early and late months of the rainy season (Fonteh and Nji 2001). The region has two main seasons (dry and wet seasons) and only for three months that rainfall exceeds evapotranspiration (Fonteh and Nji 2001). Annual rainfall in the region ranges between 300 mm to about 1200 mm (WorldClim-Global Climate Data: Credits: Hijmans et al. 2005). The region has a total surface area of about 34 263 km^2 and shares international boundaries with Chad and Nigeria located in the east and west respectively. Maroua is the capital of the region. Figure 1 shows a map of the region and some physical characteristics.

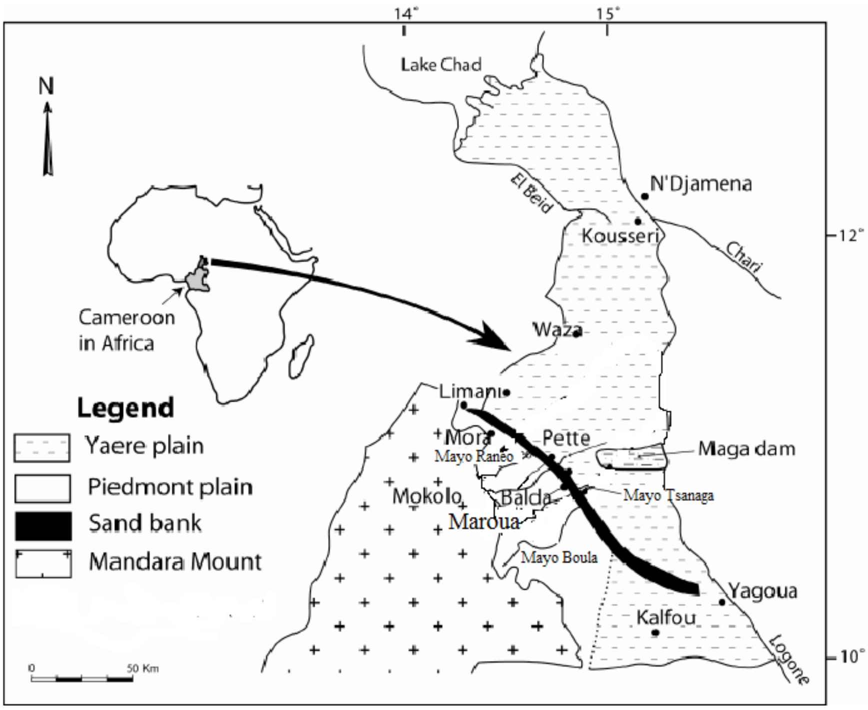

Figure 1: The map of the Far North Region (adapted from Ngounou et al. 2007)

The region has a population of about 3.5 million inhabitants which makes it the most populated region in the country (Cheo et al. 2014). High poverty rate in the region has reduces accessibility to the services of the national water distribution company. And this is more severe in rural communities. To meet water demand, communities are forced to rely on traditional methods such as wells, rainwater, direct extraction from streams and during the dry season, sand bed are dug to harvest water. Sometime these water sources are unsafe and not well protection from animals or contaminants. According Cameroon's Minister of Public Health, "poor sanitation and limited access to good drinking water are the main causes of recurrent cholera outbreak in the Far North (Nfor, 2014). Environmental risk factors have also contributed to the outbreak, particularly the rainy season and the increase in flooding along lakes and rivers (Djomassi et al. 2013). This raises the concern of climate change and the increasing occurrence of floods and how water storage facilities are protected or constructed.

Water availability and climate variability poses a major problem in agriculture and domestic water supply. About 80% of the population depends on agriculture for subsistence with little or no surplus for marketing. Crops grown in the Far-North region are short duration crops or drought tolerant crops. The most cultivated crops include Sorghum, millet, maize, rice and cotton. The region is characterized by low soil moisture, which tends to make irrigation and water harvesting technologies very important adaptation strategies. Most often the costs, resources and the construction methods tend to determine the capacities of the water harvesting facility rather than the roof area or needs of consumers. Nji and Fonteh (2002) identified six successful water harvesting technologies in the region. Table 1 gives a brief description of the six identified water harvesting technologies in the Far-North region.

