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IMPACT OF WEATHER ON ROAD TRAFFIC ACCIDENTS IN ONDO STATE, NIGERIA: 2005 - 2012

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Abstract: Road traffic accidents and their related deaths have become a major health problem and concerns. Studies have examined the impact of weather on road traffic accidents and casualties. However, the effect of weather on road traffic accidents in the existing literature is scanty in Nigeria. In the light of the growing interest in understanding the interrelationship between climate change and transportation including road traffic accidents, this study examines the impact of rainfall and temperature on road traffic accidents in Ondo State, Nigeria between 2005 to 2012. Secondary data on monthly road traffic accidents, rainfall and temperature were derived for the study duration from the Federal Road Safety Commission (FRSC) and Nigerian Meteorological Agency (NIMET). A total of 337 road traffic accidents occurred between 2005 and 2012, 30.83% were fatal, 52.56% were serious and 16.60% were minor accidents. The main finding is that the total road traffic accident is a function of several other factors than rainfall and temperature. Specifically, correlations between road traffic accidents and elements of weather were generally low and never exceeding 0.41. Both rainfall and temperature were negatively and positively correlated on yearly bases. Similarly, multiple linear regression models between road traffic accidents and the weather elements on yearly bases show that the variations in road traffic accidents accounted for by rainfall and temperature are equally low never exceeding 25.7%. In order to determine whether or not the weather effects on road traffic accidents are significant, continued research using additional weather and no weather variables is needed to replicate this study in the country.

Key words: road, traffic, accidents, weather, Ondo state, Nigeria

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INTRODUCTION

Road traffic injuries are the eighth leading cause of death globally (WHO, 2013). About 1.24 million people die in road traffic accidents and between 20 and 50 million people are injured (WHO, 2013). Road traffic accidents and their related deaths have become a major health problem and concerns worldwide. In Nigeria, road traffic safety has been a subject of considerable public debate. Hence, studies on road traffic accidents in the country have generally focused on issues such as spatio-temporal analysis of road traffic accidents (Jegede, 1988; Asogwa, 1992; Filani & Gbadamosi, 2007); variability in road traffic accidents (Atubi & Onokala, 2009; Atubi, 2010, 2012); determinants of road traffic accidents (Osayomi, 2013); safety issues and socio economic

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cost of road traffic accidents (Ipingbemi, 2008; 2012; Adaramo, 2012a) and Epidemiology of road traffic accidents (Oyemade, 1973). Other studies concentrated on: Road Traffic Accident Injuries and Productivity (Adaramo, 2012b); traffic regulations and road traffic accidents (Gbadamosi, 2002).

Missing from these studies is a study on the contribution of weather and climate to road traffic accidents. Available studies on weather and road traffic accidents are in Nigeria are recent and very few (see Enente & Igu, 2011) as compared to many studies on the subject in the developed countries (Brijs et al., 2008; Stipdonk, 2008; Eisenberg, 2004; Shankar et al., 2004; Andrey et al., 2002; Edwards, 1996; Smith, 1982). The paucity of knowledge on the relationship between road traffic crashes and elements of weather and the increase in fatality and injuries associated with road traffic accidents has necessitated this study. The need for this study is also necessary due to the growing interest in understanding the interrelationship between climate change and transportation worldwide.

The present study builds on the existing works by providing insights into the impact of weather on road traffic accidents in Ondo state, Nigeria between 2005 and 2012. The objectives of the study are to explore the relationship between road traffic accidents and elements of weather (rainfall and temperature). The rest of this paper is organized as follows: a synthesis of literature is presented in Section 2. Section 3 describes the study area, while data sources and method of analyses are discussed in Section 4. The results and discussion are presented in Section 5 while section 6 is the conclusion.

LITERATURE REVIEW

In developed countries, studies on weather and road crashes and associated fatality and injury have a long history. Empirical evidence on the impact of precipitation (rain and snow) on the frequency and severity of road accidents is abundant (Eisenberg, 2004; Edwards, 1996; Aguero-Valverde, 2005; Aguero-Valverde & Jovanis, 2006), most of the studies indicate a positive relationship between precipitation and frequency (severity) of road accidents. For instance, Andrey et al. (2002) using data from mid-sized Canadian cities, found that extreme increases in road accidents and injuries due to precipitation. On average, precipitation increases the number of accidents by 75% and the number of related injuries by 45%, with snowfall having a more substantial effect than rainfall.

