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RAINFALL VARIABILITY ASSESSMENT AND ITS TEMPORAL IMPLICATIONS FOR CROP PRODUCTION AND WATER MANAGEMENT IN AKWA IBOM STATE, NIGERIA

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ABSTRACT

Assessing rainfall variability over a given location provides useful information for sustainable water management and crop production. The study examined temporal rainfall variability and its trend in Eket and Oron (Coastal areas) and Uyo and Ikot (Ekpene), Akwa Ibom state, Nigeria. The study was conducted in four different locations – coastal areas (Eket and Oron) and upland areas (Uyo and Ikot Ekpene). Daily rainfall data were obtained from Nigeria Meteorological Agency (NiMet) for a period of 30 years (i.e. 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017 and 2018). The standardized precipitation index (SPI) was used to evaluate drought index; and time series was also used to determine its trend. The results showed that coastal areas of Eket and Oron witnessed moderate spell condition in 1990 and 1993 respectively. Moreover, the upland areas of Uyo and Ikot Ekpene witnessed severe dry sell condition in 1990 and 1993. In addition, the upland areas of Uyo and Ikot Ekpene witnessed moderate dry spell condition in 1991 and 1995. The annual rainfall standardized anomaly index of both areas is characterized by moderate dry spell to extreme wet conditions, with increase in near normal, moderately wet, very wet and extreme wet conditions. In addition, the trend of SPI rainfall series for coastal areas shows that Eket, $R^2 = 0.0239$ and $y = 0.056x - 0.9739$; Oron, $R^2 = 0.0306$ ad $y = 0.0637x - 1.0781$; Uyo, $R^2 = 0.0575$ and $y = 0.0735x - 1.143$; and Ikot Ekpene, $R^2 = 0.0568$ and $y = 0.082x – 1.4354$. This shows that the areas witnessed very minimal occurrence of dry spell with the highest recorded in the upland areas compared to coastal areas. Therefore, Akwa Ibom state annual rainfall trend required effective monitoring to prevent flooding, erosion and economic losses.

Keywords: Drought, rainfall, variability, sustainable, crop production, Akwa Ibom State, climate, temporal trends, water management, standardized precipitation index (SPI)

1.0 INTRODUCTION

Climate change and its variability pose a great threat to global food security and socio-economic development (Agbor *et al.*, 2019). Despite the recent advancement in science and technology, climate remains the most important determining factor in agricultural production (Ezenwaji and Nzoiwu, 2016). Therefore, climate variability study is very essential for sustainable agricultural production and developmental planning. Climate variables play a major role in determining the availability of food (Isaiah *et al.*, 2020b). Furthermore, Climate variables play a major role in determining the availability of food (Isaiah *et al.*, 2020b), for example, rainfall, played an essential and crucial role in crop production. In addition, its support plant growth development and ensures physiological plant stability.

It provides the needed soil moisture in which nutrients and chemical constituents are carried through the plant. It also provides water, which is the main constituent of the physiological plant tissue and a reagent in photosynthesis (Yamusa *et al.*, 2015).

Moreover, excessive rainfall can affect crop productivity in various ways, including direct physical damage, restricted root growth, oxygen deficiency and nutrient loss. According to Umoh (2009), continuous heavy downpour decreases yield of maize and other cereal crops in cooler areas and the effect is exacerbated in areas where there is no proper drainage system. Regular rainfall pattern is vital for healthy plants, too much or insufficient rainfall is detrimental to plants growth and development (Udoinyang and Edem, 2012).

Furthermore, in an agricultural drought condition moisture content of the soil will decrease and crop will be desiccated and more vulnerable to pests and diseases attack. A drought in agriculture is defined as a set of environmental factors that cause unfavorable plant reactions, which can vary from decreased crop and forage yields to complete crop or forage failure. Agricultural drought is concerned with the soil moisture deficiency in relation to climatic factors and their impacts on agricultural production and economic profitability (Abaje *et al.*, 2013). It is considered to have set in when the soil moisture availability to plants has dropped to such a level that it adversely affects the crop yield and hence agricultural profitability (Musa, 2010). Insect and plant disease outbreaks that stress vegetation can be caused by drought. Additionally, drought raises the dangers of wind erosion and wildfire, both of which can be harmful to the wellbeing of agricultural communities. Finally, ecosystem processes necessary for agriculture, such as pollination, soil retention, and soil fertility, can be affected by drought. Rainfall provide a critical framework for assessing drought index in an area (Umoh, 2009). Thus, change in climate can leads to different events such as drought, flood and rise in temperature resulting in soil degradation leading to low crops yield (Udoh *et al.*, 2005).

Therefore, objective of the study is to examine rainfall variability and trends in selected areas of Akwa Ibom state, with a view to assess the potential impacts on water management and crop production

2.0 MATERIALS AND METHODS

2.1 Description of study area

The study was conducted in Akwa Ibom State in four different locations; two each from upland and coastal areas; i.e. coastal areas (Eket and Oron) and upland areas (Uyo and Ikot Ekpene), (Fig. 2.1).