Table 1: Identified water harvesting technologies in the Far-North region, Cameroon (adapted from Nji and Fonteh, 2002)

Types / Local Names	Description of the technology	Purpose
1. Flood Diversion or Water Spreading (Locally called *Guimelther*)	It consists of diverting water from ephemeral streams into cultivated basins enclosed by a permeable dry stone wall. The stone wall never exceeds 30 cm and it's determined by flow rate during floods. Width and length vary from 1-3 m (Van Oostrum, 1994)	Agricultural production
2. Mini Dams (Locally called *Bief*)	A small dam designed to reduce the speed of water flow in small ephemeral streams. By reducing velocity, water is retained temporarily for infiltration and groundwater recharges (Damien, 1990). Wells are then constructed downstream where the harvested water empties. It requires mostly local materials (stone, labour) for construction.	Domestic consumption
3. Micro Sand Dams	It consists of water-tight stone/mortar or concrete walls built across the rivers or mayos on relatively flat section of a waterway. The target is to reduce the flow rate, increase infiltration for water storage in the sand so as reduces evaporation. They are similar to the biefs described above, except that the structures are larger and backfilled with sand.	Domestic consumption and sometime for agricultural use
4. Water Ponds (Locally called *mares*)	Water ponds are large holes, dug 4-6m deep into the ground to collect and hold surface runoff during the rainy season for use in the dry season. They are constructed in the path of runoff flow with clayish soils so as to reduce percolation. A sedimentation basin is constructed at the entrance of the pond to reduce silting.	Animal grazing (e.g cattle, goats and sheep)
5. Rooftop Rainwater Harvesting	Rainwater is collected from the tinned roof into specially designed reservoirs mounted above the ground or in underground storage tanks. It is an old practice in the Mandara Mountains by household with tin roofs.	Domestic purposes
6. Rock Bed Rainwater Harvesting	It consist of a large flat rock which serve as a rock bed catchment with a 40cm retaining wall of cement and mortar constructed at the edges of the rock. The rainwater harvested is canalled into a rectangular stone-wall tank constructed below.	Domestic consumption (especially as drinking water)

According to Nji and Fonteh (2002), these technologies have achieved success because of their efficiency, affordability and their acceptability by the poor inhabitants. An erratic variation in rainfall will impact the efficiency of these technologies. For example, with flood diversion or water spreading technology, an unprepared increase in rainfall might be catastrophic given that the height of walls are determine by the flow rate during flood. Another example is the rock bed rainwater harvesting technology. An increasing rainfall will also require an increasing storage tank or else water will overflow and this might cause erosion or destroy properties.

2.2 Data quality control and time series analysis

Temperature and rainfall data were obtained from the University Cooperation for Atmospheric Research (UCAR) East Anglia. The dataset obtained were observed daily data measured between

1957 and 2006 in the Maroua Salak Station, Cameroon. The dataset was assumed to represent the Far-North region given that other dataset were not available. Data quality control was done by using ClimDex Version 1.3 software developed by Byron Gleason from NCDC/NOAA, U.S.A. The software assists users to identify common gross errors that might exist within daily station data. The observed daily data was then sum-up to have the monthly dataset which was further separated into dry seasons and wet seasons for the different years.

A time series analysis was computed using Microsoft Excel program. Trend lines were generated on the graphs to depict trends in the existing data. XLSTAT software was employed to perform the Mann-Kendall (M-K) test. M-K test statistically assess whether the time-ordered data set exhibits an increasing or decreasing trend, within a predetermined level of significance. According to M-K test, rejecting the null hypothesis (Ho) means that the result is said to be statistically significant and accepting the null hypothesis (Ho) means there is no trend in the time series data. Mann-Kendall statistics (S) is one of non-parametric statistical test used for detecting trends of climatic variables.

3. RESULTS AND DISCUSSION

Long term observation of average annual rainfall and average annual temperatures showed a downward trend for rainfall and no significant change in temperature as illustrated in Figure 2 and Figure 3 respectively. Even though a downward trend was observed in Figure 2, the amount of rainfall is still quite significant if properly managed (Cheo et al. 2014).

