PLASU Journal of Environmental Sciences, E-ISSN 2360-9222, Vol.2, No. 2, December 2025,
Published by the Faculty of Environmental Sciences, Plateau State University, Bokkos.
https://journals.plasu.edu.ng, DOI: 10.5281/zenodo.21854300

EFFECTS OF VISIBILITY ON MILITARY FLIGHT OPERATIONS IN MALLAM AMINU KANO INTERNATIONAL AIRPORT, KANO STATE, NIGERIA

[1]Auwal Mahmud Tijjani [1]Isah Shuaibu [1]James Kayode Aremu [1]Habibu Sada Maiwada
[1]Department of Geography, Nigerian Defence Academy, Kaduna, Kaduna State.
Corresponding Author's Email: isahshuaibu@nda.edu.ng
ORCID: https://orcid.org/0009-0009-9731-3575

ABSTRACT
Visibility is one of the weather elements that has a direct effect on flight operations, particularly during take-off and landing. Secondary data were obtained from the Nigerian Meteorological Agency (NiMet) and the 403 Flying Training School (403 FTS), Nigerian Air Force, for the period 2011 to 2020. The data collected covered annual visibility (number of days with visibility below 2,000 metres), dust haze occurrence, rainfall, flight delays, flight cancellations and flight diversions. Trend analysis, Pearson correlation, simple and multiple regression and an independent samples t-test were used to analyse the data with the aid of SPSS version 23. The results showed that visibility-affected days averaged 7.30 days per year and did not record a significant trend (R^2 = .083, p = .420) while rainfall declined significantly over the period (R^2 = .529, p = .017) and flight delay increased significantly (R^2 = .655, p = .005). The correlation between visibility and flight cancellation was not significant (r = .002, p = .995), and the null hypothesis was therefore not rejected. Dust haze, however, correlated significantly with flight delay (r = .688, p = .028). Findings also showed that the dry season (November to March) recorded significantly more delays, cancellations and diversions than the wet season (p < .01 in all cases). The study concludes that poor visibility on its own is not the major cause of flight disruption at MAKIA but that dust haze and seasonal factors play a more significant role. The study recommends a dedicated Harmattan flying schedule for 403 FTS, dust haze specific operational thresholds and an upgrade of visibility monitoring equipment at the airport.

Keywords: Visibility, Dust haze, Flight delay, Flight cancellation, MAKIA, Nigeria

1. INTRODUCTION

Weather has a direct effect on flight safety and efficiency in both civil and military aviation. Visibility is one of the most important weather elements in aviation because it determines a pilot's ability to see the runway, the terrain and other aircraft during take-off and landing (Awoyemi, 2022; Kwasiborska, Grabowski, Sedláčková & Novák, 2023). ICAO (2025) reported that the global accident rate for scheduled commercial flights rose to 2.56 accidents per million departures in 2024 from 1.87 in 2023, with turbulence responsible for almost 75% of serious in-flight injuries recorded that year. Weather is the state of the atmosphere over an area at a particular time, such as a minute, hour, day or season, while climate is the average of these conditions taken over a much longer period (Aremu, 2020).

These risks are not limited to civil aviation. The United States military recorded over 6,000 aviation safety incidents between 2013 and 2018, resulting in 198 deaths and the loss of 157 aircraft at a cost of over $9.41 billion, excluding combat losses (National Commission on Military Aviation Safety (NCMAS), 2020). This shows that weather-related disruption is a major concern for any air force that depends on flying safely and on schedule. In Africa, the International Air Transport Association (IATA, 2026) reported that the continent recorded the highest accident rate of any region in 2025 at 7.86 accidents per million flights, although this was an improvement on the 12.13 accidents recorded in 2024. The global average that year was 1.32 accidents per million flights. Many of the accidents recorded in Africa involved runway excursions and turboprop aircraft, occurrences that are often linked to poor visibility and difficult approach conditions.

In Nigeria, poor visibility caused by fog, Harmattan dust haze and heavy rainfall, along with wind shear and squall, has been linked to flight delay, diversion, cancellation and accident (Weli & Ifediba, 2014; Dan-Okoro, Hassan & Agidi, 2018). Mande (2019) identified fog, Harmattan dust haze and thunderstorm as the three major weather hazards facing air transport in Nigeria, noting that thunderstorm is associated with the rainy season while fog and dust haze are associated with the dry season. These hazards are of particular concern to the Nigerian Air Force (NAF), whose flying activities have increased in recent years. In 2025 alone, the NAF flew 379 combat sorties and about 800 flight hours on air interdiction missions against insurgents and bandits across the North East, North West and North Central parts of the country (Eyiangho, 2025). The aircrew carrying out these missions have to contend with the same seasonal weather that affects civil flights. Kano, because of its location in the tropical savannah, experiences Harmattan dust haze in the dry season, and rainfall and thunderstorm in the wet season. Mallam Aminu Kano International Airport (MAKIA) hosts both civil flights and the 403 Flying Training School (403 FTS) of the NAF. Poor visibility at the airport is therefore as much a military readiness issue as it is a commercial one.

Aviation is one of the weather sensitive sectors of the economy and poor visibility is considered the most important weather hazard to all forms of transportation (Ayoade, 2004). The demand for NAF air operations has grown because of insurgency and banditry across the country, requiring the Air Force to fly more sorties under difficult terrain and weather conditions (NAF, 2024). Poor visibility caused by Harmattan dust haze, fog or heavy rainfall therefore poses a direct threat to military flight schedules and to the safety of aircrew carrying out these operations.

A number of studies have examined the effect of visibility on flight operations at Nigerian airports but these studies focused only on civil aviation. Dan-Okoro, Hassan & Agidi (2018) found that visibility and cloud cover were the strongest predictors of flight cancellation at Nnamdi Azikiwe International Airport, Abuja between 2000 and 2014, with weather elements explaining up to 88% of cancellations. Iornongo, Yahaya, Babanma & Masha (2020) also working in Abuja, found that poor visibility was significantly and negatively correlated with flight diversion, accounting for 66.4% of the variation in diversion between 2009 and 2018. Onwuadiochi, Ijioma, Ezenwaji & Obikwelu (2019) at Sam Mbakwe Airport, Imo State found that wind shear explained 51% of flight delay and 67% of flight cancellation. Awoyemi (2022) at Akure Airport found that visibility related disruption had distinct seasonal peaks. At MAKIA itself, Zakari (2013) found that 94% of Harmattan dust haze events occurred between November and March, with January recording the highest frequency.

