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Statistical Analysis of Extreme Rainfall Trends Events over Savanna Zones of Nigeria and its' Possible Impacts

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Abstract: This study analysed the trends in extreme rainfall of fourteen (14) synoptic stations in the savanna zones of Nigeria for the period of 35 years (1981-2015). The study acquired daily rainfall data from Environmental Management Programmed, Federal University of Technology Minna. The data was categories into seven extreme indices (heavy, very heavy, extremely heavy rainfall days, 1-day annual maximum rainfall amount, five 5-days annual maximum rainfall amount, Consecutive wet days, and simple daily intensity index) by using ETCCDI indices through RClimDex software. Statistical tests of Mann-Kendall (MK), based on a non-parametric approach was use to evaluate the possible trend in the derived indices. Results showed mixed trends of significant and insignificant in the seven selected extreme indices in some stations across the study areas. Three stations (Bauchi, Kano, and Katsina) in Sudano-Sahelian savanna zones showed consistent significant increasing trends in most of the extreme indices while two stations (Abuja and Yola) showed consistent decreasing trends in most of the extreme indices. Generally, the results showed an increase in the occurrence of extreme rainfall events in the selected variables. The increase trends are possible pointer to climate change and a possible influencing factor to the frequent occurrence of flooding across the study areas.

Keywords: Extreme, Mann-Kendall, Nigeria, Rainfall, Savanna

Introduction

Scientific studies suggest that the global climate has changed and its impact is currently a major issue (Worku, et al., 2018). One of the pointers to the global climate change is an extreme rainfall, although rainfall extreme could occur under normal climate conditions (Zhang et al., 2017). It is understood that "global warming is responsible for high frequency of rainfall events (Panthou, et al., 2014) Other researches (Kug & Ahn, 2013; Sibanda, et al., 2017) suggest that an increased in atmospheric moisture content resulting in an increasing rainfall extreme events is linked with global climate change. Therefore, understanding an extreme rainfall events could aid possible understanding of global climate change and frequent flooding across the world and at local level.

Researches across the world indicate a mixed tendency in extreme rainfall. For example Lupikasza, Hansel, & Matschullat, (2011) in southern Poland and central-eastern Germany observed downward trends in extreme rainfall in southern Poland and an upward trend in central-eastern Germany. Shahid, (2011) in Bangladesh found an increased trend in days of heavy rainfall and decreased trends in consecutive dry days, Basher et al., (2017) over northeast Bangladesh found a decreased trend in the indices of extreme rainfall and Chandrashekar & Shetty, (2018) in Western Ghats and coastal regions of Karnataka found contrasting trends in the extreme rainfall indices. Chandrashekar & Shetty, (2018) reported that the global warming is responsible for the variation in extreme rainfall. Although studies climate extreme exist at global, continental and sub-regional, (Basher et al., 2017) suggested that scientific investigations should be based on local observations of historical climate.

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In Africa researches have also showed a mixed tendency of extreme events. For example Ongoma, et al., (2016) in equatorial East Africa found a downward trend in extreme rainfall for all indices investigated. Worku, et al., (2018) in Jemma Sub-Basin, Upper Blue Nile Basin, Ethiopia detected an increased extreme rainfall event. Gummadi et al., (2017) in south-western parts of Ethiopia found an increased annual extreme rainfall event. Atiah, et al., (2020) in Ghana found a mixed trend of significant decreased in wet indices over the Volta Lake and insignificant increased trends in the Northern parts of the country. It is noteworthy that most the previous studies adopted the designed of Expert Team on Climate Change Detection and Indices (ETCCDI) to analysed extreme rainfall.

In Nigeria like many other developing countries where the bulks of her population's primary economic activities dependent on climate, climate extremes has negative impacts on most of the rural and poor urban inhabitant (Sa, et al., 2017). Similarly, the bulk of the inhabitants are vulnerable to climate extreme as houses constructions are of organic origin such as thatch, mud, and timber based on the creativity and indigenous technological know-how (Amasuomo & Amasuomo, 2017; Osun, 2016). Therefore any above normal rainfall could lead to earth building deterioration, leaking of roof, and collapse of buildings (Osun, 2016) with loss of life and properties. Generally, extreme climate events do not only affect individual but also the national economy

Nigeria, in the recent past has witness an increased event of flooding across savanna zones. For example, Magami, et al., (2014); Nwigwe & Emberga, (2015) reported flooding across of Nigeria while (Panthou et al., 2014) reported an increase flooding across West Africa. The flooding in the savanna zones of Nigeria has been attributed to an increased in rainfall trends (Ifabiyi & Ojoye, 2013; Okonkwo et al., 2015). The increase in the rainfall imply that rainfall extremes analysis is important currently.