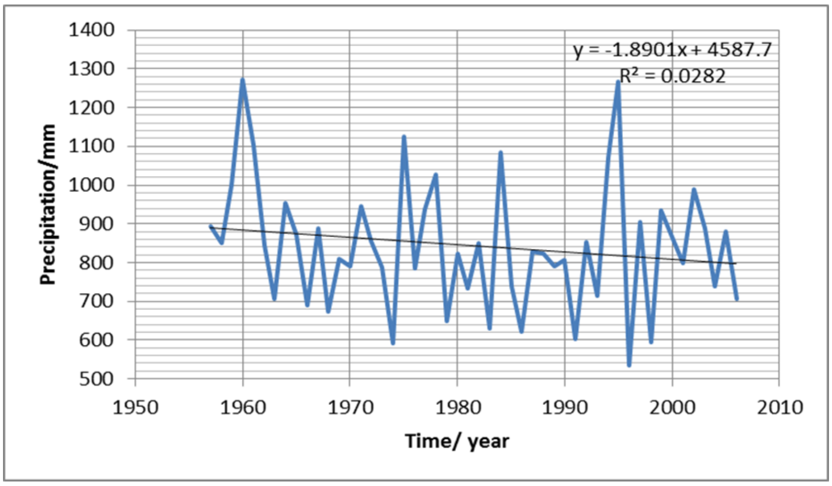

Figure 2: Annual average rainfall in Maroua (Cheo et al. 2013; 2014)

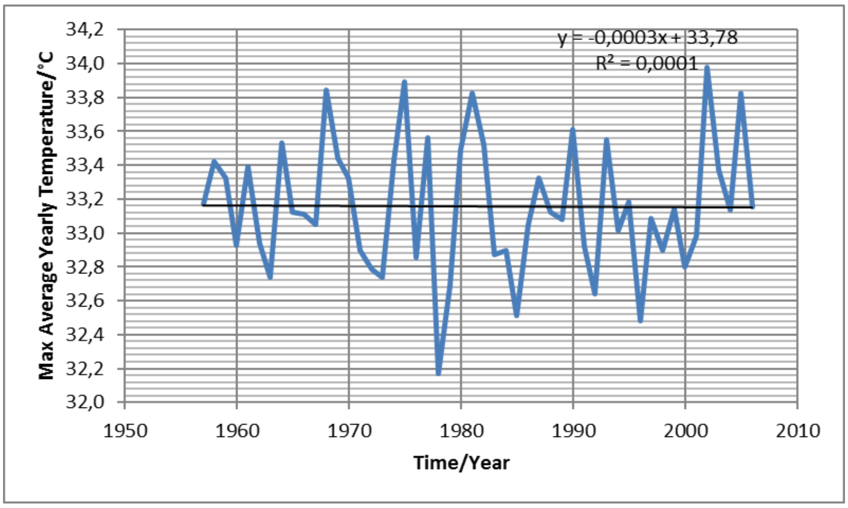

Figure 3: Average annual maximum temperature (Cheo et al. 2013; 2014)

The seasonal observation of long term rainfall data for the two main seasons in the region produced contrasting results. Figure 4 shows the annual wet season rainfall for 49 years. Maximum rainfall occurred in the year 1960 and has an annual rainfall of approximately 1250 mm. Minimum rainfall occurred around the years of 1996 and 1998 with a total rainfall of about 460 mm. The trend line shows a decreasing trend which was interpreted as a decrease in the quantity of rainfall with time. On the contrary, annual average wet season temperature witness a slight increase as demonstrated in Figure 5.