None of these studies however, examined military flight operations, even though military aircraft use the same airspace and runways and are exposed to the same weather as civil aircraft. No study was found online that also combined visibility, dust haze and rainfall together to assess flight disruption for a military flying school in Nigeria, and Zakari (2013), who studied MAKIA, did not make use of the operational records of the 403 Flying Training School. This study was designed to fill these gaps by examining the effect of visibility, rainfall and dust haze on flight operations at 403 FTS, MAKIA between 2011 and 2020.

The aim of this study is to examine the effect of visibility on military flight operations at MAKIA, Kano. The objectives are to: (i) examine the trend of visibility frequency in the study area, (ii) examine the effect of poor visibility on flight operations in the study area, (iii) determine whether there is a significant relationship between poor visibility and flight cancellation in the study area, and (iv) determine the seasonal variation in weather-related flight disruption in the study area between 2011 and 2020. The hypotheses tested are stated as: H_{01}, there is no significant relationship between poor visibility and flight cancellation at MAKIA, Kano, and H_{02}, there is a significant relationship between poor visibility and flight cancellation at MAKIA, Kano. The study is limited to horizontal visibility because of time and resource constraints, and the flight operation data used were obtained from 403 FTS subject to the confidentiality required of NAF records.

2. LITERATURE REVIEW

Visibility is one of the weather elements that is measured through observation. It is the greatest horizontal distance at which an object can be seen and recognised with the unaided eye (Aremu, 2020). ICAO Annex 3 also defines visibility in terms of the distance at which a dark object can be seen against the sky in daylight or at which a light can be identified at night, and this is the basis for the meteorological optical range and the runway visual range used in instrument approaches. Visibility of less than 100 metres is usually recorded as zero. The Glossary of Meteorology (2009) considers fog to be a reduction of visibility to below 1,000 metres, a limit that is also useful for aviation purposes. The minimum runway visual range required for landing depends on the category of Instrument Landing System (ILS) in use, as shown in Table 1.

Table 1: Minima for Landing Operations under Different Categories of Instrument Landing System

Airfield Category	Decision Height	Runway Visual Range
CAT I	60.96 m	550 m
CAT II	30.48 m	300 m
CAT III A	15.24 m	175 m
CAT III B	4.57 m	125 m
CAT III C	Nil	Nil

Source: ICAO Doc 9365-AN/910.

This study is based on the Natural Hazards Theory proposed by White (1974) and later developed by Burton, Kates & White (1978). The theory holds that a natural event only becomes a hazard when it affects human activities and causes loss or damage. Smith (2013) added that the effect of a hazard depends on how people and institutions respond to it, and not on the physical event alone. In this study, the hazard is poor visibility caused by Harmattan dust haze, fog or heavy rainfall. The exposure is determined by aircraft capability, navigational aids, pilot training and operational demands, while the adjustment includes weather forecasting, low visibility procedures and instrument landing systems. The theory has been criticised for paying more attention to the physical hazard than to the social factors that shape its effect, but it is still useful for a study that looks at visibility as a specific weather hazard affecting flight operations.

Several studies have identified dust haze, fog, rainfall, thunderstorm and cloud cover as the major causes of poor visibility at Nigerian airports (Dan-Okoro, Hassan & Agidi, 2018; Iornongo, Yahaya, Babanma & Masha, 2020). In northern Nigeria, Harmattan dust haze is the most common cause of poor visibility. Zakari (2013) found that 94% of dust haze events at MAKIA occurred between November and March, with the highest frequency recorded in January, and that the haze was most severe between 0900 and 1200 GMT, a period that coincides with morning flight schedules. Balarabe, Abdullah & Nawawi (2015) also found a nationwide decline in visibility between 1984 and 2013 caused by Saharan dust. In other parts of the country, rainfall and thunderstorms matter more than dust haze. Dan-Okoro et al. (2018) found that cloud cover and rainfall were strongly related to flight cancellation at

Abuja, while Onwuadiochi, Ijioma, Ezenwaji & Obikwelu (2019) found that wind shear, which often comes with thunderstorms, explained 51% of flight delay and 67% of flight cancellation at Sam Mbakwe Airport. Mande (2019) found a rising trend in fog occurrence at Abuja between 2000 and 2017 with a significant effect on flight cancellation, while Lawal, Owolawi, Tu, Ojo, Ojo & Sodunke (2025) showed that fog reduces visibility across many Nigerian cities, mostly during the wet season in the coastal areas.

Poor visibility affects flight operations in different ways, including delay, cancellation, diversion and accident. Olabode (2021) found that delay was more common than diversion or cancellation at Lagos airport, with thunderstorm and cloud cover as the significant predictors. Iornongo et al. (2020) found a significant relationship between visibility and diversion at Abuja, explaining 66.4% of the variation in diversion. Most of these studies also report a seasonal pattern, dust haze affecting the dry season and rainfall and fog affecting the wet season. Ndubuisi, Chineke & Nwofor (2025) studied Lagos, Abuja, Owerri and Ilorin between 1994 and 2023 and found significant seasonal and regional differences in visibility, with rainfall responsible for wet season reduction and aerosols responsible for dry season haze.

Outside Nigeria, similar findings have been reported. Kwasiborska, Grabowski, Sedláčková & Novák (2023) used about 52,000 METAR reports from three Polish airports and found that low runway visual range often stopped landing operations in autumn and winter, and that airports with a higher category of Instrument Landing System recorded fewer interruptions. Kim, Lee, Lee, Bae, Kim & Kim (2024) studied fourteen South Korean airports and found that rainfall had a greater effect on flight cancellation than wind speed, Jeju Airport being the most affected because of its exposure to monsoon rain and typhoon. Lei, Jin & Qi (2022) used satellite reanalysis data across China and found that poor visibility was the main cause of disruption in southern airports in winter while wind shear mattered more in the north, a pattern not too different from the dry season Harmattan and wet season rainfall pattern observed in Nigeria.

Iornongo et al. (2020) recommended that NiMet and the Nigerian Airspace Management Agency should be equipped with better visibility monitoring equipment, while Onwuadiochi et al. (2019) recommended regular training of air traffic controllers and meteorologists on weather hazard management. Igbo-Uchi (2025) noted that dust haze remains a serious problem for aviation and public health in northern Nigeria and called for better forecasting and operational procedures. All the studies reviewed however focused on civil aviation and none examined military flight operations. Although Zakari (2013) studied MAKIA, the study did not make use of 403 FTS records. This is the gap that the present study sets out to address.

