A 30-YEAR ANALYSIS OF LOCAL RAINFALL CHANGE AND VARIABILITY IN IJEBU-ODE, SOUTH WEST NIGERIA

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Abstract
This present paper examines temporal variability of rainfall in Ijebu-Ode using monthly and annual instrumental records covering from 1989-2018. The time series analysis is necessary for flood risk measurement and management. Data for study were retrieved from archives of Synoptic Meteorological Station in Ijebu-Ode. Descriptive methods used for the analyses include: innovation trend analysis (ITA), coefficient of variation (CV), seasonality index (SI), annual rainfall anomaly index (RAI), and monthly Rainfall Anomaly (MRA).Result from the (ITA) implies that rainfall consistently increase through time in Ijebu-Ode; CV ranges from 0.71mm to 1.10mm for all years, suggesting that climate in Ijebu-Ode can be described as having high/very rainfall variability over time; long-term seasonality index score is relatively stable with peaks in 0.74 (1998), 0.41 (2006) and 0.70 (2015) respectively, which indicate that the rainfall regime in Ijebu-Ode over last three decades is relatively stable but susceptible to seasonal instabilities in precipitation; RAI showed only positive values for years 1989 to 2018, ranging from moderately wet (one year), slightly wet (five years), and near normal (24 years) or all humid years (30 years) with varying degrees of intensity - the 30-year study period are all rainy ones; a clear monthly rainfall anomaly is established with dominant rainy seasons and dry seasons in Ijebu-Ode. The results showed both inter-annual variability (CV) and intra-annual variability (SI) over study period, signalling uncertainty associated with rainfall over Ijebu- Ode communities (local levels). The overall result of this study underlies occurrence of droughts and floods and an index of climate change. Likelihood of flood risk is high in months of May-July and September-October in Ijebu-Ode. The findings of this study are important for planning and management of agriculture, water resource systems and climate and its impact etc. in Ijebu-Ode.There is crucial need to explore sustainable activities and measures that aim at maintaining or improving capability of the inhabitants to cope with and mitigate floods.

Key words: Rainfall, variability of rainfall, seasonality index, trend, anomaly, mitigation.

Introduction

Climatic change crisis has spur continued interest in the in-depth understanding of constant change of the climatic variability over time because rainfall variability in response to climatic change poses a severe threat to global livelihood and the human development. Nigeria has a tropical climate with variations in rainfall and temperature affected by interaction between the moist southwest monsoon winds and dry northeast trade winds (Asadu & Asadu, 2015). Major paradigm shift indicated that inter-annual variability is connected to changes in higher features like the African Easterly Jet (AEJ), the Tropical Easterly Jet (TEJ), and the Lower-Level Westerly Jet, African Westerly Jet (AWJ) over the continent and West Westerly Jet (WAWJ) over the Atlantic (Okoro, U.K., Chen, W., Chineke, T.C., and Nwafor, O.K, 2014). Each of these features has its climatic importance particularly with respect to inter-annual variability (Okoro et al., 2014). The Inter-Tropical Discontinuity (ITD) is most popularly accepted medium that influence rainfall distribution in Nigeria (Clackson, 1960; Lamb, 1968; Ayoade, 1988; Adejuwon et al., 1990). In other words, the rain falls mostly when an area is overlain by the Continental Tropical (CT) air mass. This makes position of ITD a great determinant of most rainfall attributes in the region. However, a new climatic phenomenon of global influence, El Nino/Southern Oscillation is being invoked as a significant cause of rainfall variability over space and time in West Africa (Adedokun, 1978; Rasmusson, 1985; Burroughs 1992; Kripalani and Kulkani, 1997; Kane, 2000; Chang, 2002). Over Nigeria in particular, correlation between global SST and rainfall has been established e.g., Adedoyin (1989) and Omogbai (2010). ENSO teleconnection is defined in two ways, namely in association with sea-level pressure (SLP) and also in association with sea surface temperature (SST) (Bjerknes, 1966 & 1969).