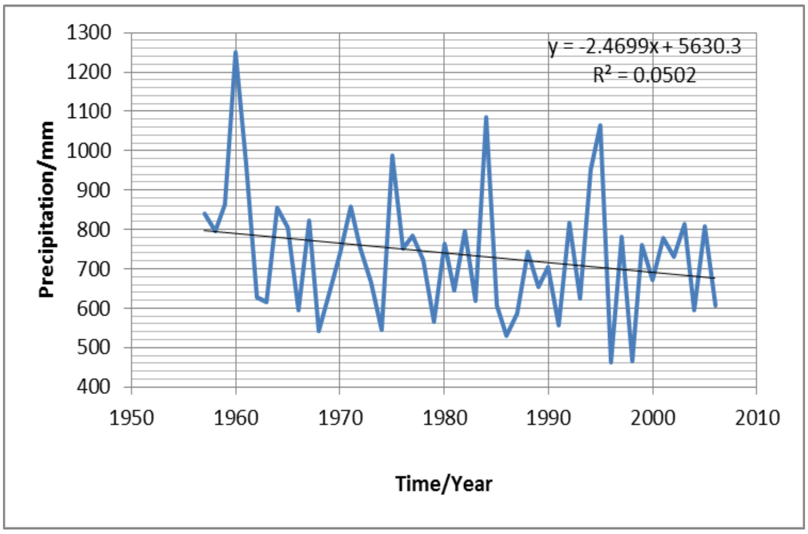

Figure 4: Maroua annual average wet season rainfall

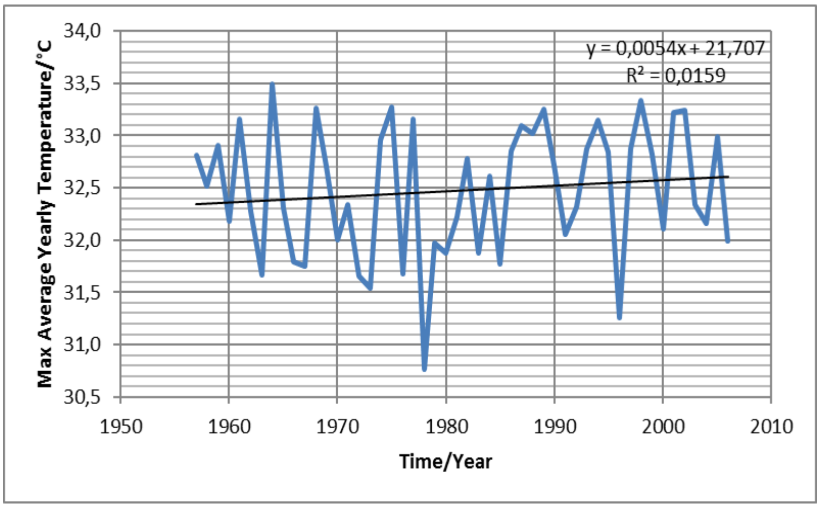

Figure 5: Wet season annual average temperature for Maroua

Performing the Mann-Kendall test for the annual average wet season precipitation revealed that the computed p-value is greater than the significance level alpha=0.05. This means that the null hypothesis (Ho) cannot be rejected. Accepting the null hypothesis means that the result is not statistically significant. The risk to reject the null hypothesis (Ho) while it is true is 12.79%. Table 2 shows the results of the Mann-Kendall test for both seasons.

Table 2: Results of the Mann-Kendall test

Maroua Season	Mann-Kendall Statistics (S)	P-value	alpha	Test interpretation
Wet Season	-183	0.128	0.05	Accept Ho
Dry Season	94	0.437	0.05	Accept Ho

During the dry season (between years of 1957 to 2006) an increasing trend was observed for the annual average dry season rainfall. Figure 6 shows a graph for the annual average dry season rainfall for 49 years in the Far-North region. Maximum rainfall of about 310mm occurred around 1978 whereas the minimum rainfall of about 0 mm occurred around 1984. The Mann-Kendall test revealed that the computed p-value is greater than the significance level alpha=0.05. This means that the null hypothesis (Ho) cannot be rejected (see Table 2). The risk to reject the null hypothesis (Ho) while it is true is 43.66%. This implies there is no trend and this is contrary to the result obtained for the time series analysis. The annual average dry season temperature showed a slight decrease for the same period as presented in Figure 7.

