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Spatial Epidemiology of Road Traffic Crashes and Mortality in Nigeria, 2007-2015

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Authors' contributions

This work was carried out in collaboration between all authors. Author OJD designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors OAA and KSO managed the statistical analyses of the study. Authors GJM and AAS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: Road traffic accidents (RTA) are an important public health problem with considerable morbidity, mortality and disability especially in low income countries. Spatial analysis tool has been used in the study of RTA in high income countries while very few studies have been carried out in Africa including Nigeria. This study was therefore conducted to explore the epidemiology of road traffic accidents in Nigeria using spatial analytical tools.
Methods: The study is an ecological study which utilizes secondary data on road traffic accidents and mortality between 2007 and 2015 from the Federal Road Safety Commission in Nigeria. The 36 states and Federal Capital Territory were used as the unit of geographical analysis. The global

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Moran's *I* and Local Moran's *I* (LISA) test were used to measure spatial autocorrelation and significant levels were taken at $p<0.05$.

Results: A total of 83,548 road traffic accidents and 76,822 deaths were reported in Nigeria from 2007-2015.The total road crashes in 2007 was 5.7/100,000 population and this increased gradually to a peak of 8.7/100,000 population in 2009 and then declined to 2.9/100,000 in 2011 and to another peak of 7.8/100,000 in 2011. However, the peak year for deaths as a result of road traffic crashes was in 2010. On the average, Federal Capital Territory had the highest frequency of road crashes while Kano state had the highest frequency of deaths associated with road crashes.Nasarawa state and the Federal Capital Territory were identified as hotspots for road traffic crashes and mortality associated with road traffic crashes in the country.

Conclusion: The study found a decline of RTA over the years under study. There was however significant clustering of RTA occurrence and death in the Federal capital territory and Nasarawa state. The findings provides evidence based information to policy makers to deploy scarce resources to the identified hot spot states in order to mitigate the occurrence and mortality associated with RTA in the country. Further research is required to explore the determinants for the high rates of RTA in the identified clusters.

Keywords: Spatial analysis; road traffic accidents; geographical analysis; spatial epidemiology; road traffic deaths; road traffic crashes; Nigeria.

1. INTRODUCTION

Road traffic accidents are an important public health problem with considerable morbidity, mortality and disability especially in low income countries. The World Health Organization estimates that about 1.25 million people die each year as a result of road traffic crashes and about 90% of these deaths occur in low - and middle - income countries, though these countries have approximately half of the world's vehicles [1]. Apart from deaths, it is estimated that about 20-50 million more people suffer non-fatal injuries, which has resulted in permanent disabilities [1].

In comparison to the high income countries, road traffic deaths are more than double in low and middle-income countries [1]. The African region has the highest road traffic deaths in the world and the region also has the highest pedestrian and cyclist deaths of all road traffic deaths partly as a result of economic development which led to an increase in the number of vehicles on the road and the fact that the road infrastructure were not improved to accommodate the increase coupled with the low level of the implementation of safety measures to protect road users [2]. The consequences of road traffic injuries includes considerable economic losses as a result of cost of treatment, reduced or lost productivity as a result of death, injury or disability or due to family members who take time off work to care for their injured loved ones [3].In 2013, 90% of disability adjusted life years (DALYs) lost from road traffic injuries occurred in low- and middle-income countries [4].

There has been a strong international response to combat the menace of road transport accidents. The United Nations General Assembly declared 2011–2020 as the Decade of Action for Road Safety in an attempt to galvanise international support to improving safety of roads and combat road traffic crashes [5]. In addition, a new road safety target was set as part of the Sustainable Development Goals which considers halving the global number of deaths and injuries from road traffic crashes by 2020. The achievement of these goals will require concerted efforts from all stakeholders especially in sub-Saharan Africa.