According to Nigerian Meteorological Agency (NiMeT, 2010, 2013, 2015), rainfall predictions over Ijebu-Ode for 2010-2018 which falls within study years is based on El-Nino phase (i.e., dryness/drought), La-Nina phase (i.e., cold/more rainfall) and Neural phase (i.e., normal weather) of the ENSO phenomenon. Continuous transition of El-Nino, La-Nina and Neural phase clearly establishes continuous rainfall variability and changes. Climate is the average weather or the statistical descriptions in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years (Murdock, T, Q., Fraser, and C. Pearce, 2007) and these variations result in drier or wetter, warmer or colder, quiescent or stormy conditions (National Oceanic and Atmospheric Administration, 2007). Climatic parameters such as rainfall. Temperature, relative humidity, sunshine hours etc. vary with time and space ((Zaman R., Malaker P. K., Murad K. F. I. and Sadat M A, 2013). Climatic variability is the fluctuation in the statistics such as mean, standard deviation (SD) (Olabode and Adeleke, 2017), the occurrence of extremes etc. of the climate on temporal and spatial scale (Adenodi, 2018). These changes may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (Murdock et al., 2007; Bates et al., 2008 &Abaje et al., 2010).

According to Intergovernmental Panel on Climate Change (IPCC, 2007)rainfall variability is instability of rainfall occurrence yearly or seasonally above or below a long-term mean value over a particular period. Rainfall is one of the most variable climatic parameters and this variability has resulted in the uncertainties associated with rainfall, both spatially and temporally (Nnaji et al., 2016). This has further been exacerbated by onset of localized climatic variability which has resulted in anomalous behaviour in rainfall amounts and distributions (Nnaji et al., 2016). Hence, study of rainfall is important and cannot be overemphasized (Obot &Onyeukwu, 2010). Rainfall is one of major resources of Nigeria and can be used as index of climate change (Adenodi, 2018), and also a significant climatic variable, underlies drought and floods (Cocarelli&Caloiero, 2012). The rainfall in Nigeria is subjected to wide variability both in time and space (Nnaji et al., 2016). This variability has assumed a more pronounced dimension as a result of climate change (Nnaji et al., 2016). Flooding in Nigeria is usually caused by heavy rainfall and thunderstorms over a short period, prolonged rainfall or excessive downpour while its deficit results in droughts of varying magnitudes (Olabode & Adeleke, 2017 &Abolade et al., 2013). Every rainy season in Nigeria is associated with tropical storms which claim lives & properties worth millions of naira across the nation (Okorie, 2015). Disasters associated with rainfall includes loss of lives and properties worth millions of dollars and traffic obstructions (Okorie, 2015). For some decades, the commonest disaster in Nigeria is flooding (Adenodi, 2018).

The effects of climate change have really affected development and have made achievement of Millennium Development Goals (MDGs) significantly more tedious in Nigeria (UkhureborSiloko, 2020). Devastating social and economic impacts occur when rainfall characteristics such as amount, intensity, distribution and seasonality differ from normal conditions. This makes the study of rainfall variability important for planning and management of agriculture & water resource systems, flood frequency analysis and associated hazard mapping, climate change and its impacts and other environmental assessments (Michaelides et al., 2009; Kumbuyo et al., 2014; Guhathakurta& Saji, 2014). Oguntade and Abiodun (2012) observed that understanding trends and variations of current and historical hydroclimatic variables is pertinent to the future development and sustainable management of water resources. The study of spatial and temporal variabilities of rainfall can be useful in monitoring and tracking climate change (Nnaji et al., 2016). Houghton et al., (1996) noted that one of very important necessities of research into climate change is to analyse and detect historical changes in the climate system. According to Nnaji et al., (2016), a 25 - to 30 - year period of rainfall is safe enough to bring out characteristics needed to predict climate change with respect to rainfall (Nnaji et al., 2016).

Ijebu-Ode frequently experiences flooding, which is typically brought on by excessive rains and inadequate drainage systems, which frequently cause major floods (Aiyewunmi, 2023). The Intergovernmental Panel on Climate Change (IPCC, 2023) has found that climate change "has detectably influenced" several of the variables that contribute to floods, such as rainfall and snowmelt. According to TVC NEWS (July 28, 2019), residents of Folagbade, Degun and adjoining streets in Ijebu Ode have continued to lament the aftermath of seasonal rainfall and flooding. People's vulnerability is made worse by the poor condition of the drainage systems in Ijebu-Ode, which can be attributed to poor urban governance, poor urban planning, unsustainable living practises, poor attitudes among locals, and inadequate funding for ongoing maintenance (Aiyewunmi, 2023). In order to efficiently manage water resources, comprehend the effects of climate change at the local level, and prepare for future droughts and floods in Ijebu Ode, this study aims to investigate the occurrence (s) of temporal trend and variability of rainfall. The temporal variability is useful in evaluating change in climate, flooding and associated hazards and environmental disasters at the local levels. These underscores need for this study.