Although studies exist on the rainfall trends in Nigeria (Ibrahim, et al., 2018; Ifabiyi & Ojoye, 2013; Oguntunde, et al., 2011), the extreme rainfall events using the novel indices by Expert Team on Climate Change Detection and Indices (ETCCDI) climatic trends has rarely been explored. How the trends of rainfall change from heavy, very heavy to extremely heavy is still unknown. This study therefore, analysed daily rainfall extremes with the aim to determine it significant. The analysis of the extreme and its trends is important because humans and the environment is understood to respond to extremes rather than mean conditions (Nandintsetseg, et al., 2007).

Materials and Methods

The Study area

Geospatial location of observation stations in Guinea and Sudano-Sahelian ecological zones of Nigeria is represented in Figure 1. Guinea and Sudano-Sahelian ecological zones cover more than 1/3 of the entire landmass of Nigeria. The zones lie between Longitudes 3° and 15° East and Latitudes 8° and 13°. The synoptic weather observation stations located in these zones are Sokoto, Yelwa, Gusau, Katsina, Kano, Kaduna, Zaria, Potiskum, Bauchi, Yola, Jos, Minna, Bida, Nguru, and Maiduguri.

These ecological zones house more than 30% of the Nigerian population, and support the bulk of agriculture in the country (Ifabiyi and Ojoye, 2013), with the main crops cultivated being cereals (cowpeas, groundnut and cotton) (Odekunle, et al, 2008).

The location of the Inter-Tropical Discontinuity (ITD) determines the season over the study area. Two air masses, Tropical Maritime (mT) and Tropical Continental (cT) influenced the position of ITD. The ITD travels northwards between January and August over Nigeria and retreats southward from the frontier of the Sahara Desert after August (Ifabiyi and Ojoye, 2013). The rainy season in this area is related with the late start and early termination. The seasonal and latitudinal variations influence daily and average temperature ranges. The highest and lowest mean air temperature is recorded in the northern part, in places north of latitude 9°N around March/April and around December/January respectively (Abdulkadir et al., 2013).

The general relief of these ecological zones is between 300 to 900m, except the Sokoto Basin that is below 300m. The zones have general savanna vegetation types; southern Guinea, northern Guinea, Sudan, and Sahel savanna. The tree and grass density decrease from south to north, in tandem with annual rainfall receipt (Abdulkadir et al., 2013).