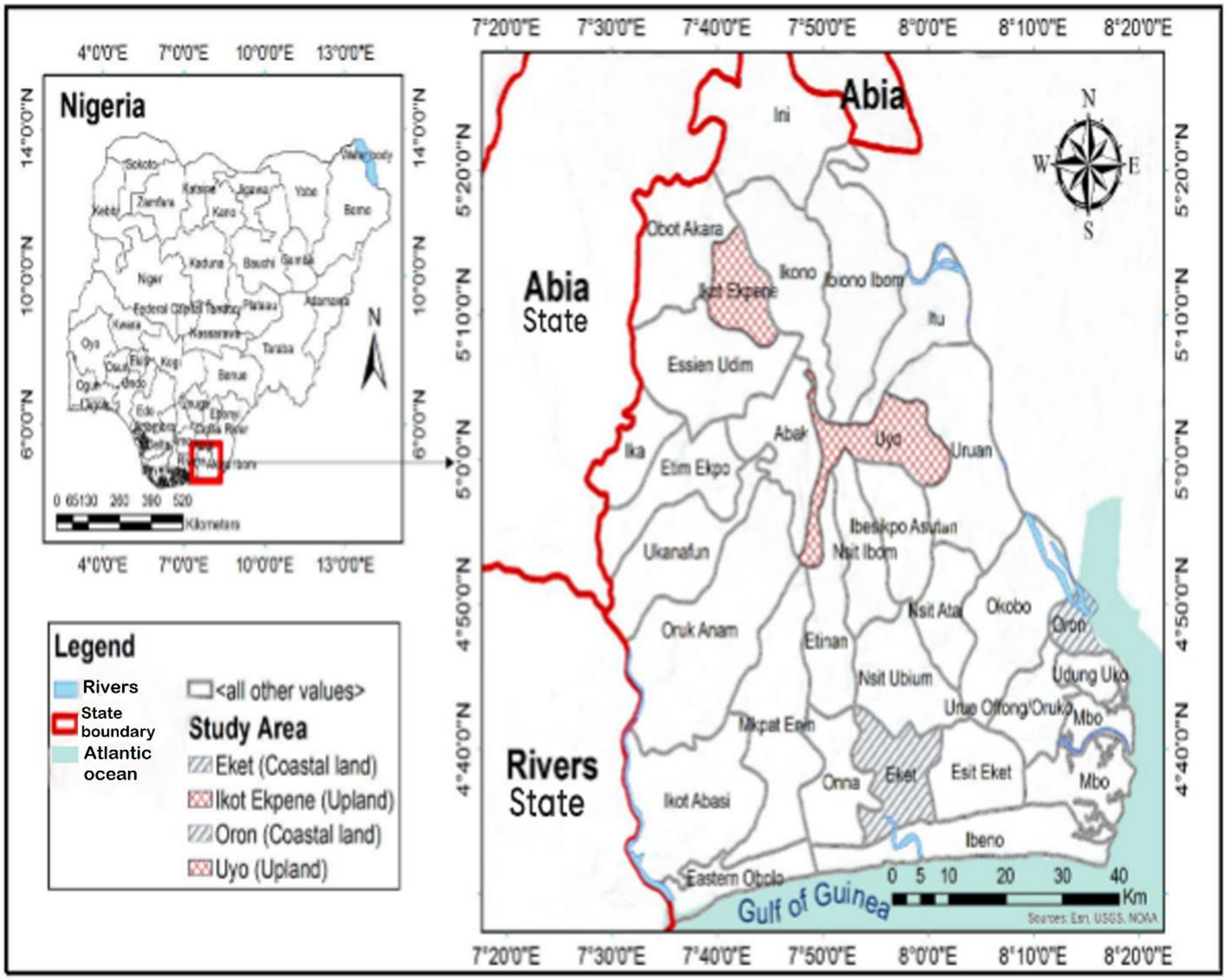

Fig. 1 Akwa Ibom State showing the study locations

Akwa Ibom State lies in the coastal plain of South Eastern Nigeria, where sediments are supplied by Cross River, Qua Iboe River, Imo River and Gulf of Guinea. Generally, landscape of the state comprises of a low-lying plain and riverine area, with elevation of 185.32 meters above sea level (AKSMLS, 2009; Petters *et al*., 1989). Akwa Ibom State lies between latitude 04^{0}56'23.06"N and longitude 07^{0}52'09.71"E. The State is bordered on the East by Cross River State, on the North and Northwest by Abia State, on the Southwest by Rivers State and on the South by the Atlantic Ocean. The state covers a total landmass of about 8,412 square kilometer and comprises of 31 Local Government Areas (AKSMLS, 2009). Akwa Ibom State has an estimated population of 3,920,208 (NPC, 2006). The geographical description of the study areas (i.e. Eket, Oron, Uyo and Ikot Ekpene) are as follow:

2.1.1 Eket

Eket is a coastal area that lies between latitude $04^0$38'50.61"N and longitude $07^0$56'34.28"E; with elevation of 24.08 meter above sea level. A total landmass of 83.21 square kilometer. It is bordered on the North and Northeast by Nsit Ubium, Urue Offion/Oruko and Esit Eket Local Government Areas, on the Northwest and Southwest by Onna, Etinan and Ibeno Local Government Areas and on the South and Southeast by Esit Eket and Ibeno Local Government Areas (AKSMLS, 2009). It has an estimated population of 200,587 (NPC, 2006).