Material and Methods

The data for this study were retrieved from archives of Nigerian Meteorological Agency, Ijebu-Ode station, covering 30 years (i.e., 1989-2018). In the context of this study, meteorology is concerned with the long-term trends in climate and weather, and their potential impact on human populations.An innovation trend analysis (ITA) method is used in this study to find out for trends in yearly rainfall. According to Dabanl et al. (2016), the ITA approach is more useful than the MK test for identifying trends in hydro-meteorological series.

Coefficient of variation (CV) also known as the relative standard deviation (RSD) determines the percent of the results that are equal to the mean of the data; seasonality index is used to evaluate seasonal trends and intra-annual rainfall variability. SI is a means of characterizing the fluctuation in rainfall by showing the different rainfall regime (Adenodi, 2018). Annual seasonality indexes for all the years were determined. In order to examine the distribution of rainfall in the years under review with the biggest anomalies, the monthly RAI was also calculated for certain historical series years.

Results and Discussion

The results of Figure (1) showed an increase in rainfall over the 30-year period and can be marked as "monotonic positive trend"/increasing monotonic trend. There is no significant trend in the hydrometeorological recordings because the scattering locations are on or near the 1:1 (45°) straight line.

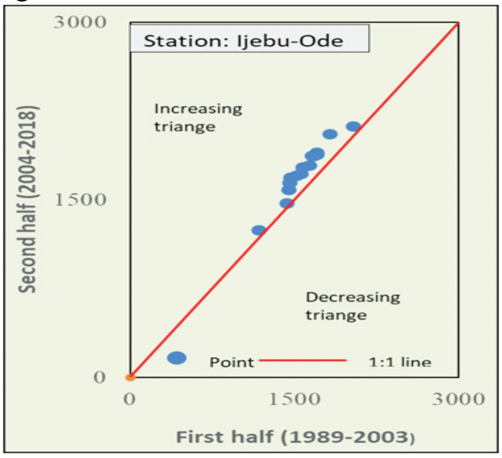

Figure 1: An innovative trend analysis (ITA) of the annual rainfall in Ijebu-Ode (1989-2018).

Coefficient of variation (CV) ranges from 0.71mm to 1.10mm for all years, indicating inter-annual variability of rainfall is present. Year 1992 (Figure 2) had the highest CV of 110% (1.10) for rainfall in the period 1989-2018. This indicates that rainfall is very highly varied in that year with highest CV, and this is supported by its minimum and maximum value of 0.69mm and 1.10mm respectively, as well as mean value of 169.37mm. 1997 had the lowest CV of 0.69mm which indicates that rainfall variability were high in the year while 1992 had the highest CV which indicate that rainfall variability were very high. According to Dewar and Wallis, (1999) the variation of CV values indicates existence of strong variability in the rainfall. This suggests that climate in Ijebu-Ode can be described as having high/very high rainfall inter- variability over time.

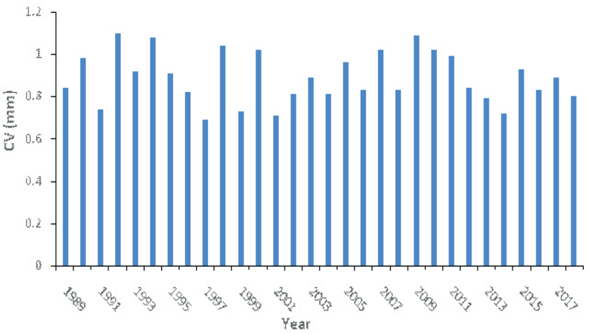

Figure 2: Showing Coefficient of Variation (CV) for Ijebu-Ode (1989-2018)