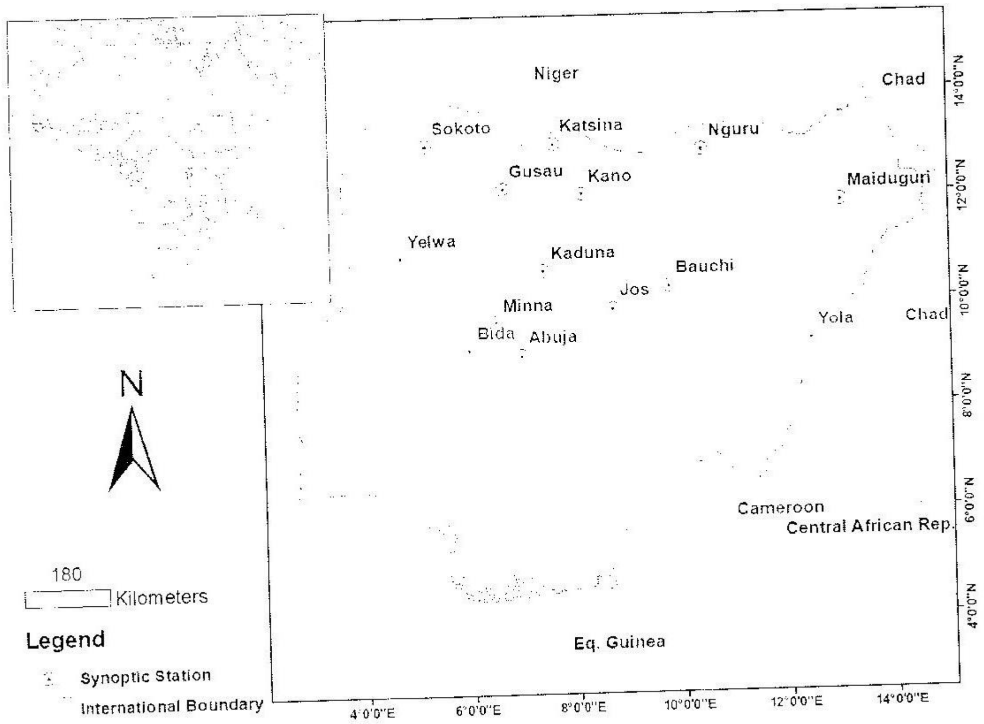

Figure 1 the Synoptic Stations in the Savanna Zones of Nigeria

The Data used

In this paper, daily precipitation data for the period of 35 years (1981-2015) from fourteen (14) synoptic stations were acquired from Environmental Management Programmed, Federal University of Technology Minna. The observation stations are globally referenced meteorological stations. We utilized the data to calculate the indices of extreme rainfall events across the Savanna zones of Nigeria. The spatial distribution of the synoptic stations is represented in Table 1.

Table 1. Observation Stations

Stations Station	WMO Abbr.	Latitude ID	Longitude (oN)	Elevation (oE)	(m)
Abuja	ABJ	65125	9.00	7.00	343.1
Bida	BID	65112	9.10	6.02	144.3
Yola	YOL	65167	9.23	12.47	186.1
Minna	MIN	65123	9.62	6.53	256.4
Jos	JOS	65134	9.87	8.75	1290.0
Bauchi	BAU	65055	10.28	9.82	609.7
Yelwa	YEL	65001	10.88	4.75	244.0
Kaduna	KAD	65019	10.60	7.45	645.4
Maiduguri	MAI	65082	11.85	13.08	353.8
Kano	KAN	65046	12.05	8.20	472.5
Gusau	GUS	65015	12.17	6.70	463.9
Nguru	NGR	65064	12.88	10.47	343.1
Sokoto	SOK	65010	13.02	5.25	350.8
Katsina	KAT	65028	13.02	7.68	517.6

Source: Adapted from Adefisan & Abatan, (2015)

Indices for extreme Rainfall

To improve a constant perspective on observed change climate and weather extremes, ETCCDI (Expert Team on Climate Change Detection and Indices) has defined a core set of descriptive indices of extreme. The indices describe special characteristics of extremes including amplitude, frequency and persistence. The core set includes 27 extreme indices for precipitation and temperature. In this paper, seven (7) indices on extreme rainfall has been use as represented in Table 2. The RClimDex software was used to extract the selected extreme indices. RClimDex program operates in R software.

Table 2. ETCCDI rainfall-related extreme indices adapted for this study

Stations	Acronym	Name of the index	Description	Unit
1	R10	Heavy Rainfall days	Annual number of days with rainfall ≥10 mm/day	days
2	R20	Very heavy Rainfall days	Annual number of days with rainfall ≥20 mm/day	days
3	R25	Extremely heavy rainfall days	Annual number of days when rainfall ≥ 25 mm	days
4	Rx1day	Max 1-day rainfall amount	Annual maximum 1-day rainfall	Mm
5	Rx5days	Max 5-day rainfall Amount	Annual maximum consecutive 5-day rainfall	Mm
6	CWD	Consecutive wet days	Maximum number of consecutive wet days in a season with RR ≥ 1mm	days
7	SDII	Simple daily intensity index	Seasonal total precipitation divided by the number of wet days in the season	mm/day

Trend Analysis

The trend analysis employed the Mann-Kendall (MK) test. It is a non-parametric approach originally developed by Mann, (1945) and modified by Kendall, (1975). The significant levels at α= 0.001, 0.01, 0.05, and 0.1 was the thresholds to classify the significance of upward and downward trends. The MK test is a non-parametric test commonly used as a standard to detect significant trends in hydrological and meteorological time series (He, et al., 2015; Kundu, et al., 2015) . The MK is distribution-free and does not assume any special form for the distribution function of the data, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. Excel template known as MAKESENS was used to performed trend analyses of the extracted extreme indices.