3. MATERIALS AND METHODS

Mallam Aminu Kano International Airport (MAKIA) is located between latitudes 12°02'N and 13°07'N and longitudes 08°31'E and 09°02'E (FAAN, 2016), about 2km north of Kano city at an elevation of 476 metres above sea level. MAKIA is one of the oldest international airports in Nigeria, established in 1936, and serves as a transit point for pilgrims travelling for Hajj as well as the main airport connecting air travellers in northern Nigeria. The remodelled airport was commissioned on 15 March 2015. The airport serves both civil and military flights. Runway 06/24 is used mainly by civil aircraft while runway 05/23 is used by the 403 Flying Training School (403 FTS) of the Nigerian Air Force on the southern side of the airport, as shown in Figures 1 and 2.

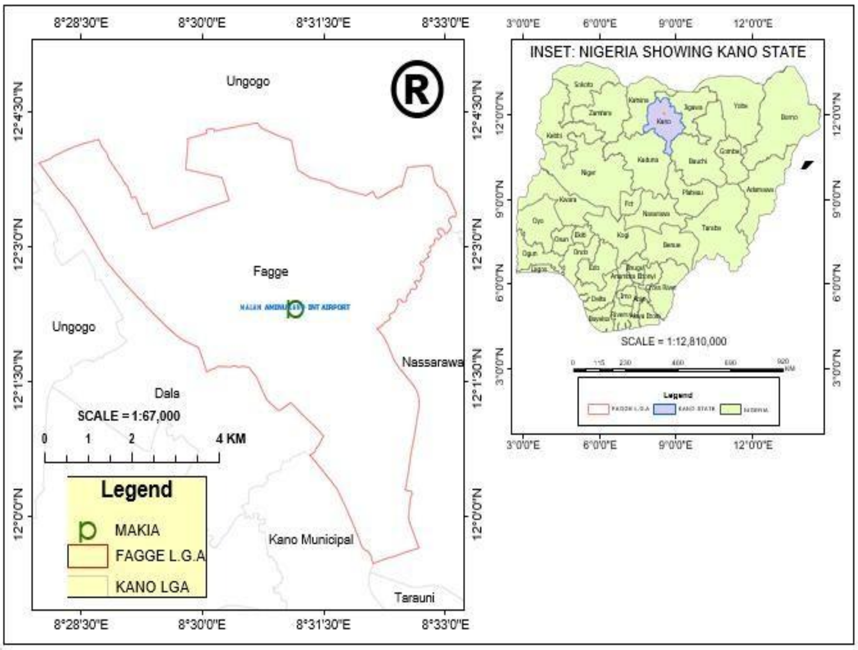

Figure 1: Map of Kano State Showing Fagge LGA and MAKIA

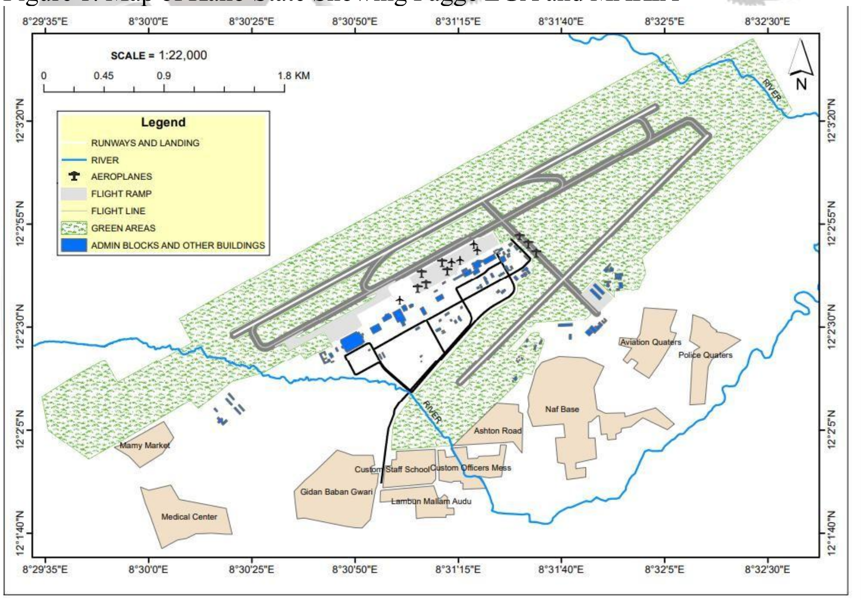

Figure 2: Layout Map of MAKIA Showing Runways and the 403 FTS/NAF Base
Source: Author's Field Map (2024).

Kano has a tropical wet and dry climate (Aw) typical of the West African savannah. The climate is controlled by two air masses, the moist tropical maritime air mass which brings the south west trade wind and the wet season between April and October, and the dry tropical continental air mass which brings the north east trade wind, known locally as the Harmattan, and the dry season between November and March (Oyegun & Ologunorisa, 2002). The 2025 annual mean maximum temperature ranges from 34°C to 36°C, while the mean minimum annual temperature ranges from 19°C to 22°C (Nigerian Meteorological Agency [NiMet], 2026). The cumulative annual rainfall for Kano metropolis is about 900mm (Nimet, 2026). The published weather minima for MAKIA require a visibility of at least 5km and a ceiling of at least 450m for take-off and landing under visual meteorological conditions, and a visibility of at least 8km within the control zone.

Data for this study were obtained entirely from secondary sources. Annual data on rainfall, number of days with Harmattan dust haze and number of days with visibility below 2,000 metres were obtained from the NiMet headquarters, Abuja for the period 2011 to 2020. Data on military flight operations, comprising arrivals, departures, delays, cancellations and diversions, were obtained from the 403 Flying Training School (403 FTS), Nigerian Air Force, Kano for the same period. This ten-year period was used because it was the most recent period for which complete records were available at both institutions at the time of data collection.
Two datasets were prepared for analysis in SPSS version 23. The first contains ten cases representing the years 2011 to 2020, with a TIME variable coded 1 to 10 used in the trend analysis. The second contains 120 monthly cases, made up of 50 dry season months (November to March) and 70 wet season months (April to October), used to examine seasonal variation. Table 2 shows the statistical technique applied to each objective of the study. All tests were carried out at the 0.05 level of significance. All the charts were produced in Microsoft Excel 2016.

Table 2: Statistical Techniques Applied to Each Research Objective

Objective	Statistical Technique	SPSS Procedure	Key Output
Trend in mean visibility frequency	Linear curve estimation	Regression > Curve Estimation	R^2, F, Sig.
Effect of poor visibility on flight operations	Simple linear regression	Regression > Linear	R^2, t, Sig.
Relationship between visibility and cancellation	Pearson correlation, multiple regression	Correlate > Bivariate; Regression > Linear	r, R^2, F, Sig.
Seasonal variation in flight disruption	Monthly means, independent t-test	Compare Means; Independent-Samples T Test	Means, t, Sig.