2.1.2 Oron

Oron is a coastal area that lies between latitude $04^0$48'27.31"N and longitude $08^0$14'15.12"E; with elevation of 39.32 meter above sea level and total landmass of 70.20 square kilometer. It is bordered on the North and Northeast by Okobo Local Government Area and Atlantic Ocean, on the Northwest and Southwest by Okobo and Urue Offiong/Oruko Local Government Areas and on the South and Southeast by Udung Uko Local Government Area and Atlantic Ocean (AKSMLS, 2009). It has an estimated population of 156,461(NPC, 2006).

2.1.3 Uyo

Uyo is an upland area that lies between latitude 05^0 02'14.29"N and longitude 07^0 54'51.11"E; with elevation of 67.06 meter above sea level. A total landmass of 187.43 square kilometer. It is bordered on the North and Northeast by Ikono, Ibeno Ibom, Itu and Uruan Local Government Areas, on the Northwest and Southwest by Abak, Oruk Anam and Mkpat Enin Local Government Areas and on the South and Southeast by Uruan, Ibensikpo Asutan, Nsit Ibom and Etinan Local Government Areas (AKSMLS, 2009). It has an estimated population of 436,606 (NPC, 2006).

3.1.4 Ikot Ekpene

Ikot Ekpene is an upland area that lies between latitude $05^0$11'22.39" N and longitude 07^0 42'53.32"E; with an elevation of 89.01 meter above sea level. A total landmass of 116.5 square kilometer. It is bordered on the North and Northwest by Obot-Akara Local Government Area, on the Northeast and Southeast by Ikono Local Government Area and on the South and Southwest by Essien Udim Local Government Area. It has an estimated population of 209,400 (NPC, 2006).

2.2 Climate of the Study Area

Akwa Ibom State has a humid tropical climate, characterized by distinct wet and dry seasons. In the South and Central parts of the state (nearer the coast), wet season lasts for about 10 -11 months (February/March – mid November), but towards the far north, it reduces to about nine months (i.e. March - October). The dry season begins in mid – November and ends in February or March (Petters *et al*., 1989). Annual rainfall amount varies from 3,200 mm along the coast to 2,250 mm in the northern fringe. Temperature values are relatively high in Akwa Ibom State throughout the year with mean annual values varying between 26 and 28^0C. The months with highest temperatures include February and March (the period just before heavy rains), while July – September have lowest temperatures (when heavy rains and cloud cover reduces insulation reaching the surface (NiMet, 2018). Also, relative humidity remains at average of 70 – 80 percent throughout the year. Average sunshine circulates to 1,450 hours per year and the annual evaporation rate range from 1,500 – 1800 mm (Ekpeyong, 2013).

2.3 Soils of the Study Area

Agricultural lands in Akwa Ibom State put to arable crop production are developed from parent materials which are grouped into (a) coastal plain sand (b) beach ridge sand (c) sand stone/shale (d) alluvial deposits. The soils are influenced by these original materials, heavy rainfall moderated by topography and general agricultural land use pattern and management (Ibia and Udo, 2009). The coastal plain sand is the most extensive parent material, occupying most of the central parts of the State, sandstone/shale occupies the north; alluvial deposit occupies the east and northeast, while the beach ridge sands occupy the southern coast bordering the Atlantic Ocean (Udoh *et al.*, 2007). Generally, soils derived from the coastal plain sands, beach ridge sands and sandstone are characteristically sandy in texture due to the nature of these parent materials. Coastal plain sands are highly weathered, better developed and more matured, compared to those of the beach ridge sand and sandstones (Ibia and Udo, 2009).

2.4 Vegetation and land use

Akwa Ibom State falls within the broad vegetation community of lowland rainforest, mangrove forest and coastal vegetation. After devastation by man, this vegetation has degraded into a mosaic farmland/oil palm forest, riparian forest and oil palm forest. The major vegetables and arable crops grown in the areas are Fluted pumpkin (*Telfairia occendentalis*), Waterleaf (*Talinum triangulare*), Okra (*Abemoschus esculentus*), Cassava (*Manihot esculenta*), Yams (*Dioscorea* spp), Cocoyam (*Colocesia* spp and *Xanthosoma* spp) and Maize (*Zea mays*). Mixed cropping is commonly practiced in the area (Udoh, 2003).

Oil palm is one of the major economic tree crops actively cultivated throughout the state. Other tree crops include Rubber (*Heaveabra siliensis*), Coconut *(Cocos nucifera*) and Cocoa (*Theobroma cocao*). Vegetation of the state is classified into five major sub-formations namely: mangrove swamps, fresh water swamps, farmland/oil palm forest mosaic, oil palm forest and farmland nature forest mosaic (Tohal, 1982).