Results and Discussion

Heavy, very heavy and extremely heavy rainfall days

The savanna zone of Nigeria is subdivided into Guinea and Sudano-Sahelian Savanna. The Abuja, Bida, Minna, Yola, Jos, Kaduna [illegible] Kano, Nguru, Katsina, Sokoto, Bauchi and Yelwa stations are in the Sudano-Sahelian savanna zones. The results show a generally mixed trend of the selected indices across the synoptic stations (Table 2). It is noteworthy that Bauchi and Kano station showed consistent significant increasing trends in the extreme rainfall indices while Bida andYola station show consistent insignificant decreasing trends in the extreme rainfall indices.

As represented in Table 2, four stations (28.57%) revealed significant increasing trends in the occurrence of heavy rainfall (R10). The R10 indicated significant trends in four (28.57%) stations (Bauchi, Maiduguri, Kano, and Katsina stations). Generally, the study detected an increasing trend (71.43%) in the heavy rainfall for the all synoptic stations with and exception to Abuja, Gusau, Bida and Yola rainfall (28.57%) station that depict insignificant decreasing trends. It is noteworthy that stations that showed significant rise in R10 are all in Sudano-Sahelian savanna zone of the study area.

The occurrence of very heavy rainfall events (R20) indicated significant increasing trends in five (35.71%) of the synoptic stations (Minna, Bauchi, Maiduguri, Kano and Katsina stations). Of these five stations, only Minna is in the Guinea savanna zones while the others are in the Sudano-Sahelian savanna zones of the study areas. The eleven of the considered stations (78.57) showed general increasing trends in very heavy rainfall while three stations (21.43%) (Abuja, Gusau and Yola) showed insignificant decreasing trends.

The extremely heavy rainfall occurrence (R25) showed an increasing trend in twelve stations (85.71%) while two stations (14.29%) (Bida and Yola) showed insignificant decreasing trends. The findings also showed a significant increasing trend in six (43%) stations at Minna, Bauchi Maiduguri, Kano, Nguru, and Katsina while Yola station reveals significant decreasing trend in R25.

Several studies (Chandrashekar & Shetty, 2018; Worku et al., 2018; Yaduvanshi & Sinha, 2017) across the world have shown similar mixed trends in the extreme indices of rainfall. Ibrahim et al., (2018) suggested that similarity in rainfall events is an indication that synoptic global weather-producing features influences rainfall regimes beside other local to regional factors. This finding is consistent with previous studies (Panthou et al., 2014; Sultan & Gaetani, 2016) that attributed rising rainfall regime to the rise in extreme rainfall.

Maximum 1-day and 5-day rainfall amounts

The RX1 showed that with exception to Abuja, Yola, and Jos stations (21.43%) that indicate insignificant decreasing trends, all other stations (78.57%) experienced an increasing trend in one day extreme rainfall. The station that showed insignificant trends cut across the two savanna zones. The finding showed significant trends in two (21.43%) (Kano and Sokoto stations) in maximum 1-day (RX1) rainfall amount.

The 5-day rainfall amounts (RX5) showed significant trends in five (35.71%) stations (Bida, Bauchi, Kano, Sokoto and Katsina). Generally, 78.57% of the stations revealed an increasing trend while three (21.43%) of the stations (Bida, Yelwa, and Yola) showed insignificant decreasing trends.

Consecutive wet days and simple daily intensity index

The study found significant increasing trends in consecutive wet days (CWD) at two (14.29%) stations. It is noteworthy that the nine (71.43%) showed a general increasing trend while four (28.57%) showed insignificant decreasing trends. The simple daily intensity index (SDII) revealed significant trends in six (42.86%) of the stations. Two stations (Yola and Bida) showed significant decreasing trends while four stations (Minna, Bauchi, Maiduguri, and Kano) showed significant increasing trends.

Table 2. Mann-Kendall Trends Test in Extreme Rainfall

Stations	R10	R20	R25	RX1	RX5	CWD	SDII
Abuja	-0.48	-0.78	0.42	-0.31	-0.39	-1.25	-1.13
Bida	-0.51	0,03	-0.16	1.25	1.99*	1.26	0.20
Yola	-1	-1.34	-2.06*	-1.39	-1.02	0.00	-1.86+
Minna	1.41	1.66+	2.04*	1.04	1.34	1.20	1.82 +
Jos	1.2	1.37	0.03	-0.54	0.03	0.19	0.09
Bauchi	2.82**	3.96***	4.62***	3.74***	4.45***	1.18	5.39 ***
Yelwa	1.1	0.93	1.43	1.19	-0.06	-0.45	-1.86+
Kaduna	0.81	0.7	1.34	1.53	0.62	-1.06	0.36
						2.29	2.28 *
Maiduguri	2.40*	2.22*	2.61**	1.11	1.57	*	
Kano	2.25*	3.63***	4.14***	4.62***	3.78**	0.34	4.39 ***
Gusau	-0.16	-0.69	0.03	0.14	1.08	-0.78	-0.20
Sokoto	1.1	0.83	1.4	2.37*	2.02*	3.54***	-0.03
Katsina	2.62**	2.92**	2.27*	1.16	2.43*	1.02	1.55
Ngura	0.77	1.45	1.81+	0.54	0.36	-0.40	0.92