One of the tools that can assist governments in sub-Saharan African to achieve the stated sustainable development goals is to combine spatial data (data on geographic units) to the increasingly available data on road traffic accidents (RTA). The use of spatial analysis in the study of RTA has the capability to identify, locate and characterize the patterns of road traffic accidents, enable the visual analysis of hot spots and the identification of contributory factors with a view to determine targeted interventions which are necessary to prevent or mitigate future occurrence of road traffic accidents. Spatial analysis tool has been used in the study of RTA in high income countries while very few studies have been carried out in Africa including Nigeria. Some studies have applied spatial analytic tools to identify hot spots for road traffic accidents and deaths in Nigeria but this has been limited to only one state or at the regional level [6-10] and there is no study to our knowledge that have either

applied spatial analytic tool to the entire country or use R statistical software to conduct spatial analysis. This study was therefore conducted to explore the spatial epidemiology of road traffic accidents in Nigeria.

2. METHODS

2.1 Study Design

The study is an ecological study of road traffic accidents in Nigeria between 2007 and 2015. The data for road traffic accidents at the national and sub-national level was obtained from the annual reports of the Federal Road Safety Commission (FRSC) in Nigeria from 2007-2015 [11]. Nigeria is the largest country in West Africa with a projected population of about 170 million people [12]. The country has 36 independent states and the Federal Capital Territory (FCT). The 36 states and the FCT are grouped into six geopolitical regions. The shape file of the country at the first administrative level (36 states and the FCT) was obtained online from the global administrative areas database website (www.gadm.org).

2.2 Spatial Exploration

The 36 states and FCT were used as the unit of geographical analysis. The Global Moran's *I* index was used to estimate the strength of the global spatial autocorrelation of the average road traffic accident rate per 100,000 populations in this study. The Global Moran's *I* share many similarities with Pearson's correlation coefficient and like a correlation coefficient, the values of Moran's *I* range from -1 to +1. A Moran *I* of +1 suggests a strong positive autocorrelation while a value of -1 suggests a strong negative spatial autocorrelation. The usefulness of Moran's *I* lie in its simplicity but its major limitations is that it tends to average local variations in the strength of spatial autocorrelation [13]. The global autocorrelation is a single measure that was used to assess the spatial autocorrelation of average road traffic accident and mortality rates per 100,000 populations in the country as a whole. The global Moran I is expressed by the formula [14].

$$I = \frac{N}{\Sigma_i \Sigma_j \omega_{ij}} \frac{\Sigma_i \Sigma_j \omega_{ij}(X_i-\bar{X})(X_j-\bar{X})}{\Sigma_i (X_i-\bar{X})^2} \quad (1)$$

Where N is the number of spatial units i.e. the 36 states and the Federal Capital territory indexed by i and j; X is the variable of interest (road traffic accident rate per 100,000 populations and mortality due to road traffic accident rate per 100,000 populations), $\bar{X}$ is the mean of X; and W_{ij} is an element of a matrix of spatial weights. In this study, we used a first order adjusted connectivity matrix, in which region i is considered neighbour of region j, if they share a common boundary. W_{ij} is zero (0) everwhere except for a contigiuos location i and j where it takes the value of 1.

The Local spatial autocorrelation (LISA) developed by Luc Anselin has become the standard tool to examine local spatial autocorrelation. This can be seen as the local equivalent of Moran's *I*. The LISA is particularly useful in situations where there are pockets of areas showing homogeneous values that do not follow the global trend of observations measured by the Global Moran *I*. The LISA can identify hot-spots where road traffic accident rate are pronounced across localities. It is expressed as [15].

$$I_i = z_i \sum_j \omega_{ij} z_j \quad (2)$$

Where z_i is the original variable x_i (road traffic accident rate per 100,000 populations and mortality as a result of road traffic accident rate per 100,000 populations) in standardized form and w_{ij} is the spatial weight as described above for global autocorrelation.