2.6 Data collection

Daily rainfall data for coastal area (Eket and Oron) and upland area (Uyo and Ikot Ekpene were obtained from Nigeria Meteorological Agency, Abuja, for a period of 30 years (1988 - 2018).

Table 1. Geographical characteristics of the weather stations

Location	Latitude	Longitude	Elevation (m)
Eket	04°38'47.43"N	07°58'00.20"E	17.67
Oron	04°48'27.24"N	08°15'00.52"E	30.16
Uyo	05°30'45.36"N	07°55'56.16"E	54.23
Ikot Ekpene	05°11'22.39"N	07°42'55.40"E	70.10

Source: NiMet, 2018

2.7 Statistical Analysis

Drought index was determined using Standard Precipitation Index (SPI) whilst time series was used to determine its trend.

Table 2. Standard Precipitation Index (SPI) Range and Classification

SPI values	categories
>2.0	Extreme wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderate wet
-0.99 – 0.99	Near normal
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
>-2.0	Extreme drought

McKee *et al.,* 1995

3.0 RESULTS AND DISCUSSION

3.1 Drought Index

Table 3 and 4 shows the standard precipitation index (SPI) values and their intensities index for the coastal areas of Eket and Oron. The coastal area of Eket witnessed moderate agricultural drought in 1990 and 1993 with SPI values of -1.5936 and -0.6582 respectively, whilst Oron also witnessed moderate agricultural drought in 1990 and 1993 with SPI values of -1.4427 and -1.0255 respectively.

Moreover, in the upland area of Uyo (Table 5), 1990 and 1993 years witnessed severe agricultural drought with SPI values of -1.6597 and -0.1662 respectively. Similarly, moderate drought was experienced in 1991 and 1995 with SPI values of -1.2049 and -1.2314 respectively. The upland area of Ikot Ekpene (Table 6) experienced severe agricultural drought in 1990 and 1993 with SPI values of -1.7921 and -1.6245 respectively. Moderate agricultural drought was also recorded in 1991 and 1995 with SPI values of -1.4558 and 1.1779 respectively.

This shows that the coastal areas of Eket and Oron witnessed less drought condition than the upland areas. According to Omotosh (2007), the rainforest zone will continue to witnessed minimal drought condition with the least effect occurring in the coastal areas due its proximity to water bodies.

The other years in both coastal and upland witnessed near normal, very wet, moderate wet and extreme wetness with the third decade recording highest wet conditions and it occurred in coastal areas. The increase in wet conditions in coastal areas than upland areas may be attributed to continentality (Omotosho and Abiodu, 2007). Intercontinental panel on climate change, IPCC (2007 and 2011) stated that an increase in global rainfall amount would be mostly concentrated in rainforest zone and other wet tropical areas, resulting in wet conditions decade by decade with coastal areas witnessing the highest wet condition.

3.2 Standardized Precipitation Index

Figures 2 – 5 show the trends of standardized precipitation index (SPI) for coastal areas (Eket and Oron) and upland areas (Uyo and Ikot Ekpene). The figures show increase in SPI in all the areas. In Eket, $R^2 =$ 0.0239 and $y = 0.082x – 0.9739$; Oron, $R^2 = 0.0306$ and $y = 0.0657x – 1.0781$; Uyo = $R^2 = 0.0575$ and $y = 0.0737x – 1.143$; and Ikot Ekpene, $R^2 = 0.0568$ and $y = 0.082x – 1.4554$. These indicate that, coastal areas experience less increase in agricultural drought condition than the upland areas. Thus, the entire areas witnessed minimal agricultural drought condition ranging from $R^2 = 0.0239 – 0.0568$. This implied that sustainable production of crop could be achieved in both areas with little or no irrigation facilities. Isaiah *et al.*, (2020a), stated that sustainable production of crops can be achieved in Akwa Ibom State provided that crops are selected based on the rainfall distribution in the state as well as its water requirement.

Table 3. Annual rainfall standardized anomaly index for Eket

Year	Rainfall (mm)	SPI	Intensity index
1989	2485.90	-0.2342	NN
1990	2253.90	-1.5936	MD
1991	2384.30	-0.3916	NN
1992	2259.00	-1.5857	NN
1993	2212.20	-0.6582	MD
1994	2657.60	-0.4682	NN
1995	2489.70	-0.2283	NN
1996	2600.30	-0.2569	NN
1997	1968.30	-0.1361	NN
1998	3125.30	-0.2436	NN
1999	3438.70	0.2420	NN
2000	3734.40	0.7001	NN
2001	3801.20	0.8036	NN
2002	3726.30	0.6876	NN
2003	3297.90	0.0239	NN
2004	3612.10	0.5107	NN
2005	3687.40	0.6273	NN
2006	3465.10	0.2829	NN
2007	3735.10	0.7012	NN
2008	3886.40	1.9356	VW
2009	3906.40	1.9666	VW
2010	3775.40	0.7637	NN
2011	3869.60	0.9096	NN
2012	4084.00	2.4418	EW
2013	3741.80	0.7116	NN
2014	3606.10	1.5014	MW
2015	3622.20	0.5263	NN
2016	3500.20	1.3373	MW
2017	3746.97	2.7196	EW
2018	3801.30	0.8038	NN