***Significant trend at $\alpha = 0.001$, ** Significant trend at $\alpha = 0.01$, * Significant trend at $\alpha = 0.05$, + Significant trend at $\alpha = 0.1$

Conclusion

The study analysed trends of five (5) of rainfall extremes for the period of 35 years (1981-2015) in the savanna zones of Nigeria, based on daily rainfall data from fourteen (14) synoptic stations. The results showed mixed trends in number of heavy, very heavy, and extremely heavy wet days, 1-day rainfall, 5-day rainfall, consecutive wet day, and simple daily intensity index. These indices showed both insignificant increased and decreased in some stations while other stations showed significant increased and decrease. The mixed trends could be a pointer to the influence of station's specific physical characteristics. It is noteworthy that Bauchi, Kano, and Katsina station showed consistent significant trends in most of the extreme indices while Abuja and Yola showed consistent decreasing trends in most of the indices. The increased trends in the extreme indices could be an influencing factor in the frequent occurrence of flooding in the savanna zones of Nigeria. The increasing trends could trigger flood with consequence on life and properties. A positive trend in indices has been linked to increase is a possible indicator of climate change in the region (Ongoma et al., 2016). These findings are critical to water resources management agency. The findings of this study are of significant to entire West African sub-region as they shared similar climate characteristics

References

Adefisan, E. A., & Abatan, A. A. (2015). Agroclimatic Zonning of Nigeria Based on Rainfall Characteristics and Index of Drought Proneness. Journal of Environment and Earth Science, 5(12), 115–128.

Amasuomo, T., & Amasuomo, J. O. (2017). Improving Durability of Rural Buildings in Riverine Niger Delta Region: A Case Study on Need to Utilize Appropriate Technology. International Journal of African Society, Cultures and Traditions, 4(1), 18–43.

Atiah, W. A., Tsidu, G. M., Amekudzi, L. K., & Yorke, C. (2020). Trends and interannual variability of extreme rainfall indices over Ghana , West Africa. Theoretical and Applied Climatology, 23, 117.

Basher, A., Stiller-reeve, M. A., Islam, A. K. M. S., Bremer, S., Stiller-reeve, M. A., & Bremer, S. (2017). Assessing climatic trends of extreme rainfall indices over northeast Bangladesh. Theoretical and Applied Climatology, 25, 27–42.

Chandrashekar, V. D., & Shetty, A. (2018). Trends in extreme rainfall over ecologically sensitive Western Ghats and coastal regions of Karnataka : an observational assessment. Arabian Journal of Geosciences, 327(11), 1–13.

Gummadi, S., Rao, K. P. C., Seid, J., Legesse, G., Kadiyala, M. D. M., & Takele, R. (2017). Spatio-temporal variability and trends of precipitation and extreme rainfall events in Ethiopia in 1980 – 2010. Theoretical and Applied Climatology, 44, 2002–2003.

Han, J., Baik, J., & Lee, H. (2014). Urban impacts on precipitation Urban Impacts on Precipitation. Asia-Pacific Journal of Atmospheric Sciences, 33, 1–16. https://doi.org/10.1007/s13143-014-0016-7

Ibrahim, I., Usman, M. T., Abdulkadir, A., & Emigilati, M. A. (2018). Analysis of Rainfall Distribution, Temporal Trends, and Rates of Change in the Savannah Zones of Nigeria. Atmosphere-Ocean, 0(0), 1–10. https://doi.org/10.1080/07055900.2018.1502149

Ifabiyi, I. P., & Ojoye, S. (2013). Rainfall Trends in the Sudano-Sahelian Ecological Zone of Nigeria. Earth Science Research, 2(2), 194–202. https://doi.org/10.5539/esr.v2n2p194

Kug, J., & Ahn, M. (2013). Impact of Urbanization on Recent Temperature and Precipitation Trends in the Korean Peninsula. Asia-Pacific Journal of Atmospheric Sciences, 49(2), 151–159. https://doi.org/10.1007/s13143-013-0016-z