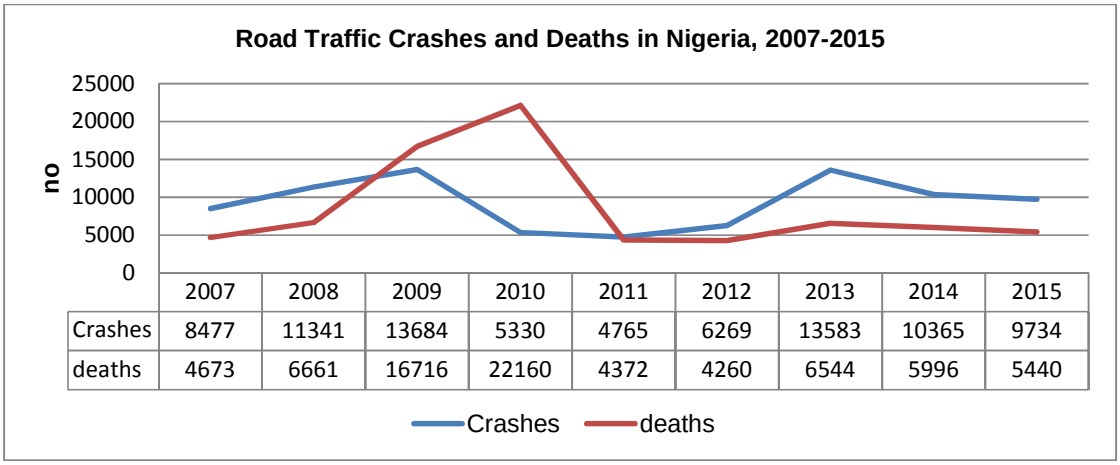
A choropleth thematic map was used to visualise possible clustering and the states with significant spatial autocorrelations were identified by mapping the P-value of the Local Moran's *I* statistics. The false discovery rate (FDR) method by Benjamin and Hochberg's was used for the adjustment of the local Moran's *I* p values [14]. A final choropleth map of local Moran's FDR-adjusted p values was produced and a P-value of ≤ 0.05 was regarded as statistically significant. The analysis of the data was carried out in R statistical package version 3.2.3

2.3 Ethical Consideration

Ethical clearance was not sought for this study because the study was based on road traffic accident data freely available at the Federal Road Safety Commission website in Nigeria with no personal identifiers.