NN = near normal, MD = moderate drought, VW = very wet, EW = extreme wet, MD = moderate drought, SD = severe drought

Table 4. Annual rainfall standardized anomaly index for Oron

Year	Rainfall (mm)	SPI	Intensity index
1989	2765.60	-0.5786	NN
1990	2729.10	-1.4427	MD
1991	2662.90	-0.3591	NN
1992	2896.40	-0.3487	NN
1993	2511.30	-1.0255	MD
1994	2904.60	-0.3343	NN
1995	3045.40	-0.0869	NN
1996	2902.80	-0.3375	NN
1997	3084.20	-1.8187	NN
1998	2802.50	-0.5137	NN
1999	3004.40	-0.1589	NN
2000	2807.40	-0.5051	NN
2001	3252.00	0.2762	NN
2002	2797.70	-0.5222	NN
2003	2561.70	-0.9369	NN
2004	3010.70	-0.1479	NN
2005	3007.00	-0.1544	NN
2006	2607.40	-0.8566	NN
2007	3427.80	0.5851	NN
2008	3061.30	-1.4589	VW
2009	2529.20	-1.9940	VW
2010	3125.20	1.0534	MW
2011	3521.10	0.7491	NN
2012	4044.90	1.6696	EW
2013	3563.60	0.8238	NN
2014	3669.50	1.0099	MW
2015	3568.90	0.8331	NN
2016	3769.10	1.1849	EW
2017	3515.60	1.7394	EW
2018	3696.70	1.0577	MW

NN = near normal, MD = moderate drought, VW = very wet, EW = extreme wet, MD = moderate drought

Table 5. Annual rainfall standardized anomaly index for Uyo

Year	Rainfall(mm)	SPI	Intensity index
1989	2253.90	-0.0607	NN
1990	2133.30	-1.6597	SD
1991	2210.30	-1.2049	MD
1992	2172.20	-0.3310	NN
1993	2222.00	-0.1662	SD
1994	2108.00	-1.3434	NN
1995	2081.40	-1.2314	MD
1996	1718.10	-0.8335	NN
1997	1823.40	-0.4851	NN
1998	2202.60	-0.2304	NN
1999	1703.50	-0.8818	NN
2000	1808.30	-1.5351	NN
2001	1909.70	-1.1996	NN
2002	2130.50	-0.4690	NN
2003	2073.50	-0.6576	NN
2004	2563.20	0.9627	NN
2005	2418.60	0.4843	NN
2006	2471.90	0.6606	NN
2007	2178.90	-0.3088	NN
2008	2410.40	1.4571	MW
2009	2391.10	1.3933	MW
2010	2509.40	0.7847	NN
2011	2548.90	0.9154	NN
2012	2615.30	1.1351	MW
2013	2899.00	2.0738	EW
2014	2787.70	1.7055	MW
2015	2507.10	0.7771	NN
2016	2333.80	1.2037	MW
2017	2324.40	1.1726	MW
2018	2656.70	1.2721	MW

NN = near normal, MD = moderately drought, VW = very wet, EW = extremely wet, MD = moderately drought

Table 6. Annual rainfall standardized anomaly index for Ikot Ekpene

Year	Rainfall (mm)	SPI	Intensity index
1989	1783.80	-0.7466	NN
1990	1830.10	-1.7921	SD
1991	1751.10	-1.4558	MD
1992	1590.10	-0.3932	NN
1993	1520.80	-1.6245	SD
1994	1829.50	-0.5941	NN
1995	2060.80	1.1779	MD
1996	1532.40	-0.5857	NN
1997	1872.20	-0.4516	NN
1998	1754.50	-0.8444	NN
1999	1699.00	-0.0297	NN
2000	1712.70	-0.9839	NN
2001	1695.70	-1.0407	NN
2002	1920.10	-0.2917	NN
2003	1700.10	-0.1260	NN
2004	1838.20	-0.5651	NN
2005	1704.10	-0.8127	NN
2006	1815.80	-0.6398	NN
2007	2277.30	0.9006	NN
2008	2167.70	0.5347	NN
2009	2690.40	2.2794	EW
2010	2429.10	1.4072	MW
2011	2692.60	2.2867	EW
2012	3144.80	3.7961	EW
2013	2650.50	2.1462	EW
2014	2038.00	0.1018	NN
2015	1814.00	-0.6458	NN
2016	2279.00	1.9062	EW
2017	2023.10	0.0521	NN
2018	2407.31	1.3345	MW

NN = near normal, MD = moderately drought, VW = very wet, EW = extremely wet, MD = moderately drought