Increase in rainfall is often linked to high accident frequencies (Fridstrøm et al., 1995; Chang & Chen, 2005; Caliendo et al., 2007; Hermans et al., 2006). However, increase in rainfall has also been found to reduce the number of accidents (Karlaftis & Yannis, 2010). The time-varying effects of rainfall have also been investigated. Eisenberg (2004) has shown that the impact of precipitation (rainfall) on a given day is reduced when precipitation was observed in the previous days, which is possibly due to driver adaptation. In the same vein, Brijs et al., (2008) have confirmed Eisenberg's finding that the longer the "dry spell" (i.e. the number days since the previous rainfall) the higher the number of accidents when rainfall occurs.

Enete and Igu (2011) examined interactions between rainfall characteristics and road crashes in Enugu, Nigeria using indices such as Rain Crash Index (RCI), Wet Crash Rate (WCRi), Dry Crash Rate (DCRi), Rain Crash Effect (RCEi) and Rain Class Crash Rate (RCCRi). The study established that 29.8% of road crashes in Enugu occurred during wet months of 2009, with the highest wet crash occurred in the month of June (28 crashes). It was also found that the effect of rainfall on road accident count depends on the length of time since the last rainfall. Large dry spell days recorded more accident counts. Higher temperatures increase accident frequencies (Scott, 1986). Extreme temperatures (low in winter and high in summer) are positively correlated with road accidents. Also, the number of hours of sunlight appears to increase road accidents (Fridstom et al., 1995; Hermans et al., 2006), while deviations from mean daily or monthly temperatures have also been found to increase road accidents (Brijs et al., 2008; Stipdonk, 2008). On the other hand, increases in sub-zero temperatures days, lower exposure thus reducing the number of road accidents (Hermans et al., 2006; Stipdonk, 2008).

In terms of methodology, a wide variety of methods (least squares, Poisson and negative binomial regressions, mean differences) have been used to examine the relationship between weather and road accidents. Using, meteorological data like temperature and rainfall variables, findings from such studies varies due to the choice weather variables and time frame. For instance, Bergel-Hayat et al (2013) explored the link between weather conditions and road accident risk at an aggregate level and on a monthly basis using aggregate datasets of injury accidents for France, the Netherlands and the Athens region, over periods of more than 20 years. Time series analytical models with explanatory variables that measure the weather quantitatively were employed in the analysis. The main results reveal significant correlations on a monthly basis between weather variables and the aggregate number of injury accidents.

STUDY AREA

Ondo state the study area is located in the south-west of Nigeria. The state lies between latitudes 50 45' and 70 52'N and longitudes 4020' and 60 05'E (figure 1). The state covers approximately 15,195 square kilometers of landmass and is bounded on the east by Edo and Delta states, on the west by Ogun and Osun States, on the north by Ekiti and Kogi States and to the south by the Bight of Benin and the Atlantic Ocean. The population of the study area is 3,460,877, from the statistic of 2006 Population Census (National Population Commission, Abuja).

The climate of Ondo State is of the Lowland Tropical Rain Forest type, with distinct wet and dry seasons. In the south, the mean monthly temperature is 270 °C, with a mean monthly range of 20 °C, while mean relative humidity is over seventy five percent (75%). However, in the northern part of the state, the mean monthly temperature and its range are about 300C and 60 °C respectively. The mean monthly relative humidity is less than seventy percent. In the south, rain falls throughout the year, but the three months of November, December and January may be relatively dry. The mean annual total rainfall exceeds 2000 millimeters (Adefolalu, 1997). However, in the north, there is marked dry season from November to March when little or no rain falls. The total annual rainfall in the north, therefore, drops considerably to about 1800 millimeters. The state has a system of road networks linking both the cities, towns and villages together. While all the inter-urban roads are tarred, few of the inter-rural roads are untarred and generally unmotorable during the raining season of April to October. Given the various sizes of the settlements in the study area, the level of interaction of people, goods and services in the state vary according to road type, and the population they served.

DATA AND METHODS

Data on road traffic accident and climatic elements used in this study were derived from different secondary sources. Monthly data of road accidents in Ondo state between 2005 and 2012 were obtained from Ondo state command of the Federal Road Safety Commission of Nigeria (FRSC). Collection and documentation of data on road accident is the official responsibility of the FRSC and the Nigerian Police Force (NPF). The monthly accident data provides the opportunity for temporal analyses of occurrence of accidents on monthly and yearly basis. The accident data from 2005 to 2012 obtained for each of years on monthly bases include: the total number of accidents recorded, total vehicles involved, number of persons involved, total killed, total persons injured, and total casualties. In addition, monthly data on rainfall and maximum temperature for the same period were obtained from Nigerian Meteorological Agency (NIMET).