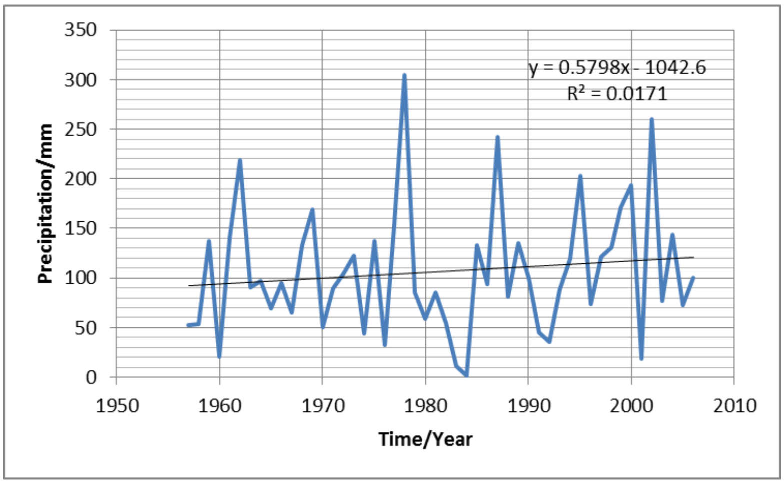

Figure 6: Maroua annual average dry season rainfall

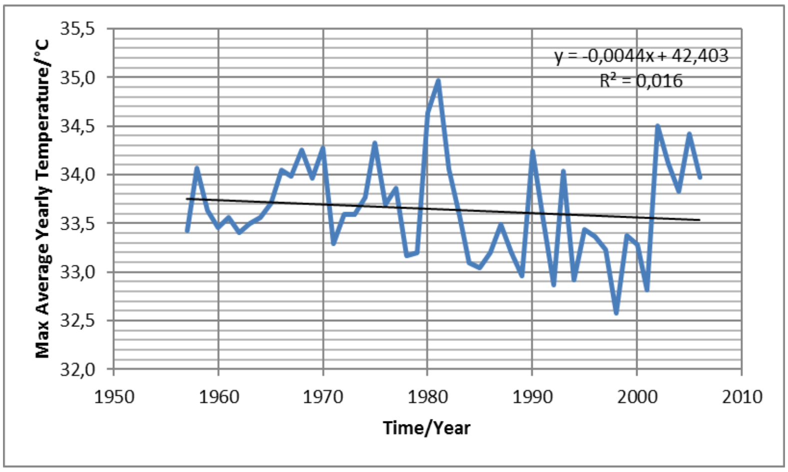

Figure 7: Dry season annual average temperature for Maroua

The water cycle is a delicate balance among precipitation, evaporation and all the steps in between. The time-ordered data set for both seasons did not exhibit any significance increase or decrease in trend within a predetermined level as illustrated by the M-K test. However, the annual seasonal variation for both precipitation and temperature cannot be ignored. Warmer temperature increases the rate of evaporation and also the holding capacity of water vapor in the atmosphere. The steady increase in temperature during the wet season might have warm the atmosphere thus increasing the holding capacity of water vapor that later falls as rainfall with an increasing trend as demonstrated during the dry season.

The decreasing wet season rainfall trend implies an overall reduction in the available water for harvesting. This also can be interpreted as an increase in water demand for crop production, in the case where irrigation was being practice. On the other hand, the increasing trend for rainfall during the dry season might imply an increase in rainwater for harvesting and a lower proportion of crop water that need to be satisfied by irrigation. The presented phenomenon might have a beneficial effect for the study area. It is important that climate change projections and scenarios are used to improve planning for water harvesting in the Far-North region. More efficient storage facilities are also recommended. Water harvesting facilities with surface reservoirs can result in large-scale water loss, given that evaporation rates are very high in the region. Past experience has shown that well-planned storage can bring significant benefits in terms of food security, health and income and prevent a waste of scarce financial resources (McCartney and Smakhtin 2010).

4. CONCLUSIONS

The time series analysis generated valuable information regarding seasonal variation of rainfall with time in the Far North region. Details of climate change are unknown, so planning for water harvesting and water storage must allow for greater uncertainty. To better plan water harvesting facilities, current and future needs of water should be determined. After that the appropriate choice should be made from the available options based on their effectiveness and suitability. Currently, in the Far-North region, there is scarcity of information regarding performance and suitability of water harvesting options at a regional scale.

Future water harvesting and water storage facilities for the region must be reliable, resilient and less vulnerable. The identified water harvesting options have strong comparative advantage under specific conditions of time and place. Planning under a changing climatic condition needs integration across levels and scales with much consideration of exploiting all possible options given that the region is a water scarce area. In order to maximize the benefits and minimize the cost for water harvesting and storage options, a wide range of complex and interrelated hydrological, social, economic and environmental factors are required. Understanding seasonal trends of rainfall from past data is just one of the basic and important requirements needed to improve planning and management of water harvesting for a particular region.

Africa has been predicted in many studies as a continent to experience the greatest negative impacts of climate change because of insufficient capacity and the high poverty rate. By making water available through water harvesting and water storage during period of natural scarcity can significantly increase agricultural and economic productivity and enhance the well-being of the local population.