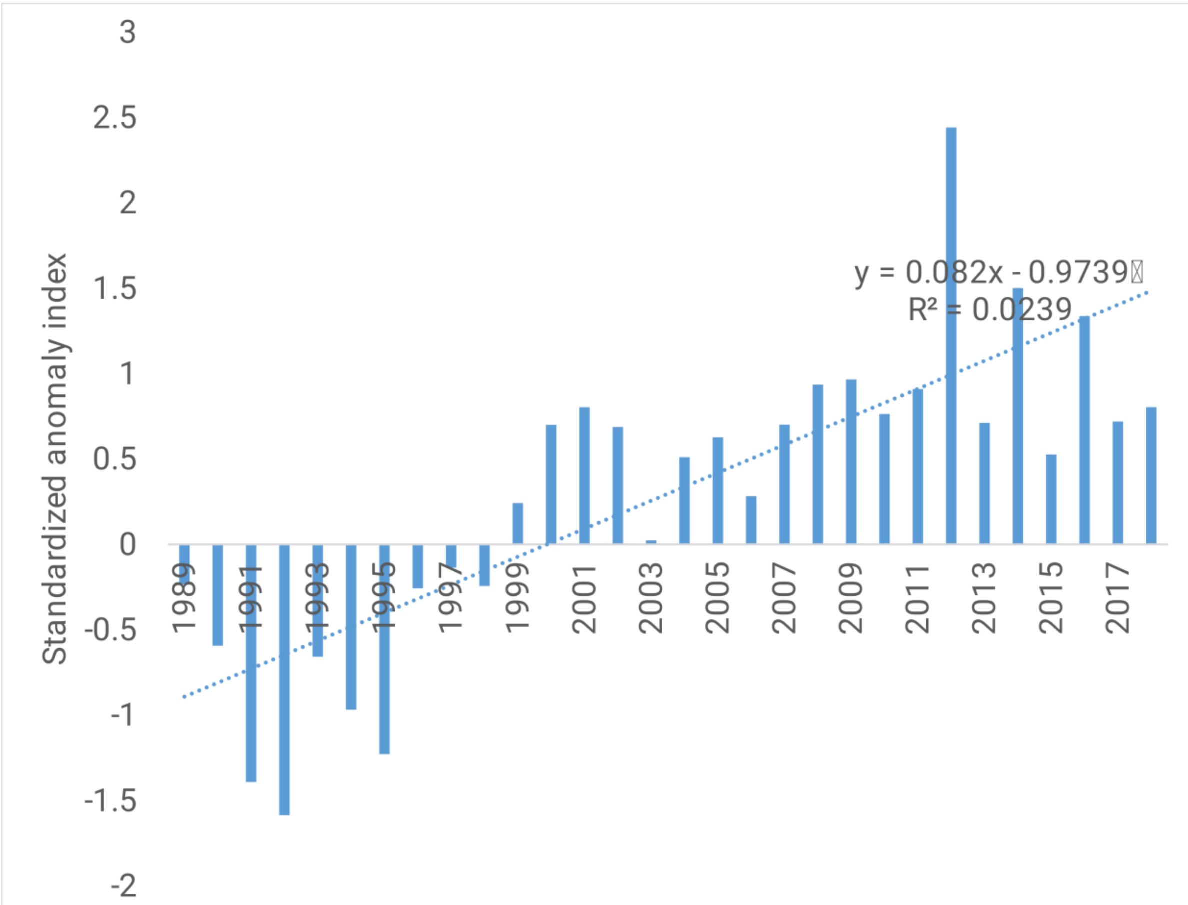

Fig. 2: Standardized precipitation index graph for Eket

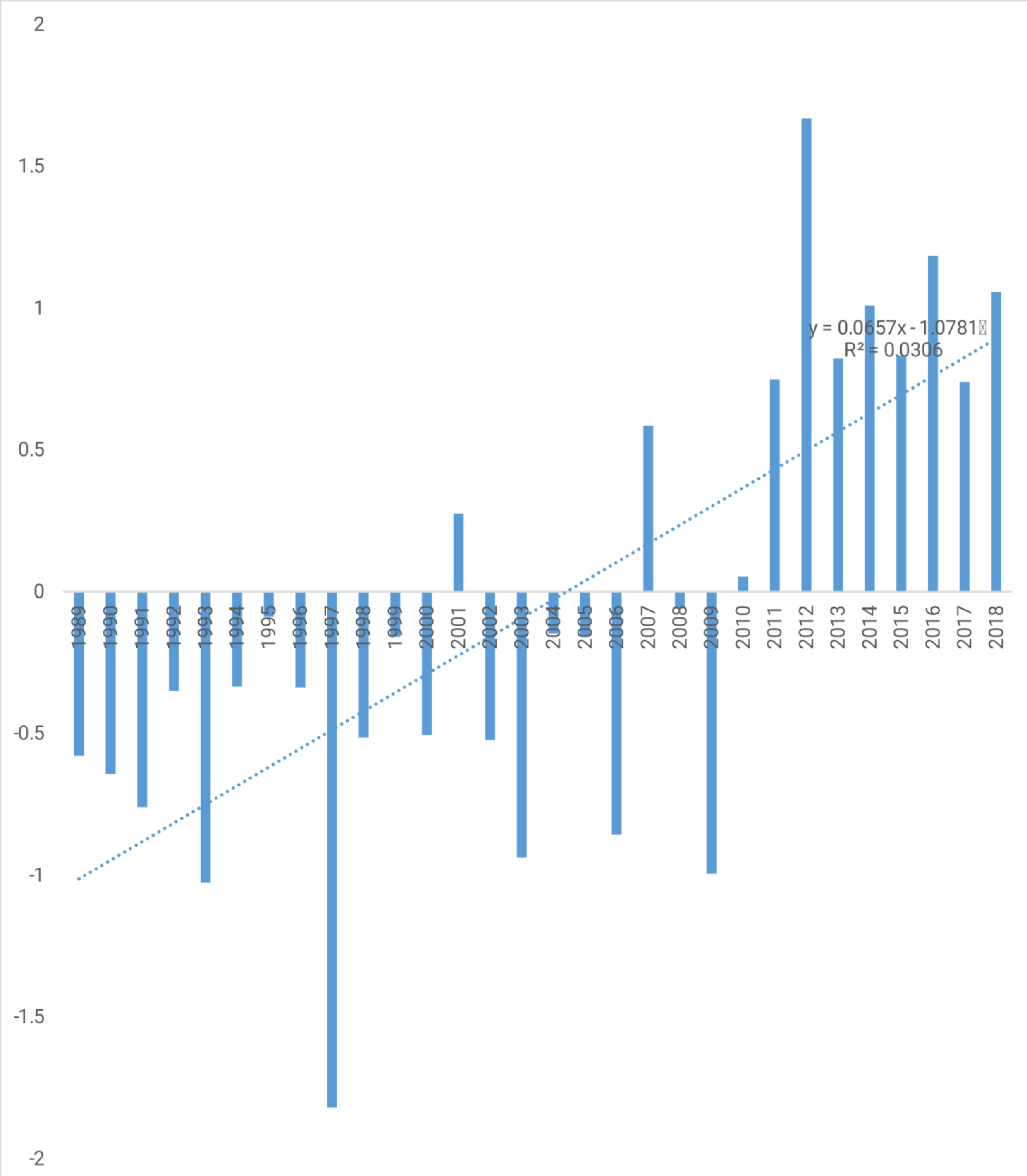

Fig. 3: Standardized precipitation index graph for Oron