This time period was chosen because it was the only period for which complete accidents and climatic data for the state are available on monthly basis. Analysis of variance (ANOVA), correlation, linear regression and simple statistical techniques such as frequencies and percentages were used for the data analysis. Linear regression models were also fitted to explain variations in road traffic accidents and to assess the degree to which the variations in road traffic accidents were associated with the monthly rainfall and maximum temperature.

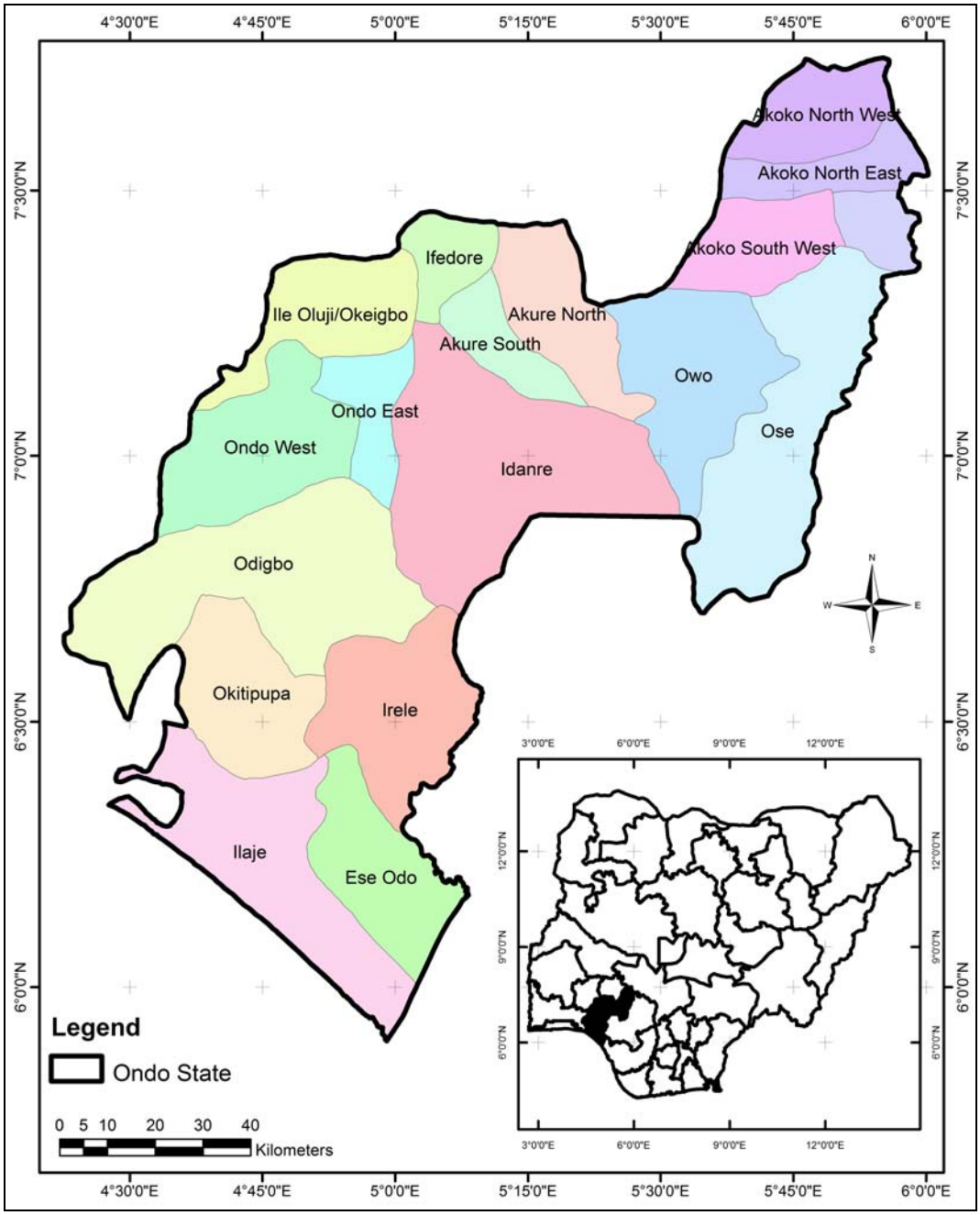

Figure 1. Map of Ondo State showing local government areas

RESULTS AND DISCUSSION

MAGNITUDE OF ROAD TRAFFIC CRASHES

During the period of analysis (2005 to 2012), a total of 1813 road traffic crashes were recorded; 30.83% were fatal, 52.56% classified as serious crashes and 16.60% are minor