For Ijebu-Ode city the SI indicates that climate is characterized by two rainfall regimes: *rather seasonal with a shorter drier season* (between 0.4 – 0.59) and *seasonal* (0.60 – 0.79) for the study period .Five (1989, 1993, 1998, 2001, 2002) of the six years that experience *seasonal* rainfall, fall within the first half of the study period (Figure 3), with only 2015 within the second half of the study period. The *rather seasonal with a shorter drier season* is found to have become a regular occurrence in the last 16 years (2006-2018), implying an increase in wet season length and shortening of the dry season. With peaks in 0.74 (1998), 0.41 (2006), and 0.7 (2015), respectively, analysis of the long-term seasonality index score shows that the year-to-year rainfall regime in Ijebu-Ode over the last three decades is relatively stable but susceptible to seasonal instabilities in precipitation Findings in Figure (3) suggest that Ijebu-Ode local climate can be characterised by temporal intra-annual variability of rainfall and have experienced a change and shift in rainfall distribution and seasonality and also getting wetter. The rainfall seasonality index classifies the type of climate in relation to water availability, the lower the seasonality index of a region, the greater the water resources variability and surplus in time, the more vulnerable the area to excess soil moisture and overland runoff when there is infrastructural deficit.

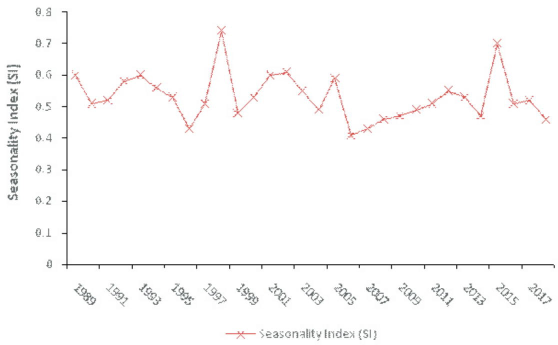

Figure 3: Annual total rainfall distribution and fluctuation of the SI over Ijebu-Ode

Deviations from 30-year normal (see **Figure 4**) revealed that the months of May, June, July, September & October recorded positive values of 42.4mm, 133.8mm, 138.7mm, 120.4mm & 82.9mm respectively, implying the monthly averages were higher than the 30-year normal whilst the remaining seven months recorded a negative anomaly with their monthly average rainfall records below 30-year average normal. The total average anomaly for 30-year period was -8.8 mm which meant that it was lower than computed reference normal.Driest month occurred in January (-128.7mm), followed by December (-125.8mm), February (-98.5mm) and November (-86.5mm) respectively. Monthly rainfall anomalies are established.

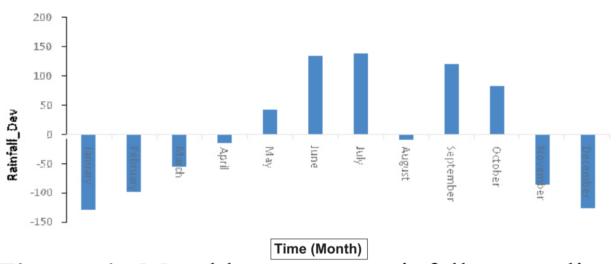

Figure 4: Monthly average rainfall anomalies compared with the mean rainfall in Ijebu-Ode (1989-2018)

Table 1: The annual rainfall total for the Ijebu-Ode area's wet circumstances for the past 30 years (1989-2018).