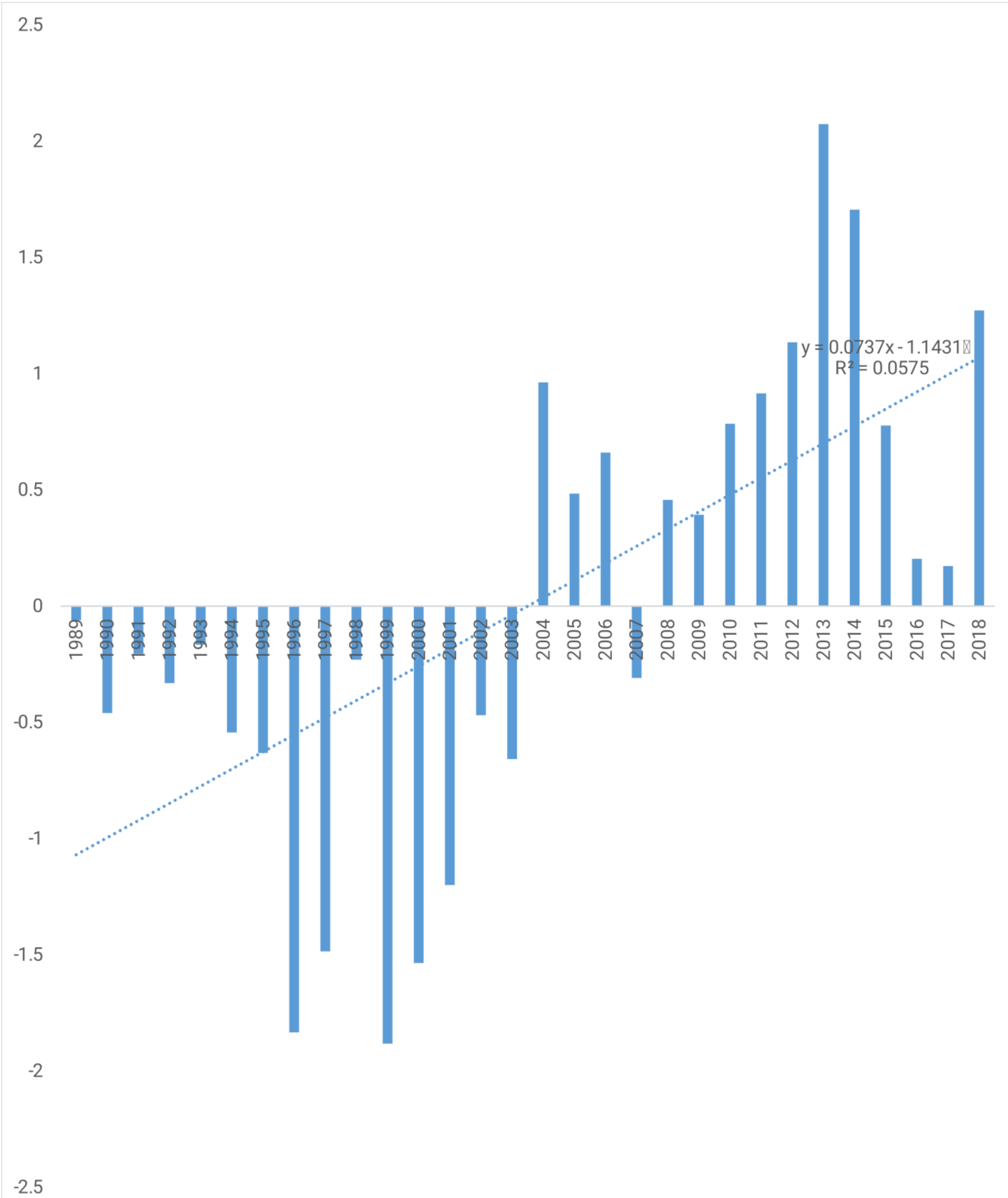
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Fig. 4: Standardized precipitation index graph for Uyo

