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EFFECTS OF CLIMATIC ELEMENTS ON SURFACE WATER IN YOLA NORTH LGA, ADAMAWA STATE, NIGERIA

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Abstract

Water resource is one of the important parts of environment which plays a very significant role in balancing the ecosystem. However, the resource is threatened by many factors among which are climate elements. It is against this background; this study examines the effect of climate on surface water resources. Climatic data such as rainfall, minimum and maximum temperature, relative humidity, sunshine hours and surface water bodies were the data used in the study. All the climatic data were collected from Meteorological station of Yola international airport while area of surface water bodies was calculated from land sat 8 OLI images. Results of the rainfall trend revealed a negative value of -5.2046 at probability level of p=0.07 while relative humidity showed a significant positive trend of 0.1925 at p=0.000. Maximum and Minimum temperature also showed a similar pattern of increase in which the two variables showed a positive trend of 0.0266 and 0.0536 for maximum and minimum temperature at p<0.01 respectively. Result on the total area cover by open water bodies revealed that surface water body in the study area is decreasing which suggested that there are factors influencing the decrease in the water bodies. Result on the relationship between surface water bodies and mean annual rainfall revealed a strong positive correlation of 0.850 at p=0.068 while relationship between maximum temperature and surface water displayed an inverse relationship of -0.412. Relationship between surface water and sunshine hours also displayed a strong negative relationship of -0.717 which clearly implies that increase in sunshine hours leads to decrease in the level of surface water bodies and decrease in sunshine hours leads to increase surface water bodies. In regards to this, it was concluded that mean annual rainfall in the area is decreasing while maximum and Minimum temperature is increasing. It was also concluded that the level of surface water in the area is decreasing and increase in mean annual rainfall will lead to an increase in the surface water bodies while increase in minimum and maximum temperature will lead to a decrease in surface water bodies. In the same vein, increase in sunshine hours will lead to decrease in surface water bodies. This therefore showed that, climate affect surface water bodies at different level and scale. As such, there is a need for climate change awareness at both local and national level to help control the consequent effects of climate change on environmental resource.

Key Word: *Climate, Surface water, Quantity and Yola North*

Introduction

Water, in its clean state is one of the rarest elements in the world. It is used mostly for domestic, fishing, farming and irrigation, and livestock purposes (Longe., *et al*., 2010). It was documented that according to 2006 census, about 48% (67 million Nigerians) make use of surface water for their domestic needs (FGN, 2007) and the principal domestic uses of the water include drinking, washing, and bathing (Kuruk, 2005). It was also documented by Ahianba *et al*. (2008); FOS (2001) that 33.82% (47.3 million) Nigerians depend exclusively on surface water for their domestic water supply, 28.27% (39.3 million) depend on hand dug well sources, 24.38% (33.9 million) on pipe borne water, 11.83% (16.4 million) on borehole water sources, and 1.7% (2.4 million) on water vendors. However, the relevant of the resource is threatened by many factors among which are climate changes.

Climate change has become a serious concern of the world today. Evidence from different part of the world clearly showed the existence of the climate change based on the behaviors of some of the climatic elements. For example, the World Meteorological Organization (WMO, 2005) reported that the global average surface temperature has risen with about 0.7°C since the beginning of the 20th century. It was also documented that in the northern and southern hemispheres, the 1990s were the warmest decade with an average of 0.38°C and 0.23°C above the 30-year mean, respectively (WMO, 2005). In the same vein, WMO (2009) reported that, 2000s was warmer than the 1990s and the 10 warmest years for the earth's surface temperature all occurred after 1990, and 2005 was the warmest year on record (Jones and Palutikof, 2006; Hansen *et al*., 2006). Much of the warming during the last four decades is attributable to the increasing atmospheric concentrations of greenhouse gases (GHGs) due to human activities (Meehl *et al*., 2003; Cayan *et al*., 2008). This global warming has been strongly linked to changes in the global hydrological cycle such as increases of atmospheric water vapor resulting in changes of precipitation patterns, intensity, and extremes; reduced snow cover and the widespread melting of ice; and changes in soil moisture and runoff.

There are many indications that water bodies are under stress and susceptible to climate change impacts. For instance, climate change caused by the increase in greenhouse gases in the atmosphere has significantly influenced on water balance by causing changes in evapotranspiration rates, temperature, and rainfall (Karamouz *et al*., 2011 and Abdelkrim, 2013). In the same vein, it was reported that, Climate change increases water resources stresses and changes in runoff from different part of the world. For example, runoff around the Mediterranean, in parts of Europe, central and southern America, and southern Africa is decreasing while in other water-stressed parts of the world particularly in southern and eastern Asia runoff is increasing (Arnell., 2004). Furthermore, climate change increase water temperature and the likelihood of flooding, droughts and water scarcity. For instance, change in temperature affect hydrological circle which also determine the supply and demand for water resources (Huntington, 2006 and Intergovernmental Panel on Climate Change, IPCC, 2007). In general, with warmer weather, water demand is anticipated to increase while water supply is anticipated to decrease

(Peterson and Keller, 1990; Oki and Kanae 2006; Kundzewicz *et al*., 2007).