REFERENCES

Agarwal, A., Narain, S. (1997) Dying wisdom: rise and fall of traditional water harvesting systems, centre for science and environment. New Delhi, India.

Boelee, E., Yohannes, M., Poda, J-N., McCartney M., Cecchi, P., Kibret, S., Hagos, F., Laamrani, H. (2013) Options for water storage and rainwater harvesting to improve health and resilience against climate change in Africa, Reg Environ Change (2013) 13:509–519.

Braune, E., Xu, Y. (2010) The role of ground water in sub-Saharan Africa. Ground Water 48:229–238.

Cheo, A.E, Amankwah, E., Techoro, P.S. (2014) Water harvesting: a potential means for water security in the Far North Region of Cameroon. Agric. Res. 3(4):331–338.

Cheo, A.E., Voigt, H-J, Mbua, R.L. (2013) Vulnerability of water resources in northern Cameroon in the context of climate change. Environ Earth Sci (2013) 70:1211–1217.

Damien, C. (1990) Manuel technique pour la réalisation de biefs: dans le cadre d'une maîtrise de l'eau à échelle villageoise sur les Monts Mandara, Extrême-nord, Cameroun. Unpublished Manual, Comité Diocesain de Devéloppement, Maroua, Cameroun.

Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (2015). Africa supraregional adaptation to climate change in the Lake Chad Basin CLIMATE CHANGE STUDY, Bonn and Eschborn, Germany.

Djomassi, L.D., Gessner, B.D., Andze, G.O., Mballa, G.A.E. (2013) National surveillance data on the epidemiology of cholera in Cameroon Journal of Infectious Diseases, 208 (SUPPL. 1) , pp. 92-97.

Feng, X., Porporato, A., Rodriguez-Iturbe, I. (2013). Changes in rainfall seasonality in the tropics. Nature Clim. Change, 3(9), 811-815.

Fonteh and Nji (2001) Water harvesting technologies in the Mandara Mountains Region of Cameroon: In, Water harvesting in western and central Africa, Proceedings of a regional workshop held in Niamey, October 1999, Regional Office for Africa Food and Agriculture Organization (FAO) of the United Nations, Accra, Ghana.

Hasson, S., Lucarini, V., Pascale, S., Böhner, J. (2014) Seasonality of the hydrological cycle in major south and southeast asian river basins as simulated by PCMDI/CMIP3 experiments. Earth Sys. Dynam., 5, 67–87.

IPCC-Intergovernmental Panel on Climate Change. Climate Change (2007) The physical science basis. contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, et al. (editors). Cambridge, United Kingdom and New York, NY, USA.

Keiser, J., Caldas de Castro, M., Maltese, M.F., Bos, R., Tanner, M., Singer, B.H., Utzinger, J. (2005) Effect of irrigation and large dams on the burden of malaria on a global and regional scale. Am J Trop Med Hyg 72(4):392–406.

Knapp, A.K, Fay, P.A., Blair, J.M. (2002) Rainfall variability, carbon cycling, and plant species diversity in a mesic grassland, Sci., 298, 2202 – 2205.

Kumar, M.D., Ankit, P., Singh, O.P. (2008) Rainwater harvesting in the water-scarce regions of India: potential and pitfalls. In Amarasinghe, Upali A.; Sharma, Bharat R. (Eds.) Strategic Analyses of the National River Linking Project (NRLP) of India, Series 2. Proceedings of the Workshop on Analyses of Hydrological, Social and Ecological Issues of the NRLP, New Delhi, India, 9-10 October 2007. Colombo, Sri Lanka: International Water Management Institute (IWMI) pp.289-314.

Lin, J.L. (2007) The double-itcz problem in IPCC AR4 coupled GCMs: Ocean atmosphere feedback analysis. J Clim., 20, 4497-4525.

Lucarini, V., Danihlik, R., Kriegerova, I., Speranza, A. (2008) Hydrological cycle in the Danube basin in present-day and XXII century simulations by IPCCAR4 global climate models. J. Geophys. Res., 113:D09, 107.

Mbomba, J.Z.T. (2010), Can fog and rain harvesting secure safe drinking water in rural Cameroon? – Case study of Bafou (mountainous) and Mora (low-lying) villages, Master Thesis, Ecological-Engineering – water management, Kristianstad University, Sweden.