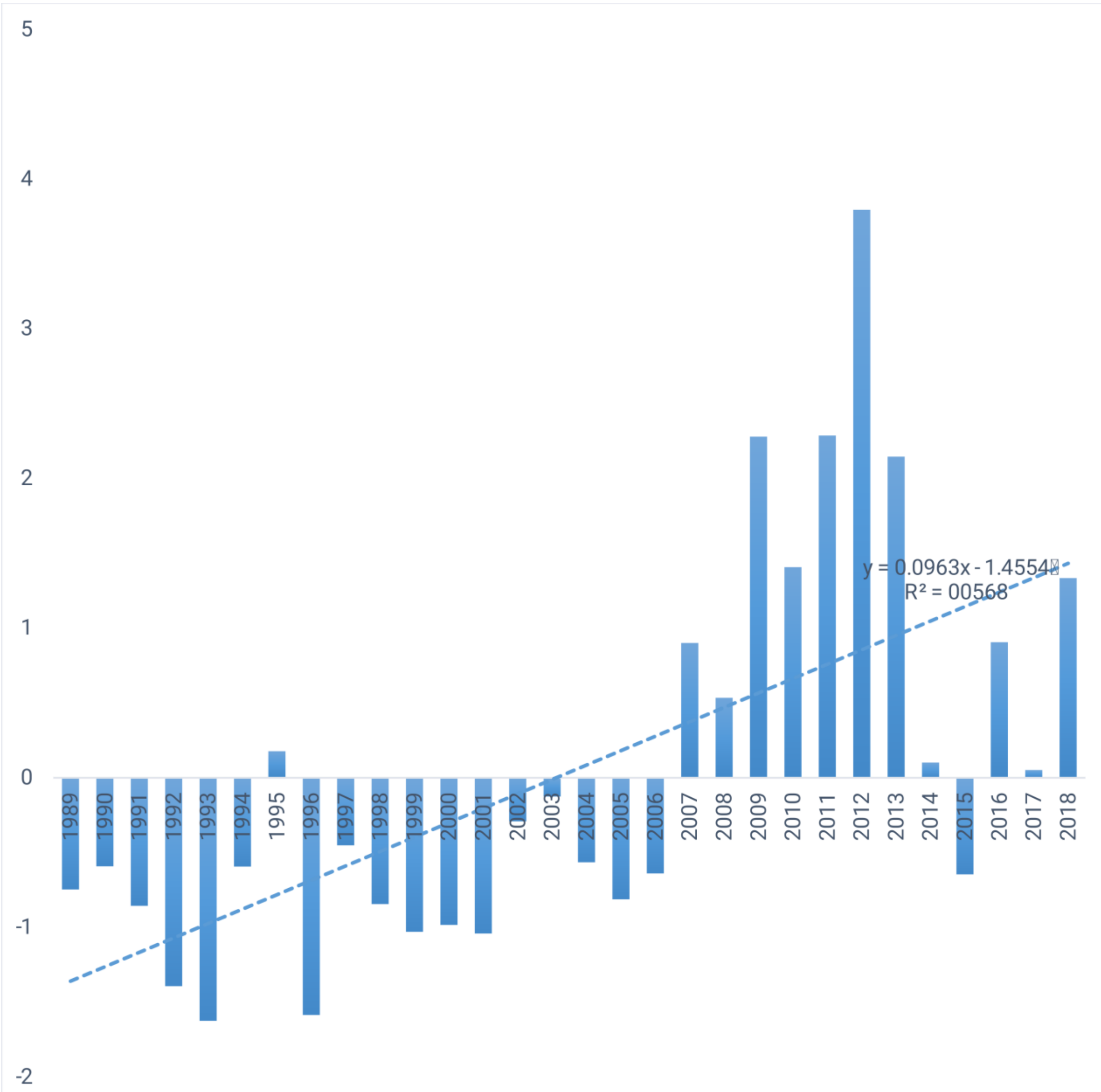

Fig. 5: Standardized precipitation index graph for Ikot Ekpene

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