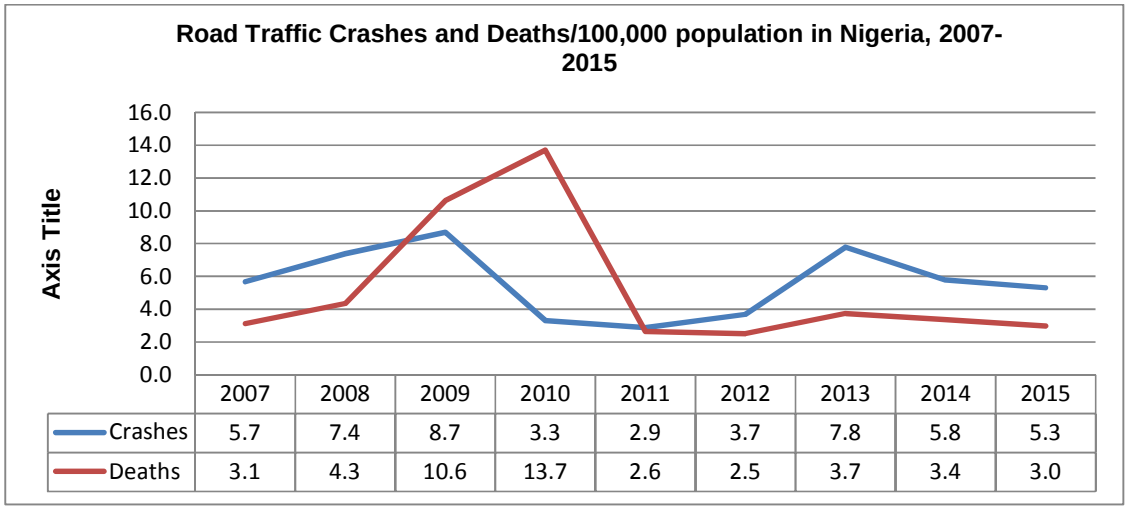
3. RESULTS

A total of 83,548 road traffic accidents and 76,822 deaths were reported in Nigeria from 2007-2015. The road traffic crashes rose from 8477 in 2007 to 13,684 in 2009 after which there was a gradual decline to 4765 in 2011. A gradual rise was observed to 13,583 in 2013 with a slight decline to 9734 in 2015 as shown in Fig. 1. Similarly the mortality associated with the road traffic crashes rose from 4673 in 2007 to a peak of 22,160 in 2010 after which there was a gradual decline to 4372 in 2011. Thereafter there was a steady increase to 6544 was observed as shown in Fig. 1. Similarly, the total road crashes per 100,000 population was 5.7/100,000 population in 2007 and this increased gradually to a peak of 8.7/100,000 population in 2009 and this declined to 2.9/100,000 in 2011 and to another peak of 7.8/100,000 in 2011. In contrast the peak year for deaths as a result of road traffic crashes was in 2010 as shown in Fig. 2. Fig. 3 presents the distribution of road traffic crashes per 100,000 populations among the 36 states and the Federal capital territory. Eight states had road traffic crashes above 7.6/100,000 population. The states are Ogun. Osun, Kwara, Niger, Kaduna, Nasarawa, Edo and the Federal Capital Territory as shown in Fig. 3. The states with high mortality rates associated with road traffic crashes above 7.7/100,000 population were Ogun, Ondo, Edo, Kwara, Nasarawa, Benue, Gombe and the Federal Capital Territory as shown in Fig. 4. Nasarawa state and the Federal Capital Territory were identified as hotspots for road traffic crashes and mortality associated with road traffic crashes in the country as shown in Figs. 5 and 6 respectively.



	2007	2008	2009	2010	2011	2012	2013	2014	2015
Crashes	8477	11341	13684	5330	4765	6269	13583	10365	9734
deaths	4673	6661	16716	22160	4372	4260	6544	5996	5440

Fig. 1. Trend of road traffic crashes and deaths in Nigeria, 2007-2015



	2007	2008	2009	2010	2011	2012	2013	2014	2015
Crashes	5.7	7.4	8.7	3.3	2.9	3.7	7.8	5.8	5.3
Deaths	3.1	4.3	10.6	13.7	2.6	2.5	3.7	3.4	3.0

Fig. 2. Trend of road traffic crashes and deaths/100,000 populations in Nigeria, 2007-2015