Source: Researcher's Analysis (2026).

4. RESULTS AND DISCUSSION
4.1 Descriptive Statistics of Weather and Flight Operation Variables

Table 3: Descriptive Statistics of Weather Parameters and Flight Operations at MAKIA (2011–2020)

Variable	Minimum	Maximum	Mean	Std. Deviation
Days with Visibility <2000m	3	16	7.30	3.89
Days with Dust Haze	9	19	13.50	3.63
Annual Rainfall (mm)	781.5	1764.7	1032.29	327.37
Total Flight Arrivals	158	978	691.80	259.18
Total Flight Departures	150	988	692.70	264.35
Total Flight Delays	2	14	8.30	4.79
Total Flight Cancellations	2	10	4.60	2.50
Total Flight Diversions	0	2	0.50	0.85

Source: NiMet and 403 FTS MAKIA Data (2011–2020), Analysed by researcher (2026).

Result in Table 3 shows that the number of days with visibility below 2,000 metres averaged 7.30 days per year, with a minimum of 3 days recorded in 2013 and 2017 and a maximum of

16 days recorded in 2011. Dust haze days averaged 13.50 per year, ranging from 9 days in 2013 to 19 days in 2012. The fact that dust haze days were always more than visibility-affected days shows that not every haze day reduces visibility below the 2,000 metre threshold used in this study, some haze events are mild and clear before they affect flight operations. Annual rainfall averaged 1,032.29mm with a wide range from 781.5mm in 2019 to 1,764.7mm in 2012, showing that rainfall at Kano varies a great deal from year to year.
Flight arrivals averaged 691.80 per year and departures averaged 692.70, which is to be expected because most 403 FTS flights are local training flights that take off and land on the same day. The range, from 158 arrivals in 2014 to 978 in 2017, however shows that flying activity differed a lot from year to year, most likely due to changes in training intake, aircraft availability and operational commitments at the school. Flight delay averaged 8.30 per year with a minimum of 2 in 2013 and a maximum of 14 recorded in each of 2018, 2019 and 2020. Cancellation averaged 4.60 per year, ranging from 2 in 2013 to 10 in 2015. Diversion was the least frequent disruption with only 5 cases recorded across the whole ten years, suggesting that 403 FTS manages most disruption through delay or cancellation rather than diverting an aircraft to another airport, an option that is costly in terms of fuel, time and logistics.

4.2 Trend Analysis of Weather Parameters and Flight Operations

The trend in each weather and flight disruption variable was examined using linear curve estimation, with year coded from 1 (2011) to 10 (2020). The summary of the results for all six variables (Visibility, dust haze, rainfall, flight delays, flight cancellations, and flight diversion) are presented in Table 4, while Figures 3 and 4 illustrate the trend in rainfall and flight delay, the two variables that recorded a significant trend.

Table 4: Summary of Linear Trend Analysis of Weather and Flight-Disruption Variables at MAKIA (2011–2020)

Variable	R^2	F	Sig.	Slope (B_1)	Direction
Visibility (<2000m Days)	.083	.723	.420	-.370	Not significant (slight decline)
Dust Haze (Days)	.152	1.430	.266	.467	Not significant (slight rise)
Rainfall (mm)	.529	8.975	.017*	-78.622	Significant decline
Flight Delays	.655	15.161	.005**	1.279	Significant increase
Flight Cancellations	.011	.085	.778	-.085	Not significant (stable)
Flight Diversions	.340	4.119	.077	.164	Not significant (borderline rise)

Note: *$p < .05$, **$p < .01$ (df = 1, 8). Source: NiMet and 403 FTS MAKIA Data (2011–2020).

Results from Table 4 shows that Visibility-affected days had an R^2 of .083 and the slope was negative (-.370), meaning poor visibility days reduced slightly over the period, but the trend was not significant ($F = .723$, $p = .420$). This finding means that visibility at MAKIA neither improved nor worsened significantly within the study period, and the airport should expect this hazard to continue at about the same level. Dust haze days had an R^2 of .152 with a positive slope of .467, also not significant ($F = 1.430$, $p = .266$), although haze days rose from 10 in 2011 to 19 in 2012, fell, and then rose again to 18 in 2018 and 16 in both 2019 and 2020. This direction, even though not significant over ten years, agrees with Igbo-Uchi (2025) that dust haze remains a serious and possibly worsening problem for aviation in northern Nigeria.

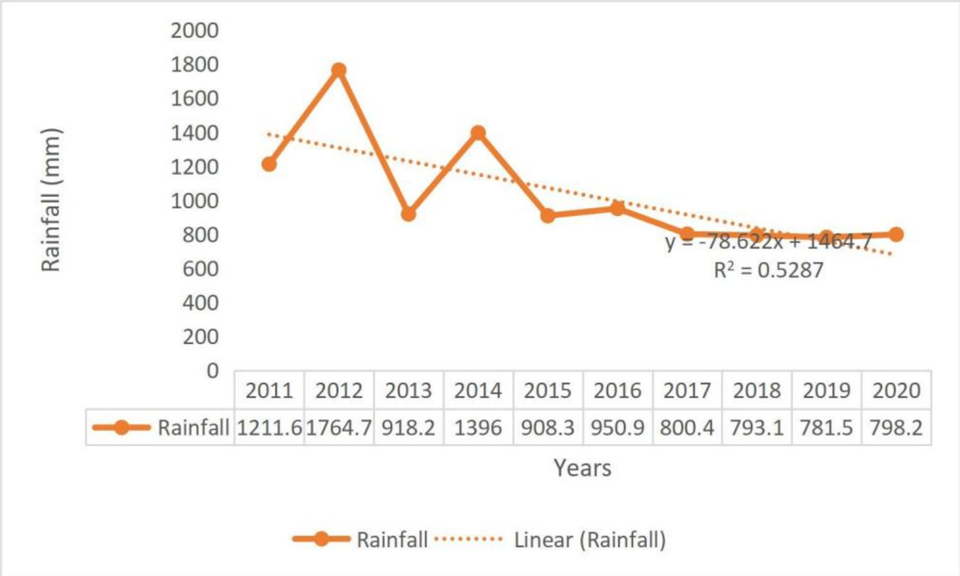

Figure 3**.** Annual Trend in Rainfall at MAKIA (2011–2020)
Source: Researcher's Analysis (2026)

As illustrated in Figure 3, Rainfall recorded the first significant trend in the analysis, with $R^2 = .529$ ($F = 8.975$, $p = .017$). The slope was -78.622, meaning rainfall reduced by about 78.6mm every year, dropping from 1,764.7mm in 2012 to 781.5mm in 2019 and 798.2mm in 2020. A drier environment means less vegetation and drier soil around the airport, which could increase the amount of dust available for the Harmattan wind to pick up in subsequent years. This agrees with Abdullahi & Adebanke (2026), who found a strong negative relationship between rainfall and dust concentration in north east Nigeria ($r = -.63$).