Year	Total annual rainfall	Annual average rainfall deviation	Annual rainfall anomaly index (RAI)	Rooy (1965) Class description	Freitas (2005) adapted by Araxjo et al. (2009) Classification
1989	1445.5	-227.93	0.477O21	Near normal	Humid
1990	**1701.8**	**28.37**	0.044459	Near normal	Humid
1991	**1676.9**	**3.47**	0.005438	Near normal	Humid
1992	1517.9	-155.53	0.325499	Near normal	Humid
1993	1458.1	-215.33	0.450651	Near normal	Humid
1994	1558.9	-114.53	0.239693	Near normal	Humid
1995	1634.6	-38.83	0.081265	Near normal	Humid
1996	**2032.4**	**358.97**	0.562552	Slightly wet	Humid
1997	**1705.7**	**32.27**	0.050571	Near normal	Humid
1998	1173.3	-500.13	1.046691	Moderately wet	Humid
1999	**1819.4**	**145.97**	0.228754	Near normal	Humid
2000	1655	-18.43	0.038571	Near normal	Humid
2001	1464.2	-209.23	0.437885	Near normal	Humid
2002	1426.5	-246.93	0.516785	Slightly wet	Humid
2003	1572	-101.43	0.212277	Near normal	Humid
2004	**1778.5**	**105.47**	0.165285	Near normal	Humid
2005	1473.3	-200.13	0.41884	Near normal	Humid
2006	**2125.6**	**452.17**	0.708608	Slightly wet	Humid
2007	**2056**	**382.57**	0.599536	Slightly wet	Humid
2008	**1885**	**211.57**	0.331557	Near normal	Humid
2009	**1875.4**	**201.97**	0.316513	Near normal	Humid
2010	**1795**	**121.57**	0.190516	Near normal	Humid
2011	**1705.1**	**31.67**	0.049631	Near normal	Humid
2012	1584.4	-89.03	0.186325	Near normal	Humid
2013	1648	-25.43	0.053221	Near normal	Humid
2014	1874.8	201.37	0.315573	Near normal	Humid
2015	1244.9	-428.53	0.896844	Sightly wet	Humid
2016	**1723**	**49.57**	0.077683	Near normal	Humid
2017	**1690.5**	**17.07**	0.026751	Near Normal	Humid
2018	**1900.8**	**227.37**	0.356318	Near normal	Humid

The findings (Table1 and 2 and Figure 6) showed that Ijebu-Ode is suitable for classification as a humid environment, which is used to describe an atmosphere with relatively high levels of water vapour and is typically very hot (warmer climates increase evapotranspiration, putting more moisture into the atmosphere that is then released as rain). The outcome suggested that the humid weather is causing the already damp environment to become even more damp. This implies that the ongoing flood risk (s) in Ijebu-Ode will be increased or made worse by additional wet weather, i.e., heavy showers. The communities of Ijebu-Ode are therefore asked to be vigilant and ready.

Only positive values are shown in Figure (5) and Table (1) for the years 1989 to 2018, ranging from moderately wet (one year), slightly wet (five years), and near normal (24 years) according to the classification of the index used by van Rooy (1965) or all humid years (30 years) with varying degrees of intensity according to the classification of the index used by Freitas (2005) and modified by Ara?jo et al. (2009). To put it another way, the 30-year study period are all rainy ones. Highest Positive values (M) = 1.046691 ÷ 30 (years of which positive anomalies occurred within the study period) = 0.0348897 near normal.

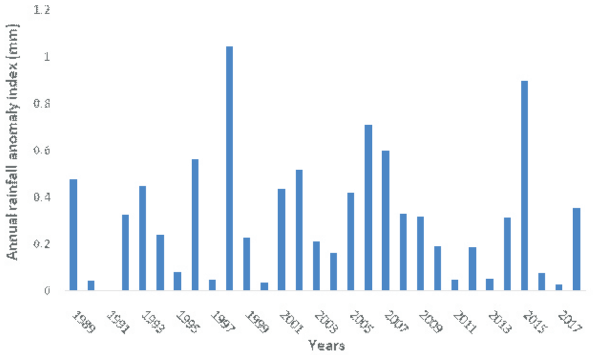

Figure 5: Rainfall Anomaly Index (RAI) for Ijebu-Ode communities,

Table 2: The average of the 10 highest and lowest historical series (mm) shows the years when wet and normal conditions occurred in Ijebu-Ode LGA during the course of 30 years, from 1989 to 2018.

Index classification of Van Roy (1965)	Years
Moderately wet	1998
Slightly wet	1996, 2002, 2006, 2007, and 2015
Near normal	1989, 1990, 1991, 1992, 1993, 1994, 1995, 1997, 1999, 2000, 2001, 2003, 2004, 2005, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2016, 2017, and 2018
Index classification by Freitas (2005) adapted by Araxjo et al. (2009)	**Years**
Humid	1989-2018

To assess the frequency and severity of dry and rainy years, rainfall data are used to calculate the Annual Rainfall Anomaly Index (RAI). The "rainy years" of the historical series were displayed (Tables 2 and Figure 6). The RAI was seen to fluctuate over the study periods.