crashes. The crashes resulted in 1393 fatalities and 6419 injuries, altogether totaling 7812 road traffic casualties between 2005 and 2012.The injury to fatality ratio thus stood at about 4.61 to 1, implying that for every person killed in road traffic crashes, about five other people injured (table 1). The number of reported crashes increased by 84.57% (n = 52 to 337) between 2005 and 2012, while road traffic injuries increased by 87.35%. During the same period, the deaths due to road traffic accidents of vehicles increased by 73% (n = 64 to 237).

In terms of yearly variation in road accidents during the study period, the result of the analysis of variance (ANOVA) shows that the F-value is 27.566 and the significance value is .000 ($F(7,88)= 27.566$, $p<0.01$). This implies that there is significant variation in yearly incidence of road accidents in Ondo state during the study duration. However, no significant monthly variation was established ($F(11,84)= 0.285$, $p>0.05$).

Table 1. Trends in road traffic accidents, casualties and vehicles involved, Ondo state, Nigeria, 2005 - 2012
Source: Author's Analysis, 2015

Year	Crashes				Casualties		
	Minor	Serious	Fatal	Total	Injured	Killed	Total
2005	12	25	15	52	174	64	238
2006	11	39	17	67	196	71	267
2007	52	109	76	237	882	176	1058
2008	63	122	63	248	926	133	1059
2009	43	128	69	240	597	141	738
2010	52	167	74	293	1097	281	1378
2011	40	181	118	339	1171	290	1461
2012	28	182	127	337	1376	237	1613
Total	301	953	559	1813	6419	1393	7812
Percent	16.60	52.56	30.83	100.00	82.17	17.83	100.00

RAINFALL IMPACT ON ROAD TRAFFIC ACCIDENTS TREND (2005 – 2012)

The distribution of road traffic accidents according to monthly rainfall on yearly basis is shown in Tables 2a & 2b. Generally the amount of rainfall increases gradually from no rainfall/ little rainfall from the dry seas months (November, December, January, February and March) to substantial amount during the wet season months (April to October). However, variation occurred in the distribution of rainfall from year to year. In terms of associated road traffic accidents, Figure 2 indicates a number of obviously differences between the monthly rainfall and road traffic accidents. For instance, in 2005, July with the highest rainfall (314.6 mm) is associated with the lowest (1) case of road traffic accident. Similarly, dry season months of 2005 had between 3 and 6 reported cases of road traffic accidents. A comprehensive examination of tables 2a and 2b show that between 2008 and 2012, dry season months had more cases of road traffic accidents than the wet season months.

Table 3 shows correlation coefficient between rainfall and accidents during wet and dry seasons respectively for the study duration. Different degrees of positive and negative correlations for the two seasons on yearly basis are revealed (table 3). The correlations were not significant, generally low and never exceeded 0.28 for wet seasons, while that of the dry seasons shows moderate level positive correlation (0.59) in 2007.

The effect of rainfall on accidents seems to be related non-linearly with accident rates, while some studies imply linear correlation with the number of accidents. The findings of this study are quite consistent with most similar studies. Studies have found negative or non-significant correlations between rain and accidents. For instance, Enete and Igu (2011) in a study in Enugun city, Nigeria

found that the effect of rainfall on road accident count depends on the length of time since the last rainfall. Large dry spell days recorded more accident counts. Aguero-Valverde and Jovanis (2006) analyzed 5-year injury and fatal crashes in Pennsylvania, U.S., and concluded that, although total precipitation was found to have a positive linear relationship in the traditional negative binomial models, it was not statistically significant in the hierarchical Full Bayesian models.