These impacts of climate on water resources are expected to affect the function and operation of existing water infrastructures including hydropower, structural flood defenses, drainage, and irrigation systems, as well as water management practices (IPCC, 2008). As such, Understanding the interaction of climate and water resources can help scientists and policy makers to mitigate the negative effects of climate change by introducing proper water management scenarios.

Against this background, this study is aim to examines the effect of climatic variables on surface water resources and the objectives are; examine the nature and extent of climatic condition in the study area, assess the level of surface water in the area and to examine the effect of climatic elements on surface water in the study area.

Study Area

The study area, Jimeta Metropolis, is located between latitudes 09° 16′N and 09° 30′N of equator and longitudes 12° 18′ E and 12° 34′ East of Greenwich meridian (Figure 1). It is situated in the Sudan savannah vegetation zone of the country. It is bounded by Girei and Yola South local government area to the South and eastern parts respectively. Like any other Nigerian cities, Jimeta comprises of so many land use types ranging from institutional, commercial and residential. The city is clearly stratified in terms of population densities (Ilesanmi, 2020). The Area has a total population of 198,247 as of 2006 national census and was projected to 211,598 in 2008, 217,824 in 2009 and 224,233 in 2010 (NPC, 2006 and Yemi, 2013). The Soil of Jimeta is derived from the basement complex rock. However, there is some alluvial soil along the Benue flood plains.

Jimeta/Yola has a tropical climate mark by two seasons; wet and dry. The rainy season begins in May and ends in October while the dry season lasts for mainly from November to April. The mean length of rainy season ranges from 120-210 days, while the mean annual rainfall ranges from 900-1000mm (Adebayo,2020). The temperature in this climatic region is high throughout the year; however, there is usually a seasonal change. The seasonal maxima usually occur in April with a maximum temperature of 40ºC while the minimum can be as low as 18ºC between December and January (Adebayo, 2020).

River Benue is the major river in the area, it rises from the highlands of Cameroon republic and flows southwards into Nigeria joining the river Niger at Lakoja. The River Benue which is main river flows all year round with the peak in the months of August-October in the Wet season. Some of the tributaries that drain into Benue are Mayo in Faro and Chochi river which are all seasonal streams. The study area generally ranges from 152m to 213m above sea level. The area is characterizing by broadly flat topography with gentle undulation hill ranges.