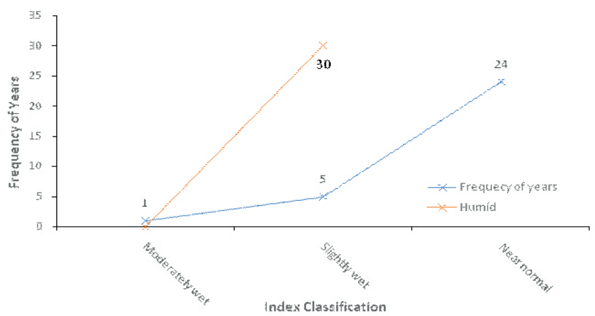

Figure 6: Displays the frequency distribution of the rainfall anomaly index for wet and normal and humid conditions in the Ijebu-Ode LGA from 1989 to 2018 (30 years), using the average of the 10 highest and lowest historical series

Conclusion

This study provides valuable insight on the temporal patterns of rainfall in Ijebu-Ode, South West Nigeria. Key indicators of primary effect of climate change are identified over the 30-year study period: Increasing annual rainfall, increase in rainy season length, inter-annual and intra-annual rainfall variabilities and months with rainfall anomalies are all evident at the local levels. Climate of Ijebu-Ode qualified to be characterised as humid environment: used to describe an atmosphere with relatively high levels of water vapour and is typically very hot (warmer climates increase evapotranspiration, putting more moisture into the atmosphere that is then released as rain). Ijebu-Ode qualifies as a high flood risk zone area: the likelihood of an area experiencing flood, hence, inhabitant's vulnerability risk factors and corresponding impact dependent largely on their hazard exposure, community's pre-existing sensitivities and level of adaptive capacities/resilience.

Overall, historical rainfall changes pose a potential threat to inhabitants and communities in and around Ijebu-Ode. Due to increased wetter months, likelihood of availability of water on the surface and soil is high which could have implication for both high runoff and floods. Also, the likelihood of occurrence of flooding throughout rainy season months, with widespread flooding across large section of urban environment is high, most especially when the flood relief infrastructures are unavailable/infrastructural deficit.

Recommendations

The result indicatedthatinhabitants of Ijebu-Ode are vulnerable to floods due to the high hazard probability. Analysis of trends and variability of rainfall provides valuable information on future change in flood occurrence and potential solution for the flood risk reduction. Hence, a good physical planning, sufficient surface water drainage systems, effective waste management strategy, good environmental behaviour of the inhabitants, adequate information, education knowledge of flood risk, good preparedness, prevention, protection, emergency response, recovery measures, including good institutional capacity, water/flood warnings and good governance at grassroot level will help minimize incidences of present and future flooding and associated disasters in communities of Ijebu-Ode:

- Some of the main causes of floods has been recognised as increasing and substantial unpredictability of rainfall, and the seasonal pattern and fluctuations is essential for formulating plans to enhance water management in response to climate change in Ijebu-Ode.
- There is urgent need to engaged with the local communities to understand their concerns, limitations, capacity to resist and recover from flood disasters and explore best adaptation options.
- Proper observation, re-assessing, re-engineering and upgrading of community drainage structures and systems, to enable effective water removal through a network of aligned and integrated channels with adequate hydraulic flow.
- Regular cleaning and desilting of the drainage channels.
- Sustainable waste management through regular environmental sanitation, provision of appropriate waste collection facilities for household and community use, prompt waste collection and evacuation by authorized government agencies.
- Relocation of the vulnerable living in critical flood prone areas to safe places, and stop building construction and developments in all flood prone areas of the town.
- Need to create flood control space, or reservoirs, for the collection of water during times of high flows, or where water is held during times of flooding and that can then be released/infiltrated/used slowly.
- Adequate funding for local government departments, employment of experienced environmental personnel, purchase of equipment's and working tools in order to enhance productivity and performance.
- Needs for all Environmental Protection Agencies at the local government level to be functional and responsible to upheld there aims and objectives.

- Development of a strong advocacy campaign at the household and community level on flood awareness and environmental management.
- Use of mass media such as the terrestrial television and radio broadcast to provide and deliver the fastest, and reliable information and effective flood mitigation to the public (household and community people).

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