Table 2a. Road traffic accidents plotted against average monthly rainfall (2005 to 2008)
Source: Author's Analysis, 2015

Month	2005		2006		2007		2008	
	RTA	AMR	RTA	AMR	RTA	AMR	RTA	AMR
January	3	0	6	38.8	9	0	24	0
February	6	12.1	4	32.8	16	26.5	25	0
March	5	161.4	7	120.9	20	90	23	136.2
April	5	108.6	8	119.2	31	41.5	14	221.8
May	5	248.2	5	161	23	133	21	122.5
June	3	298.3	8	153.1	18	244.2	19	375.2
July	1	314.6	8	188.8	24	356.9	18	423.9
August	2	30.1	8	237.6	19	136.3	15	164.8
Septemeber	9	278.2	5	300.5	24	262.1	10	209.8
Octobe	6	142.4	3	153.2	18	111.9	23	218.9
November	4	38.4	1	49.9	17	108.9	24	9.5
December	3	17	4	0	18	10.7	32	48.4

RTC - Road traffic accidents, AMR - Average monthly rainfall

Table 2b. Road traffic accidents plotted against average monthly rainfall (2009 to 2012)
Source: Author's Analysis, 2015

Month	2009		2010		2011		2012	
	RTA	AMR	RTA	AMR	RTA	AMR	RTA	AMR
January	18	25.3	31	0	28	0	21	54.5
February	26	37.1	28	11	33	88.4	36	93.2
March	18	129.4	29	21.7	15	68	30	24.5
April	25	152.1	21	109.8	19	73.6	33	92.8
May	4	242.9	28	147.1	22	189.9	26	153
June	22	207.1	20	213.4	23	223.8	29	261.6
July	30	320.3	29	177.4	28	364.4	36	255.4
August	16	107.7	21	454.9	42	180.5	21	102.3
Septemeber	15	98.4	25	323.3	31	270.4	25	188.5
Octobe	17	146.5	21	194.7	25	232.3	18	247
November	35	53.5	20	149.3	23	5.2	24	107.4
December	14	0	20	65.2	50	0	38	11.6

RTC - Road traffic accidents, AMR - Average monthly rainfall

Karlaftis and Yannis (2010) used 21 years of daily count data for Athens, Greece, and found that high amount of precipitation may reduce the number of accidents. This effect according to Jaroszweski & McNamara (2014) may be *"attributed to driver risk compensation behaviour or to a simultaneous decrease of exposure"*.

Nonetheless, some positive results have also been reported which also support the findings of this study. Increased rainfall have also been found to increased accident frequencies (Andrey & Yagar, 1993; Fridstrøm et al., 1995; Caliendo et al., 2007; Levineet al., 1995; Edwards, 1996; Chang & Chen, 2005). Haghighi-Talab (1973) found a positive effect of rainfall on accident rates, but observed no statistical difference between moderate and heavy rainfall, as these two weather conditions have similar effects. An earlier study in Nigeria affirmed the positive relationship between rainfall and road traffic accidents. Enete and Igu (2011) in their study of the interactions between rainfall characteristics and road crashes in Enugu, Nigeria found that 29.8% of road crashes in Enugu occurred during wet months of 2009, with the highest wet crash occurred in the month of June (28 crashes).

Table 3. Correlation between rainfall and road traffic accidents on seasonal basis (2005-2012)
Source: Author's Analysis, 2015

Year	Dry Season		Wet Season	
	r	sig	r	sig
2005	0.325	0.59	0.068	0.88
2006	0.472	0.42	-0.112	0.81
2007	0.597	0.28	-0.224	0.62
2008	-0.07	0.91	0.09	0.84
2009	0.107	0.86	0.283	0.53
2010	-0.862	0.05	-0.239	0.6
2011	-0.34	0.57	0.254	0.58
2012	-0.216	0.72	0.156	0.73

TEMPERATURE IMPACT ON ROAD TRAFFIC ACCIDENTS TREND (2005 - 2012)

Tables 4a and 4b display monthly distribution of road traffic accidents and maximum monthly temperature on yearly bases. Obviously, there are differences between the two variables on monthly and yearly bases. Variations in temperature appear to have mixed effects on road traffic accidents. For instance, higher temperatures have decreasing effects on accidents frequencies especially in the month of December of 2005, 2006, 2009 and 2010, while it exert increasing effects on accident frequencies in same month in 2008, 2011 and 2012.

A similar trend for other months for the study period is shown in tables 4a and 4b. The correlation coefficient between accidents and temperature revealed a non significant relationship for the study period ($r=-0.04$, $p>0.05$). On yearly basis, monthly maximum temperature and road traffic accidents are negatively correlated in 2006, 2007 and 2011, while the two variables are positively correlated in 2005, 2008, 2009, 2010, and 2012 (table 5). The mixed effects of temperature on road traffic accidents established by this study are in line with findings of several studies at international level. Studies from developed countries confirmed that higher temperatures increase accident frequencies (Scott, 1986; Brijs et al., 2000). The number of hours of sunlight appears to increase road accidents (Fridstom et al., 1995; Hermans et al., 2006), while deviations from mean daily or monthly temperatures have also been found to increase road accidents (Brijs et al., 2008; Stipdonk, 2008).