Kundu, S., Khare, D., Mondal, A., & Mishra, P. K. (2015). Analysis of spatial and temporal variation in rainfall trend of Madhya Pradesh, India (1901– 2011). Environmental Development, 201, 333–352. https://doi.org/10.1007/s12665-014-3978-y

Łupikasza, E. B., Hansel, S., & Matschullat, J. (2011). Regional and seasonal variability of extreme precipitation trends in southern Poland and central-eastern Germany 1951–2006. International Journal of Climatology, 31, 2249–2271. https://doi.org/10.1002/joc.2229

Magami, I. M., Yahaya, S., & Mohammed, K. (2014). Causes and consequences of flooding in Nigeria : a review. Biological and Environmental Sciences Journal for the Tropics, 11(2), 154–162.

Nandintsetseg, B., Scott, J., & Goulden, C. E. (2007). Trends in extreme daily precipitation and temperature near Lake Hovsgol, Mongolia. Theoretical and Applied Climatology, 27, 341–347. https://doi.org/10.1002/joc

Nwigwe, C., & Emberga, T. T. (2015). An Assesment of causes and effects of flood in Nigeria. Standard Scientific Research and Essays, 2(7), 307–315.

Odekunle, T. O., Andrew, O., & Aremu, S. O. (2008). Towards a wetter Sudano-Sahelian ecological zone in twenty-first century Nigeria. Weather, 63(3), 66–70.

Oguntunde, P. G., Abiodun, B. J., & Lischeid, G. (2011). Rainfall trends in Nigeria , 1901 – 2000. Journal of Hydrology, 411, 207–218. https://doi.org/10.1016/j.jhydrol.2011.09.037

Okonkwo, C., Demoz, B., Sakai, R., Ichoku, C., Anarado, C., Amadou, A., & Abdullahi, S. I. (2015). Combined effect of El Niño southern oscillation and Atlantic multidecadal oscillation on Lake Chad level variability. Cogent Geoscence, 1, 1–19. https://doi.org/10.1080/23312041.2015.1117829

Ongoma, V., Chen, H., & Omony, G. (2016). Variability of extreme weather events over the equatorial East Africa, a case study of rainfall in Kenya and Uganda. Theoretical and Applied Climatology, 39, 86–101. https://doi.org/10.1007/s00704-016-1973-9

Osun, A. O. J. (2016). Conservation of Traditional Earth Building in Nigeria: Case Study Of Origbo in Ife North, Osun State. International Journal of African Society, Cultures and Traditions, 4(2), 20–31.

Panthou, G., Vischel, T., & Lebel, T. (2014). Recent trends in the regime of extreme rainfall in the Central. International Journal of Climatology, 34, 3998–4006. https://doi.org/10.1002/joc.3984

Sa, Z., Ismail, T., Sung, E., Xiao, C., & Wang, J. (2017). Trends analysis of rainfall and rainfall extremes in Sarawak , Malaysia using modified Mann – Kendall test. Meteorology and Atmospheric Physics, 22, 79–93. https://doi.org/10.1007/s00703-017-0564-3

Shahid, S. (2011). Trends in extreme rainfall events of Bangladesh. Theoretical and Applied Climatology, 104, 489–499. https://doi.org/10.1007/s00704-010-0363-y

Sibanda, S., Grab, S. W., & Ahmed, F. (2017). Spatio-temporal temperature trends and extreme hydro-climatic events in southern Zimbabwe. South African Geographical Journal, 62, 1–23. https://doi.org/10.1080/03736245.2017.1397541

Sultan, B., & Gaetani, M. (2016). Agriculture in West Africa in the Twenty-First Century: Climate Change and Impacts Scenarios, and Potential for Adaptation. Frontier in Plant Science, 7, 1–20. https://doi.org/10.3389/fpls.2016.01262

Worku, G., Teferi, E., Bantider, A., & Dile, Y. T. (2018). Observed changes in extremes of daily rainfall and temperature in Jemma Sub-Basin , Upper Blue Nile Basin, Ethiopia. Theoretical and Applied Climatology, 34, 33–55.

Yaduvanshi, A., & Sinha, A. K. (2017). Extreme event characterization for the river basins of Eastern Indian Gangetic Plains. Hydrology Research, 12, 1–12. https://doi.org/10.2166/nh.2017.211