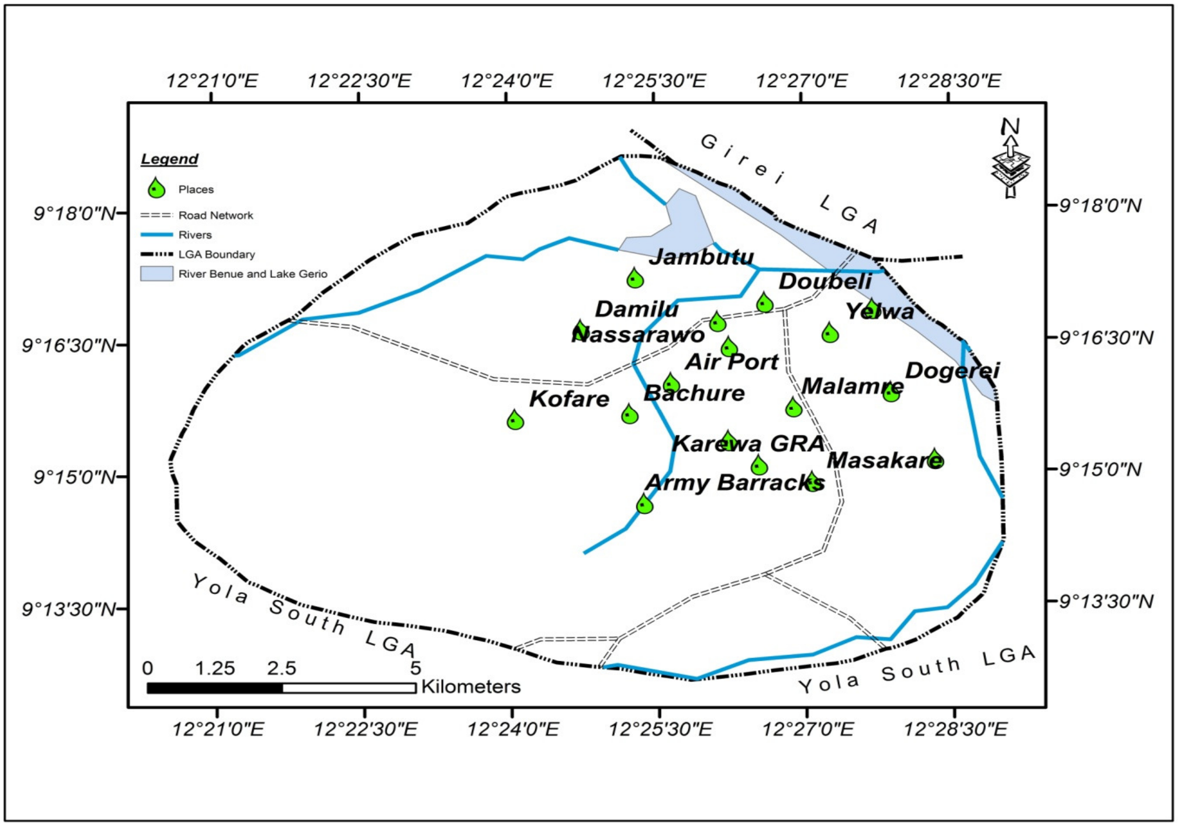

Fig. 1: Map of the Study Area

Methodology

Data which includes climatic variables and surface water body area were used for the study. Mean annual rainfall, relative humidity, minimum and maximum temperature and sunshine hours were the climatic data used in this study while Land sat 8 OLI for 2013, 2014, 2015, 2016 and 2017 were used to extract area of surface water bodies.

All Climatic variables were collected from NIMET, Yola International Airport for a period 1988 to 2017 which land sat 8 OLI were downloaded from USGS web site (glovis.usgs.gov). All the climatic data were summarized in monthly and annual record for easy analysis. Trend analysis was used to examine the annual changes in the climatic variables and the nature of the changes (Increase or decrease) while Land sat 8 was used to extract the area of surface water bodies and then examine the changes over the years. Excel was used to examine the monthly and annual pattern of the climatic variables while Arc GIS 10.2 was used to extract the surface water bodies.

In extracting the surface water bodies of the area, the method suggested by Gao, (1996) was used in Arc GIS 10. 2 with the help of raster calculator tool.

NDWI= (NIR-SWIR)/ (NIR+SWIR)

Where: NDWI = Normalized Difference in Water Index

NIR= near infrared

SWIR= short wave infrared

The raster output produce from the NDWI was used to extract the study area and then reclassified to calculate the surface water body area.

Results and Discussion

Analysis of the Climatic Variables

Seasonal Pattern of Climate Variables in the Study Area

The seasonal analysis of rainfall value is presented in Figure 2. Result of the analysis revealed that the highest rainfall amount is recorded in the month of August with a mean value of 192.8mm while the lowest rainfall was recorded in the month of March with mean value of 4.8mm. In addition, the monthly rainfall distribution showed that onset date of rain in the area is in the month of June where rainfall amount in the month is above 51mm. The pattern also showed that rainfall distribution in the area concurs with the movement of maritime air mass which control rainfall distribution in the country. The result further reveals that, the month of October marks the cessation of rainfall in the study area and then followed by onset of harmattan dust in the month of November which is connected with continental air mass.

Figure 3 shows the Relative humidity of the study area and the lowest value (27.2%) was recorded in the month of February, thus indicating the driest month of the year. This is connected with movement of the continental air mass in which the air mass is dry and makes the humidity to be low. The humidity started to increase from March and reached its peak in August, and then started declining toward December. The highest amount of relative humidity in the month of August clearly explains the peak of Maritime air mass at the northern region.

Maximum and minimum temperature of the study area show almost similar seasonal pattern as revealed in Figure 4. The highest maximum temperature value of 38.7°C was recorded in April and the lowest value of 29.8°C in August. This is attributed to the fact that the high rainfall and relative humidity in the month of August reduce the amount of temperature because of the high amount of cloud cover which reduce the number of sunshine hours and radiation compared to the month of April where the cloud cover is low there by allowing high rate of radiation and sunshine hours. This result is similar with what was obtained in the case of Minimum temperature where the highest value was recorded in the month of April with 27.3°C which later drops to 17.7°C in December.

Result on the sunshine hours as displayed in Figure 5 showed a decrease from February to August and then begins to rise from September to November. The longest duration in terms of sunshine hours is in November with 9.2 hours which can be attributed to the absence of cloud cover; while the shortest duration in sunshine hours is in the month of August with 6.0 hours, which coincides with the occurrence of high cloud cover associated with the month of August as shown in figure 2. Result on wind speeds as displayed in Figure 6 on the other hand shows an increase and decrease characteristic with rising peak of 45 km/hr in the month of May and then falls to minimum of 24 km/hr in November. It then rises again towards the Month of January as shown in Fig 6.