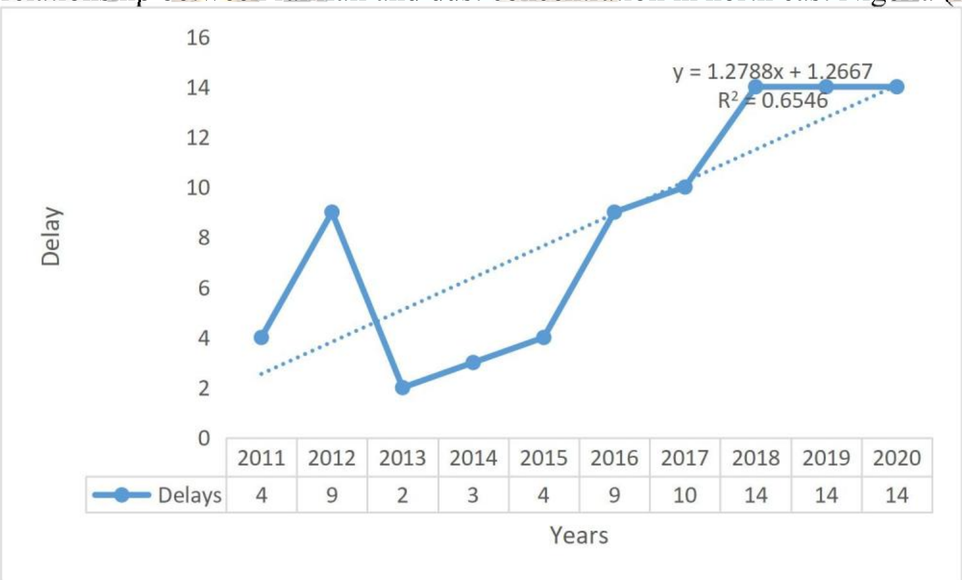

Figure 4. Annual Trend in Flight Delays at 403 FTS, MAKIA (2011–2020)
Source: Researcher's Analysis (2026)

The results from Table 4 and shown in Figure 4 reveal that Flight delay recorded the strongest trend in the whole study, with the model explaining 65.5% of the year-to-year variation ($R^2 = .655$, $F = 15.161$, $p = .005$). The slope of 1.279 means about one extra delay was recorded every year, rising from 4 in 2011 to 14 in each of 2018, 2019 and 2020 (Figure 4). This rise is however, not matched by a significant worsening in visibility ($p = .420$) or dust haze ($p = .266$), so weather on its own cannot be said to be the cause of the rising delay.

A more likely explanation is that 403 FTS had more flights as their pilots' training and NAF operational commitments expanded over the years, and a higher number of planned flights naturally creates more chances for individual delay to occur, regardless of whether the weather changed.

Finding from Table 4 further shows that Flight cancellation did not show a significant trend ($R^2 = .011$, $F = .085$, $p = .778$), moving up and down between 2 and 10 per year with no clear direction. This is different from delay, which rose steadily, and suggests that 403 FTS prefers to hold a flight on the ground and reschedule it rather than cancel it outright, since a cancelled sortie is a training opportunity lost for that day. Diversion also showed a non-significant trend ($R^2 = .340$, $F = 4.119$, $p = .077$). No diversion was recorded between 2011 and 2016, one occurred in 2017, two in each of 2018 and 2019, and none in 2020. The appearance of diversion only in the later, busier years may explain the rising slope, although with only 5 cases recorded in ten years the result should be treated with caution.

4.3 Relationship between Weather Parameters and Flight Disruption

Table 5 presents the Pearson correlation matrix covering all six weather and disruption variables. This table also serves as the test for hypothesis H_{01}, that there is no significant relationship between poor visibility and flight cancellation at MAKIA.

Table 5: Pearson Correlation Matrix – Weather Parameters and Flight Disruption Variables at MAKIA (2011–2020)

		Visibility	Dust Haze	Rainfall	Delays	Cancellations	Diversions
Visibility	Pearson Correlation	1	.185	.258	.108	.002	.151
	Sig. (2-tailed)		.609	.472	.766	.995	.677
Number of Days with Dust Haze	Pearson Correlation	.185	1	.152	.688*	.012	.486
	Sig. (2-tailed)	.609		.675	.028	.973	.154
Annual Rainfall (mm)	Pearson Correlation	.258	.152	1	-.391	.031	-.484
	Sig. (2-tailed)	.472	.675		.264	.932	.156
Total Flight Delays	Pearson Correlation	.108	.688*	-.391	1	-.082	.669*
	Sig. (2-tailed)	.766	.028	.264		.823	.034
Total Flight Cancellations	Pearson Correlation	.002	.012	.031	-.082	1	-.209
	Sig. (2-tailed)	.995	.973	.932	.823		.562
Total Flight Diversions	Pearson Correlation	.151	.486	-.484	.669*	-.209	1
	Sig. (2-tailed)	.677	.154	.156	.034	.562	
	N	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

Source: NiMet and 403 FTS MAKIA Data (2011–2020), Analysed by Researcher (2026).

Two significant correlations were found in Table 5. Dust haze and flight delay were significantly related ($r = .688$, $p = .028$), as shown in Figure 5, meaning years with more haze days also recorded more delay. Flight delay and flight diversion were also significantly related (r = .669, p = .034), suggesting that conditions that first cause delay may eventually push some flights to divert.