Table 4a. Road traffic accidents and average monthly maximum temperature (2005 - 2008)
Source: Author's Analysis, 2015

Month	**2005**		**2006**		**2007**		**2008**	
	RTA	**MMT**	**RTA**	**MMT**	**RTA**	**MMT**	**RTA**	**MMT**

January	3	34.1	6	32.9	9	30.8	24	30.6
February	6	34.9	4	34.8	16	33.9	25	32.5
March	5	33.9	7	33.4	20	33.3	23	32.4
April	5	32.4	8	33.9	31	32.3	14	32.3
May	5	31.7	5	31.3	23	30.9	21	30.3
June	3	30	8	30.9	18	29.5	19	29.5
July	1	28.3	8	28.9	24	24.5	18	27.6
August	2	27.7	8	27.9	19	26.2	15	27.2
Septemeber	9	29.9	5	28.7	24	27.6	10	28.3
Octobe	6	31	3	30.4	18	29.3	23	28.8
November	4	33.5	1	30.2	17	30.2	24	31.1
December	3	33	4	31.2	18	31.2	32	32.3

RTC - Road traffic accidents, MMT - Maximum monthly temperature

Table 4b. Road traffic accidents and average monthly maximum temperature (2009 - 2014)
Source: Author's Analysis, 2015

Month	2009		2010		2011		2012	
	RTA	MMT	RTA	MMT	RTA	MMT	RTA	MMT
January	18	31.9	31	31.8	28	33.6	21	32.9
February	26	32.9	28	32.1	33	33.1	36	34.6
March	18	32.4	29	31.8	15	32.3	30	34.5
April	25	31.3	21	32.2	19	30.4	33	31.6
May	4	30.3	28	30.4	22	31.4	26	31.7
June	22	29	20	28.4	23	30.1	29	29.7
July	30	27.3	29	27.3	28	28.9	36	28.3
August	16	26.4	21	26.8	42	27	21	28
Septemeber	15	27.3	25	28.3	31	28.9	25	29.1
Octobe	17	29.1	21	29.2	25	29.9	18	31.2
November	35	30.3	20	30.6	23	32	24	32.4
December	14	30.3	20	31.7	50	33.4	38	33.3

RTC - Road traffic accidents, MMT - Maximum monthly temperature

Malyshkina et al., (2008) found that extreme temperatures (both low during winter and high during summer) are positively correlated with road accidents; on the other hand, when the monthly number of days with temperature below zero increases, road accidents are reduced possibly due to reduced exposure (Hermans et al., 2006; Stipdonk, 2008).

Table 5. Correlation between temperature and road traffic accidents on yearly basis (2005-2012)
Source: Author's Analysis, 2015

Year	Maximum Temperature (Monthly)	
	r	sig

2005	0.30	0.33
2006	-0.03	0.93
2007	-0.15	0.65
2008	0.57	0.05
2009	0.08	0.81
2010	0.20	0.53
2011	-0.44	0.89
2012	0.19	0.56

RELATIONSHIP BETWEEN ROAD TRAFFIC ACCIDENTS AND WEATHER ELEMENTS

A multivariate regression model was computed to capture the simultaneous effect of rainfall and temperature on the number of road traffic accidents. The analysis show that the variation in road traffic accidents accounted for by monthly rainfall and maximum temperature are generally low never exceeding 25.7%. This is to be expected do the low level of correlation between the two metrological variables and road traffic accidents. This indicates that there are other factors which should be used to explain the variance in yearly road traffic crashes in the study area.

CONCLUSION

This study has examined the role of temperature and rainfall as it affects road traffic accidents in Ondo state, Nigeria between 2005 to 2012. The study has particularly highlighted the dual roles of temperature and rainfall. Road traffic accident rate continues to increase from year to year, even though the contribution of temperature and rainfall varies on monthly and yearly bases. The study is particularly timely in Nigeria as FRSC and the Nigerian Police Force (NPF) are trying to reduce the rates of road traffic accidents in the country. For these reductions to occur, the weather condition of accident spots needs to be part of traffic accident data collected by FRSC and NPF. Clearly, additional studies are needed elsewhere in Nigeria to ascertain whether the relationships outlined above apply throughout the country.

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