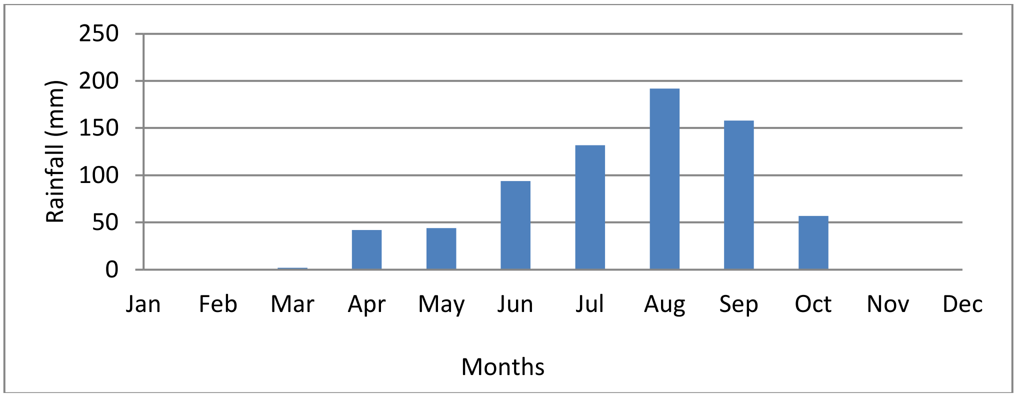

Fig. 2: Seasonal pattern of Rainfall in the Study Area

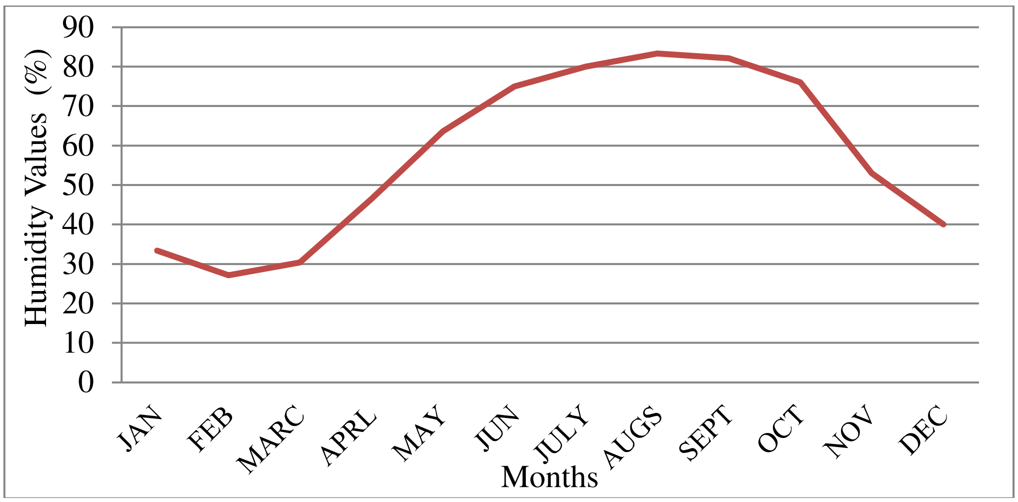

Fig. 3: Seasonal pattern of Relative humidity in the Study Area

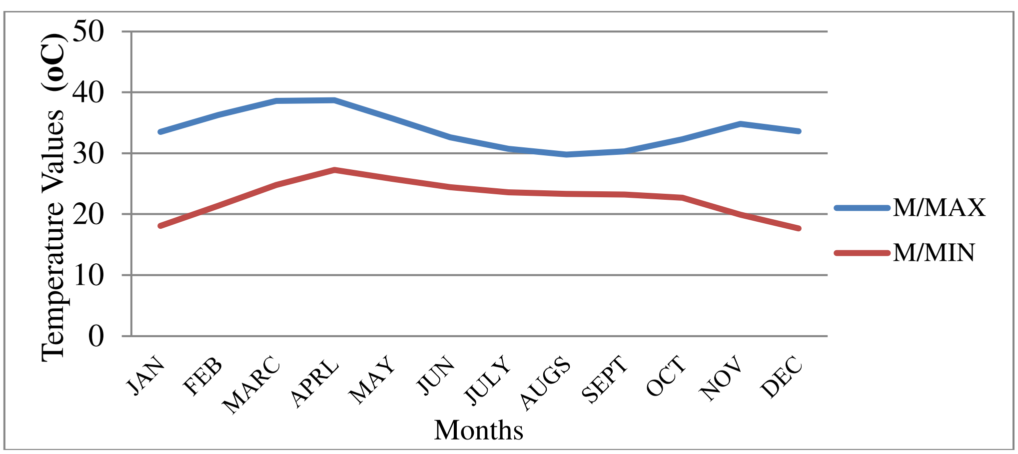

Fig. 4: Seasonal pattern of Maximum Temperature and Minimum Temperature

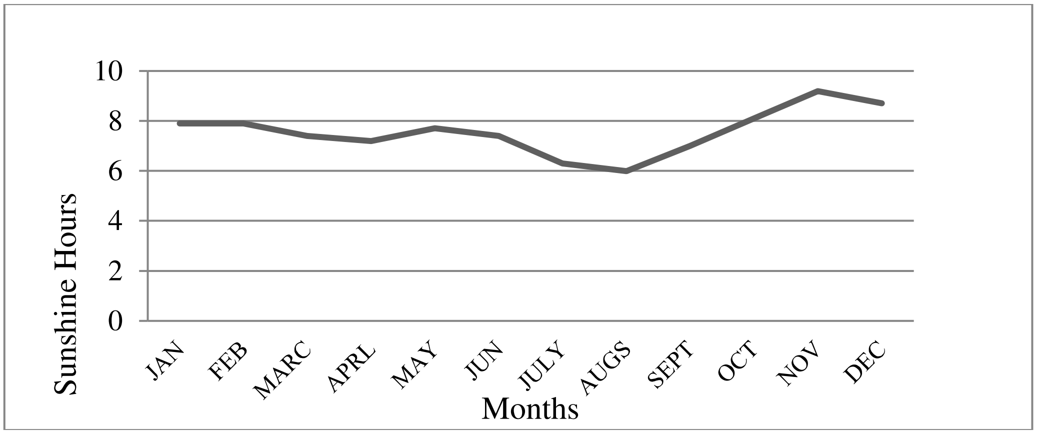

Fig. 5: Seasonal pattern of sunshine hours in the Study Area

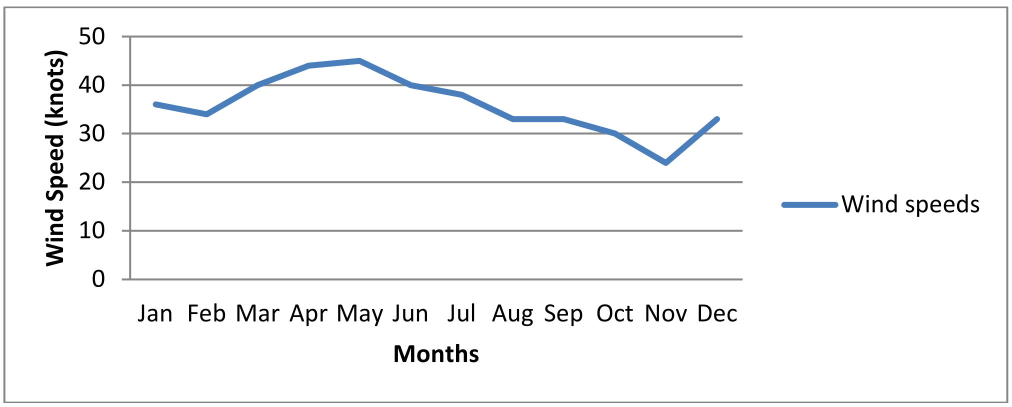

Fig. 6: Seasonal pattern of wind speeds in the Study Area

Annual Trend of Climate Variables in the Study Area

Results of the climatic trends of all the selected climatic variables are presented in figure 7-12. Result of the rainfall trend in the study area revealed a negative trend of -5.2046 at probability level of p=0.07. This negative trend clearly shows that annual rainfall in the study area is decreasing which signified that rainfall amount in the area are decreasing with respect to time. Result of the relative humidity on the other hand showed a significant positive trend of 0.1925 at p=0.000 which implies that the amount humidity in the area is increasing with respect to time. Maximum and Minimum temperature also showed a similar pattern of increase in which the two variables showed a positive trend of 0.0266 and 0.0536 for maximum and minimum temperature at $p<0.01$ respectively. Following the result presented, it is clear that mean annual rainfall and temperature has an inverse relationship within themselves which explained that, as temperature amount increases, the mean annual rainfall decreases and reverse is the case.