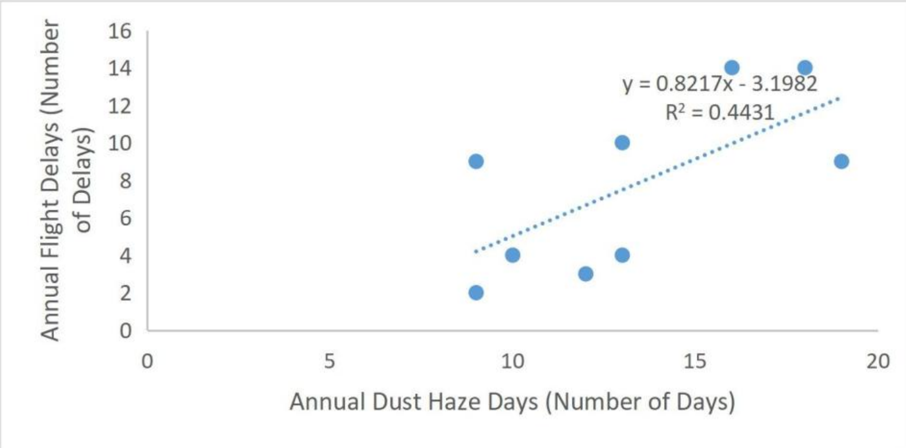

Figure 5: Relationship between Dust Haze Days and Flight Delays at 403 FTS, MAKIA (2011–2020)

As shown in Table 5, Visibility and flight cancellation had a correlation of r = .002 (p = .995). Since this is far above the 0.05 mark, the null hypothesis H_{01} is not rejected, meaning there is no significant relationship between poor visibility and flight cancellation at MAKIA over the period covered by this study. Visibility was also not significantly related to delay (r = .108, p = .766) or diversion (r = .151, p = .677). A possible explanation is that the 2,000 metre threshold used to measure visibility in this study includes mild morning haze that clears before scheduled flights, so not every day below the threshold leads to a disruption, while dust haze on its own is a more severe and longer lasting event, which explains why it correlates significantly with delay. Cancellation decisions at 403 FTS are also influenced by command priorities, aircraft availability and aircrew readiness, and not by weather alone. This finding disagrees with Dan-Okoro et al. (2018), who found that weather elements explained up to 88% of cancellation at Abuja, but the difference can be explained by the fact that civil cancellation at Abuja follows commercial schedules while military cancellation at 403 FTS is guided by command decisions that can override weather considerations.

Table 5 further shows that Rainfall was also not significantly related to any of the three disruption types (delay: r = -.391, p = .264; diversion: r = -.484, p = .156). Rainfall at Kano is mostly short and convective, so a high rainfall total in a particular year does not necessarily mean more days of disruption, since each storm passes quickly and conditions clear soon after. This disagrees with Olabode (2021), who found rainfall to be a major cause of disruption at Lagos, but Lagos receives rainfall all year round while Kano has a sharply defined wet and dry season, which makes the dry season the more disruptive period.

4.4 Effect of Visibility on Flight Disruption

Simple regression was used to test how well visibility predicts each type of disruption, while multiple regression was used to test the combined effect of visibility, dust haze and rainfall on cancellation. Table 6 summarises the result.

Table 6: Summary of Simple and Multiple Regression Models – Visibility Predicting Flight Disruptions at 403 FTS, MAKIA

Dependent Variable	Predictor(s)	R^2	Adj. R^2	F	Sig. (F)	B (Visibility)	Sig. (B)
Flight Delays	Visibility	.012	-.112	.095	.766	.133	.766
Flight Cancellations	Visibility	.000	-.125	.000	.995	.002	.995
Flight Diversions	Visibility	.023	-.099	.188	.677	.033	.677
Flight Cancellations	Visibility + Haze + Rainfall	.001	-.498	.002	1.000	-.005	.987

Source: NiMet and 403 FTS MAKIA Data (2011–2020), processed by SPSS Version 23.

The Result from Table 6 show the Visibility explained only 1.2% of the variation in flight delay ($R^2 = .012$), and the model was not significant ($F = .095$, $p = .766$). The constant of 7.329 means that even with zero poor visibility days in a year, about 7.3 delays would still be expected, confirming that delay is caused mostly by factors other than visibility, operational tempo being the more likely driver of the delay. For cancellation, visibility explained none of the variation ($R^2 = .000$, $F = .000$, $p = .995$), but the constant of 4.589 was itself significant ($t = 2.465$, $p = .039$), meaning a baseline of about 4.6 cancellations occurs every year regardless of visibility, pointing to non-weather factors such as aircraft serviceability and aircrew scheduling as the real driver of cancellation. For diversion, visibility explained 2.3% of the variation ($R^2 = .023$, $F = .188$, $p = .677$). The direction agrees with theory, more poor visibility days associated with more diversion, but with only 5 diversion cases across the decade the data lacks the power to confirm this at the annual level.

The multiple regression model combining visibility, dust haze and rainfall shown in Table 6 also failed to predict cancellation ($R^2 = .001$, Adjusted $R^2 = -.498$, $F = .002$, $p = 1.000$). None of the three predictors were significant, visibility ($B = -.005$, $p = .987$), dust haze ($B = .006$, $p = .984$) and rainfall ($B = .000$, $p = .943$), and even the constant lost significance once three predictors were entered into a model built on only ten observations. This confirms what the correlation and simple regression results already suggested, that weather, taken together, does not predict military flight cancellation at 403 FTS, and that effort to reduce cancellation should focus more on aircraft serviceability, aircrew scheduling and training pipeline management than on weather monitoring alone. This disagrees with Dan-Okoro et al. (2018) at Abuja, where combined weather elements explained most of the cancellation recorded, a difference that reflects the fact that civil operations at Abuja follow fixed commercial schedules while military operations at 403 FTS involve command flexibility that can override weather constraints.

4.5 Seasonal Variation in Weather-Related Flight Disruption

Table 7 presents the mean monthly values of the weather and flight disruption variables, averaged across the ten years covered by the study.

Table 7: Mean Monthly Weather Parameters and Flight Disruption Variables at MAKIA (2011–2020)

Month	Season	Vis. Days	Haze Days	Rainfall (mm)	Delays	Cancel.	Divers.
January	Dry	2.20	2.90	0.00	1.60	1.00	.20
February	Dry	1.70	3.50	0.00	0.70	0.20	.00
March	Dry	0.30	1.20	0.10	0.80	0.30	.20
April	Wet	0.20	0.30	5.98	0.30	0.30	.00
May	Wet	0.00	0.80	76.38	0.10	0.00	.00
June	Wet	0.20	0.00	185.25	0.60	0.00	.00
July	Wet	0.00	0.00	226.97	0.70	0.50	.00
August	Wet	0.00	0.00	372.65	0.90	0.30	.00
September	Wet	0.00	0.00	149.93	0.60	0.40	.00
October	Wet	0.10	0.00	15.03	0.30	0.10	.00
November	Dry	1.10	1.10	0.00	0.20	0.50	.00
December	Dry	1.50	3.70	0.00	1.40	1.00	.10

Note: N = 10 per month (2011–2020). Dry Season = Nov–Mar; Wet Season = Apr–Oct. Source: NiMet and 403 FTS MAKIA Data.