McCartney M. and Smakhtin V. (2010) Water Storage in an Era of Climate Change: Addressing the Challenge of Increasing Rainfall Variability, BLUE PAPER, Colombo, Sri Lanka, http://www.iwmi.cgiar.org/Publications/Blue_Papers/PDF/Blue_Paper_2010-final.pdf (Accessed 3 March 2016)

Mehran, A., AghaKouchak, A., Phillips, T.J. (2014) Evaluation of CMIP5 continental precipitation simulations relative to satellite-based gauge-adjusted observations, J. Geophys. Res. Atmos., 119: 1695-1707.

Neba, A.S. (1987) Modern Geography of the Republic of Cameroon; Neba Publishers, Camden, New Jersey.

Nji, A., Fonteh, M.F. (2002) Water harvesting: It's potential in the greening and poverty reduction of Northern Cameroon. J. Cam. Acad.of Sci., 2 (1): 33- 48.

Nfor, M.K. (2014) Recurrent cholera outbreak in Far-North Cameroon highlights development gaps, IPS Inter Press Service News Agency, http://www.ipsnews.net/2014/08/recurrent-cholera-outbreak-in-far-north-cameroon-highlights-development-gaps (accessed 26 February 2016).

Ngounou, N.B. (2009) Water resources protection in the Lake Chad basin in the changing environment. European Water, 25/26: 3-12.

Ngounou, N.B., Mudry, J., Leduc, C. (2008) Water resources management in the Lake Chad Basin, Diagnosis and Action Plan, In Applied Groundwater studies in Africa, IAH Selected Papers on Hydrogeology, vol. 13, Adelana S, MacDonald A (eds). Taylor & Francis; Chapter 5, 65–85.

Ngounou NB, Mudry J, Sarrot-Reynauld J (2007) Groundwater recharge from rainfall in the southern border of Lake Chad in Cameroon. World Applied Sciences Journal, 2 (2): 125 - 131.

Palazzi, E., von Hardenberg, J., Provenzale, A. (2013) Precipitation in the Hindu-Kush Karakoram Himalaya: Observations and future scenarios. J. Geophys. Res. Atmos. 118: 85-100.

Pascale, S., Lucarini, V., Feng, X., Porporato, A., Hasson, S. (2014) Projected changes of rainfall seasonality and dry spells in a high concentration pathway 21st century scenario, arXiv preprint arXiv:1410.3116.

Philander, S.G. (2008) Encyclopedia of global warming and climate change. SAGE Publications, California.

Sabeerali, C.T., Suryachandra, A.R., Dhakate, A.R., Salunke, K., Goswami, B.N. (2014) Why ensemble mean projection of south Asian monsoon rainfall by CMIP5 models is not reliable? Climate Dynamics DOI 10.1007/s00382-014-2269-3.

Sharad, K.J., Vijay, K. (2012) Trend analysis of rainfall and temperature data for India, Current Science, Vol. 102, No. 1, 10January 2012.

Sillmann, J., Kharin, V.V., Zhang, Z., Zwiers, F.W., Bronough, D. (2013) Climate extremes indecisionthe CMIP5 multimodel ensembles: Part I. Model evaluation in the present climate. Journal of Geophysical Research 118(4):1716 – 1733.

Smakhtin, V., Pavelic, P., Amarnath, G., Mc Cartney, M. (2014) Managing Water Variability: Floods and Droughts: van der Bliek, J.; McCornick, M.; Clarke, J. (Eds.). 2014. On target for people and planet: setting and achieving water-related sustainable development goals. Colombo, Sri Lanka: International Water Management Institute (IWMI). 52p.

Steinmann, P., Keiser, J., Bos, R., Tanner, M., Utzinger, J. (2006) Schistosomiasis and water resources development: systematic review, meta-analysis, and estimates of people. Lancet Infect Dis 6:411–425.

Van Oostrum, K. 1994. Sustainable land use and social change: a study on ecological knowledge, soil and water management and social dynamics of Mafa in Nord Cameroon. M.A. Thesis; Institute for Cultural and Social Studies, Leiden, Netherlands.

WorldClim-Global Climate Data: Credits: Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., Jarvis, A. (2005) Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.