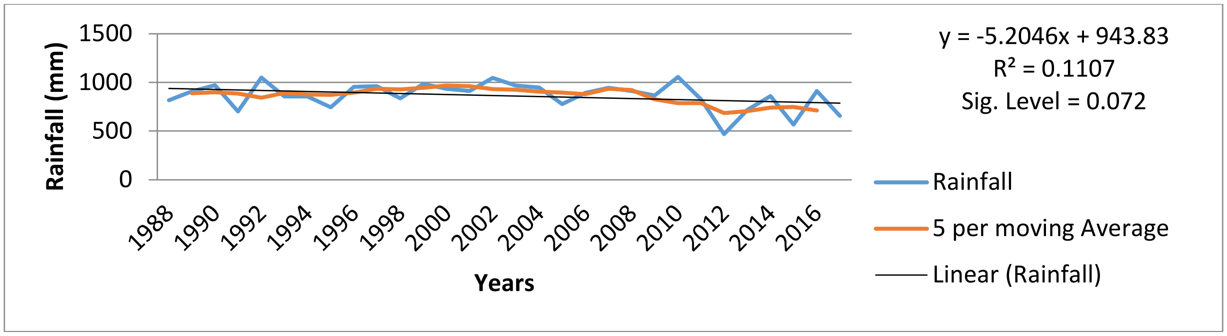

Fig. 7: Rainfall Trend

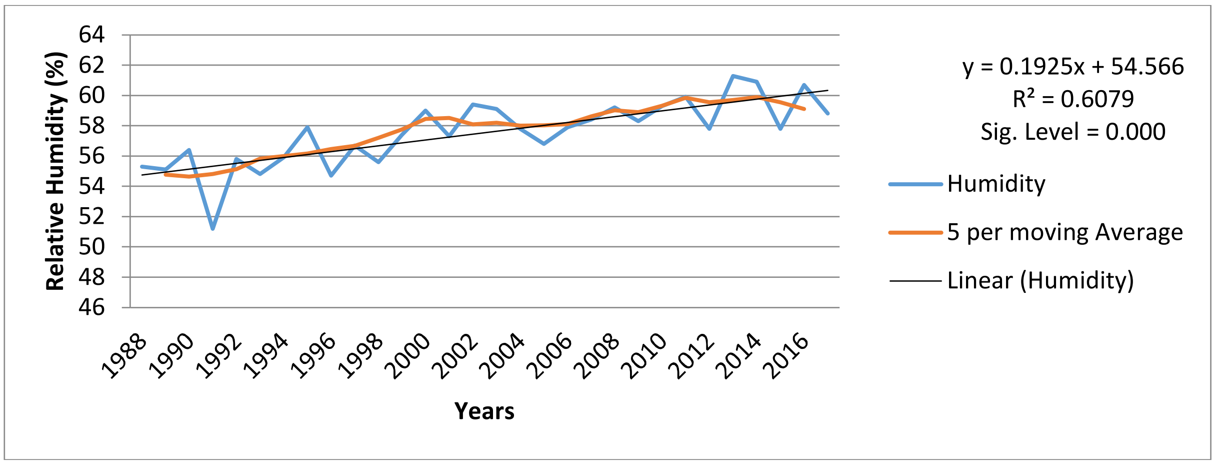

Fig. 8: Relative Humidity Trend

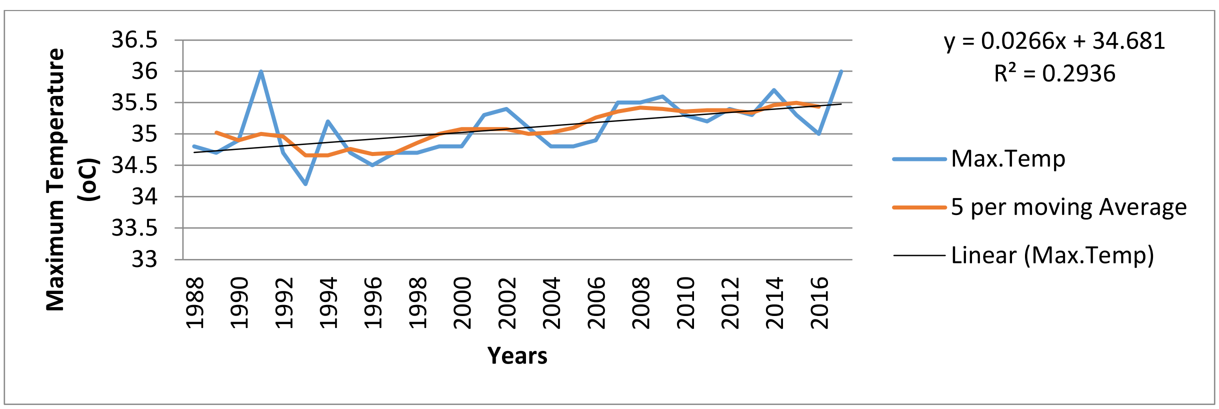

Fig. 9: Maximum Temperature Trend

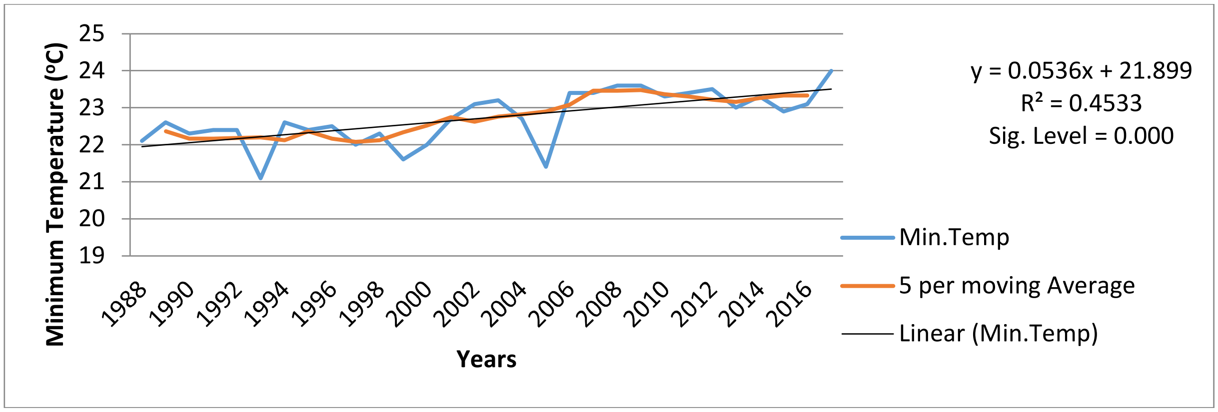

Fig. 10: Minimum Temperature Trend

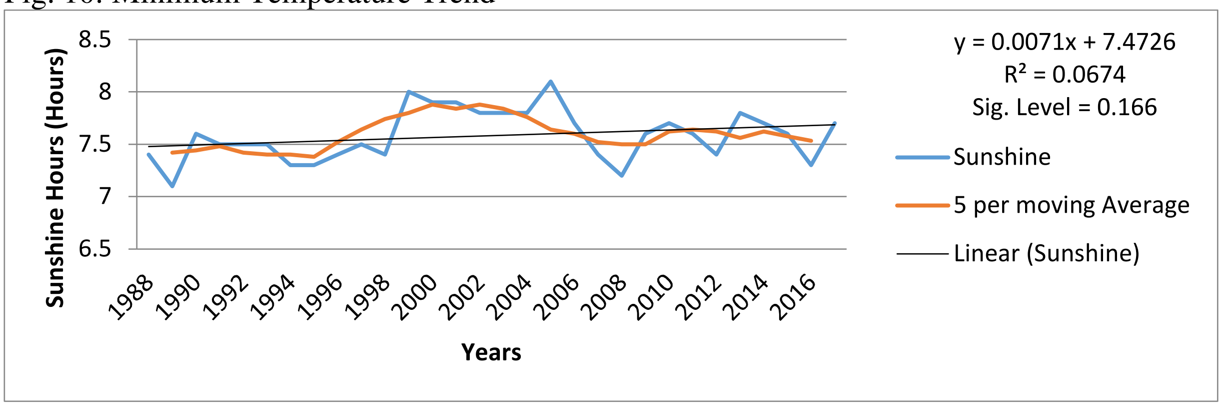

Figure 11: Sunshine Hours Trend

Assessment of the Level of Change in Surface Water Body

Result on the total area cover by open water body is presented in Table 1 and Figure 4. 12. The result revealed that 2016 has the highest area covered by surface water body of 9.961973km^2 while 2013 has the least surface water area of 8.182484km^2. The result also revealed that, surface water body in the study area recorded an increase of 8.182484km^2 and 8.275765km^2 from 2013 to 2014 respectively and then decreases to 7.357435 km^2 in 2014. The area again increases to the highest value of 9.961973km^2 in 2016 and then drop to 8.199833km^2 in 2017. Following the trend of the surface water body in the area, it is clear that, the water area is not stable which clearly implies that there are factors that control the fluctuation of the surface water area as also viewed by Sharma (2003) who documented that, Deforestation, burning of timber and forest vegetation in shifting cultivation has caused water, land and environmental degradation and in many cases irreversible damage to water resources