A clear seasonal pattern can be seen in Table 7. Visibility-affected days and dust haze days are concentrated in the dry season, with January recording the highest visibility days (2.20) and the second highest haze days (2.90), while December recorded the highest haze days (3.70). Both variables averaged zero from May to September, confirming that Harmattan-related visibility loss at MAKIA is purely a dry season phenomenon. Rainfall followed the opposite pattern, peaking in August (372.65mm) and falling to zero from November to February. Flight disruption followed the dry season pattern closely. January recorded the highest mean delay (1.60) and the joint highest mean cancellation (1.00), while May and October recorded the lowest delay figures. All diversions recorded in the study period occurred in the dry season months of January, March and December, with no diversion recorded in any wet season month as shown in Figure 6.

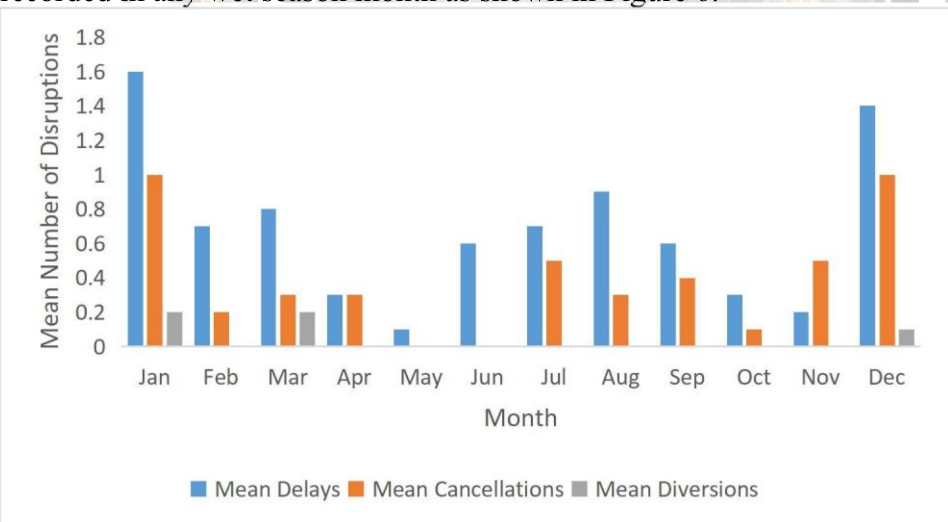

Figure 6. Mean Monthly Distribution of Flight Disruptions at 403 FTS, MAKIA (2011–2020)
Source: Researcher’s Analysis (2026)

An important point from Table 7 is that August, which recorded the highest rainfall of the year (372.65mm), had a mean delay of only 0.90 and mean cancellation of just 0.30, while January, with zero rainfall, recorded a higher mean delay of 1.60 and mean cancellation of 1.00. This shows that the dry Harmattan season, and not the wet season, is the more disruptive period at MAKIA. Rainfall at Kano is intense but short-lived and clears within hours, while Harmattan dust haze can persist for several days at a stretch, which makes it harder to plan flights around. This agrees with Zakari (2013) that 94% of dust haze events at MAKIA occur between November and March, and with Mande (2019) that Harmattan dust haze is the most significant aviation weather hazard in northern Nigeria, more significant than fog, rainfall or thunderstorm. Table 8 presents the result of an independent samples t-test comparing the mean monthly disruption figures between the two seasons.

Table 8: Independent-Samples T-Test – Dry Season versus Wet Season Flight Disruption at 403 FTS, MAKIA

Variable	Dry Season Mean (N=50)	Wet Season Mean (N=70)	Mean Diff.	t	df	Sig. (2-tailed)
Flight Delays	0.94	0.50	0.44	3.078	118	.003**
Flight Cancellations	0.60	0.23	0.37	3.431	118	.001**
Flight Diversions	0.10	0.00	0.10	2.765	118	.007**

Note: **p < .01 (equal variances assumed).
Source: 403 FTS MAKIA Operational Records (2011–2020), processed by SPSS Version 23.

As shown in Table 8, all three disruption types were significantly higher in the dry season than the wet season. Delay was almost twice as high in the dry season (0.94 per month) as in the wet season (0.50), t = 3.078, p = .003. Cancellation was more than twice as high in the dry season (0.60) as in the wet season (0.23), t = 3.431, p = .001. Diversion was recorded only in the dry season, t = 2.765, p = .007, with no diversion at all recorded in any wet season month across the ten years. This result means that the dry season, particularly the months of December to February, is the period 403 FTS should pay closer attention to in terms of flight scheduling, weather briefing and contingency planning. It also helps explain why the annual correlation analysis in section 4.3 did not find a significant relationship between visibility and cancellation, since combining the data into yearly totals hides the strong dry season pattern that only becomes visible when the data is examined at the monthly level.

5. CONCLUSION

This study examined the effect of visibility on military flight operations at MAKIA between 2011 and 2020. The study concludes that visibility, measured as the number of days below 2,000 metres in a year, does not significantly predict flight delay, cancellation or diversion at 403 FTS, and the null hypothesis of no significant relationship between visibility and cancellation was not rejected (r = .002, p = .995). Rainfall declined significantly over the period while flight delay increased significantly, an increase that appears to be tied more to higher flying activity rather than to bad weather. Cancellation remained fairly stable through the period, and the combination of all three weather variables together still failed to predict cancellation, which confirms that non-weather factors are the bigger influence on disruption decisions at the school.

Dust haze, examined on its own, was however found to correlate significantly with delay (r = .688, p = .028), and when the data were broken down by month rather than by year, the dry Harmattan season was found to produce significantly more delay, cancellation and diversion than the wet season. All five diversions recorded in the study period occurred in dry season months. The study concludes that weather-related risk at 403 FTS is real but is more seasonal and dust haze specific than a general visibility problem, and is better addressed through targeted seasonal planning than through year round weather monitoring alone. This study contributes to knowledge by combining three weather parameters, namely rainfall, dust haze and visibility, in assessing military flight operations, and by showing specifically that visibility on its own has no significant effect on flight cancellation at a dual use Nigerian airport.

6. RECOMMENDATIONS

The study recommends the development of a dedicated Harmattan flying schedule for 403 FTS that reduces high risk flights during peak morning haze hours in December, January and February. Dust haze specific operational thresholds should also be developed for 403 FTS aircraft, separate from the general visibility minima currently used for MAKIA as a whole. An internal review by 403 FTS of the actual causes of flight cancellation is also recommended. Finally, visibility monitoring equipment at MAKIA should be upgraded to improve flight planning during the Harmattan season.

REFERENCES

Abdullahi, L. K., & Adebanke, A. K. (2026). Spatio-temporal variability and climatic drivers of Harmattan dust over Northeast Nigeria using MERRA-2 reanalysis. *Science World Journal, 21*(1). Faculty of Science, Kaduna State University. https://dx.doi.org/10.4314/swj.v21i1.52

Aremu, J. K. (2020). *The languages of meteorology*. Cee Kay Bee.

Awoyemi, P. N. (2022). *Effect of visibility limiting weather elements on flight operations in Akure Airport, Ondo State, Nigeria* (Master's dissertation). Nigerian Defence Academy, Kaduna.

Ayoade, J. O. (2004). *Introduction to climatology for the tropics*. Spectrum Books.

Balarabe, M., Abdullah, K., & Nawawi, M. (2015). Long-term trend and seasonal variability of horizontal visibility in Nigerian troposphere. *Atmosphere*, 6(10), 1462–1486.

Burton, I., Kates, R. W., & White, G. F. (1978). *The environment as hazard*. Oxford University Press.

Dan-Okoro, R., Hassan, S. M., & Agidi, V. A. (2018). Seasonal effects of weather elements on flight operations at Nnamdi Azikiwe International Airport, Abuja, Nigeria. *Current Journal of Applied Science and Technology, 28*(6). https://doi.org/10.9734/CJAST/2018/41590.

Eyiangho, J. (2025, December 31). 2025: NAF neutralises 2,351 terrorists in 274 airstrikes. *The Guardian*. https://guardian.ng/news/2025-naf-neutralises-2351-terrorists-in-274-airstrikes/

FAAN. (2016). *Mallam Aminu Kano International Airport*. Federal Airports Authority of Nigeria. www.faan.gov.ng/airports/international

Glossary of Meteorology. (2009). American Meteorological Society.

Igbo-Uchi, C. N. (2025). Dust haze and implications on aviation and human health over Northern Nigeria. *International Innovative Journal of Physics, 1*(1), 73–89.

International Air Transport Association. (2026). *IATA annual safety report – 2025: Executive summary and safety overview*. https://www.iata.org/contentassets/a8e49941e8824a058fee3f5ae0c005d9/safety-report-executive-summary-and-safety-overview_2025.pdf

International Civil Aviation Organization. (2023). *Global aviation safety plan 2023–2025* (Doc 10004). Montreal, Canada: Author.

International Civil Aviation Organization. (2025). *Safety: State of global aviation safety. ICAO safety report 2025 edition*. Montréal, Canada: Author. https://www.icao.int/sites/default/files/sp-files/safety/Documents/ICAO_SR_2025.pdf

Iornongo, T., Yahaya, T. I., Babanma, J. S., & Masha, I. J. (2020). Evaluation of the effects of low horizontal visibility on flight operations in Nnamdi Azikiwe International Airport, Abuja. *International Journal of Environmental Design & Construction Management, 18*(4), 1–15.

Kim, K., Lee, H., Lee, M., Bae, Y., Kim, H. S., & Kim, S. (2024). Impact analysis of weather factors on aircraft cancellation using multilayer complex network. *Research Square*.

Kwasiborska, A., Grabowski, M., Sedláčková, A. N., & Novák, A. (2023). The influence of visibility on the opportunity to perform flight operations with various categories of the instrument landing system. *Sensors, 23*(18), Article 7953

Lawal, Y. B., Owolawi, P. A., Tu, C., Ojo, J. S., Ojo, O. L., & Sodunke, M. A. (2025). Spatio-temporal distribution of visibility over Nigeria using kernel density estimation techniques for fog-induced attenuation. *Telecom, 6*(3). https://doi.org/10.3390/telecom6030062

Lei, T., Jin, C., & Qi, C. (2022). Spatio-temporal characteristics of hazardous weather affecting Chinese airports based on the ERA5/ERA5-land reanalysis dataset. *Frontiers in Climate, 4*, Article 835362. https://doi.org/10.3389/fclim.2022.835362

Mande, K. H. (2019). Effect of climate change on airline flights operations at Nnamdi Azikiwe International Airport Abuja, Nigeria. *Science World Journal, 14*(2), 33–41. http://www.scienceworldjournal.org

National Commission on Military Aviation Safety. (2020). *Military aviation losses FY2013–2020: Report to the President and the Congress of the United States*. Washington, DC: Author

Nigerian Air Force. (2024, February 14). *Air power remains indispensable and unrivalled in tackling current security challenges*. Nigerian Air Force News.

Nigerian Meteorological Agency. (2025). *Aerometeorological bulletin (April–June 2025)*. Nigerian Meteorological Agency

Nigerian Meteorological Agency. (2026). *2025 State of the climate in Nigeria*. NiMet.

Olabode, A. D. (2021). Statistical analysis of weather parameters for sustainable flight operation in Nigeria. *Journal of Environmental Geography, 14*(3–4), 47–53. https://doi.org/10.2478/jengeo-2021-0011

Onwuadiochi, I. C., Ijioma, M. A., Ezenwaji, E. E., & Obikwelu, M. C. (2019). Effects of wind shear on flight operations in Sam Mbakwe Airport, Imo State, Nigeria. *Tropical Built Environment Journal, 7*(1), 12-23.

Oyegun, C. U., & Ologunorisa, T. E. (2002). Weather and climate. In C. U. Oyegun & A. A. Adeyemo (Eds.), *Port Harcourt region*. Paragraphics.

Seinfeld, J. H. (2005). *Atmospheric chemistry and physics: From air pollution to climate change*. John Wiley & Sons.

Smith, K. (2013). *Environmental hazards: Assessing risk and reducing disaster* (6th ed.). Routledge.

Weli, V. E., & Ifediba, U. E. (2014). Poor weather conditions and flight operations: Implications for air transport hazard management in Nigeria. *Ethiopian Journal of Environmental Studies and Management*, 7(3), 235–243.

White, G. F. (Ed.). (1974). *Natural hazards: Local, national, global*. Oxford University Press.

Zakari, N. (2013). Analysis of temporal variation of Harmattan dust haze and airline operation in Kano metropolis (2002–2007). *International Journal of Innovative Research and Studies,* 2(9), 12–20.