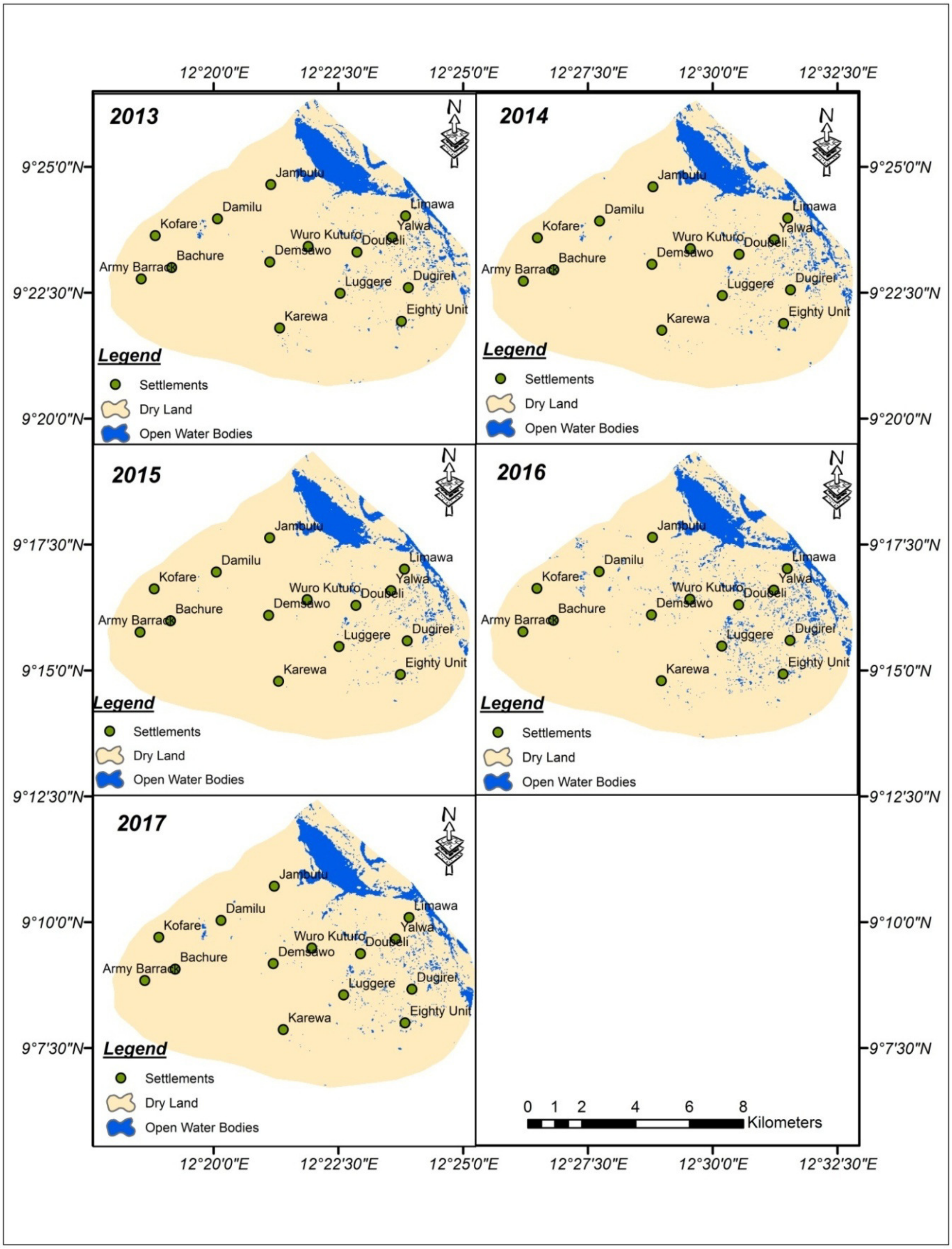

Fig. 12: Measurement of Surface Water Bodies

Table 1: Area covered by surface water

Years	Area Covered (km^2)
2013	8.182484
2014	8.275765
2015	7.357435
2016	9.761973
2017	8.199833

Assessment of the Relationship Between Climatic Variables, Population and Surface Water Body

Assessment of the relationship between climatic variables, population and surface water bodies is presented in Table 2. Result of the analysis revealed that there is a strong positive relationship between surface water and mean annual rainfall in the area at 0.850. This positive relationship clearly revealed that increase in mean annual rainfall amount leads to increase in surface water and reverse is the case. This relationship is not surprising because reduction in the precipitation will generated many hydrological difficulties and problems which include shortage of surface water supply, severe and frequent droughts and flooding as also documented by (Chung-Ho, 2014). Unlike the relationship between rainfall and surface water, relationship between minimum and maximum temperature and surface water on the other hand displayed an inverse relationship of 0.040 and 0.412 respectively. The relationship clearly explained that increase in minimum and maximum temperature lead to decrease in surface water body and reverse is the case. The negative relationship is attributed to the fact that, increase rate of temperature leads to increase rate of evaporation and evapotranspiration which force the surface water to escape to the atmosphere there by reducing the volume of surface water. This is similar with the view of Brown, *et al*., (2007) who also documented that increase temperature affect flow velocity, hydraulic characteristics, water levels, inundation patterns, residence types, changes in wetted areas and habitat availability, and connectivity across habitats. In the same vein, as the atmospheric water vapor content increases, precipitation patterns and runoff change as also documented by IPCC, (2007). Relationship between surface water and sunshine hours also displayed a strong negative relationship of -0.717 which clearly implies that increase in sunshine hours leads to decrease in the level of surface water bodies and reverse is the case. This relationship is attributed to the fact that high rate of sunshine hours determines the rate of evaporation which reduce the level of surface water bodies. Relationship between relative humidity and surface water on the other hand displayed a strong positive relation of 0.580 which signified that increase in amount of humidity lead to increase in level of surface water. This relationship is not surprising because the content of water vapor in the air determines the volume of precipitation received and also determines the volume of surface water as also documented by (IPCC, 2007).

Table 2: Relationship between open water body, climatic variables and population dynamics of the study area

		Surface water bodies	Max. Temp	Min. temp	Rainfall	Humidity	sunshine
Surface water bodies	Pearson Correlation	1	-.412	.040	.850	.580	-.717
	Sig. level		.490	.949	.068	.305	.173
Max. Temp	Pearson Correlation	-0.412	1	.847	-.294	-.257	.611
	Sig. level	0.490		.070	.631	.677	.273
Min. Temp	Pearson Correlation	0.040	.847	1	-.073	-.191	.219
	Sig. level	0.949	.070		.908	.758	.724
Rainfall	Pearson Correlation	0.850	-.294	-.073	1	.789	-.481
	Sig. level	0.068	.631	.908		.112	.412
Humidity	Pearson Correlation	0.580	-.257	-.191	.789	1	.026
	Sig. level	0.305	.677	.758	.112		.967
sunshine	Pearson Correlation	-0.717	.611	.219	-.481	.026	1
	Sig. level	0.173	.273	.724	.412	.967	

Conclusion

Following the result obtained from this study, it was concluded that mean annual rainfall in the area is decreasing while maximum and Minimum temperature is increasing at a steady rate. It was also concluded that the level of surface water in the area is decreasing and that mean annual rainfall have a positive influence on surface water bodies while maximum temperature and sunshine hours have a negative effect on the level of surface water bodies. This is based on the fact that temperature and sunshine hours are major factors that positively influence the level of evapotranspiration. Finally, it was concluded that climatic variables affect surface water bodies at different level and scale.

Recommendations

Base on the findings of this study, the following recommendations were identified;

1. There is a need for climate change control at both local and national level to help control the consequent effect on environmental resource.
2. Members of the public should be enlightenment on the effect of climate change is important by related Government agency. Government at all level should join hands with NGO's and other international communities to enlighten the people on the importance of tree planting.
3. Water resource management and conservation strategies need to be developed and motivated. This will help in both livestock and domestic management; it will also be useful in productive purpose such as irrigation.

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