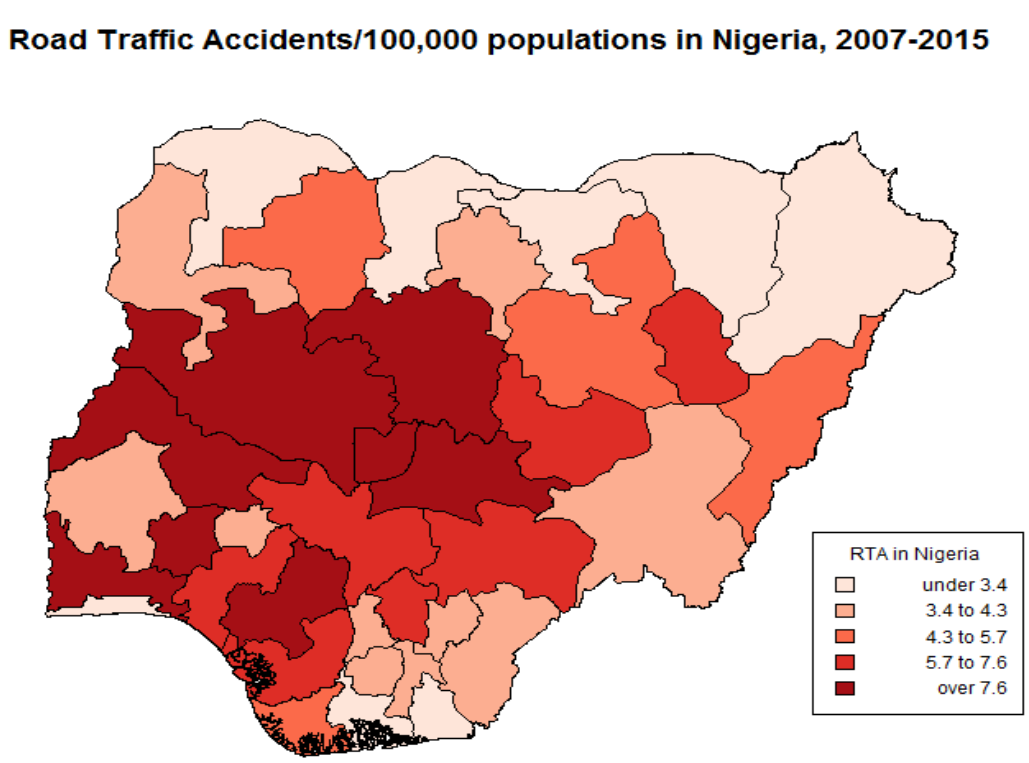


Fig. 3. Road traffic accidents/100,000 population in Nigeria, 2007-2015

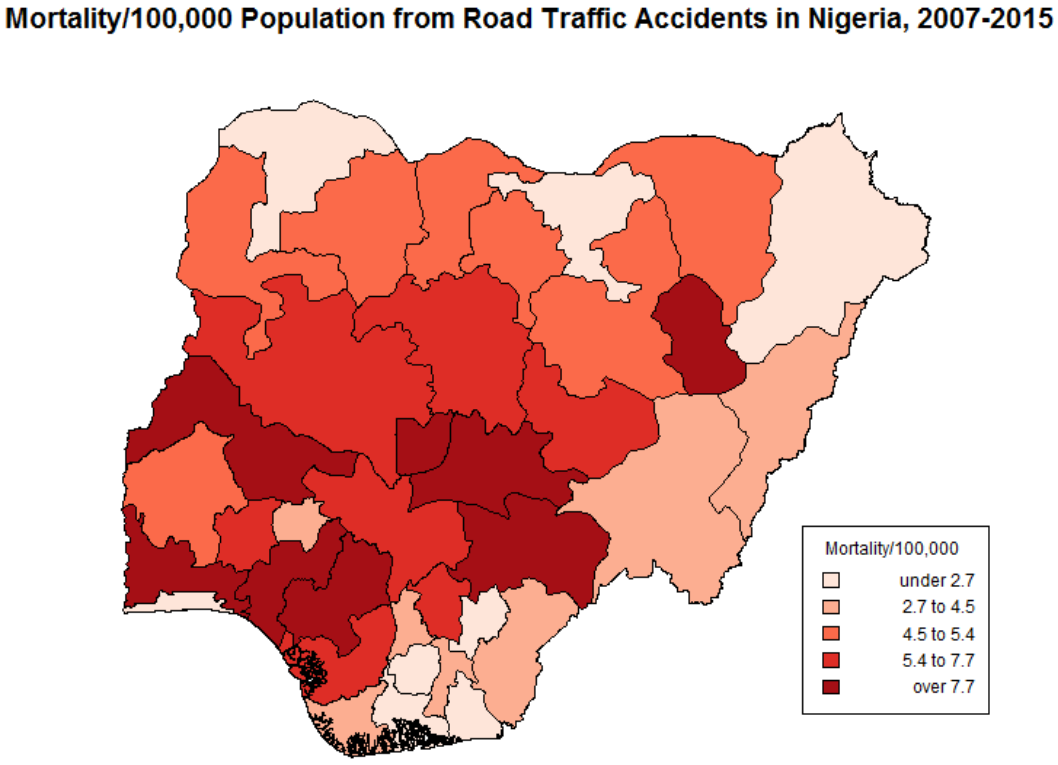


Fig. 4. Mortality/100,000 population from road traffic accidents in Nigeria, 2007-2015

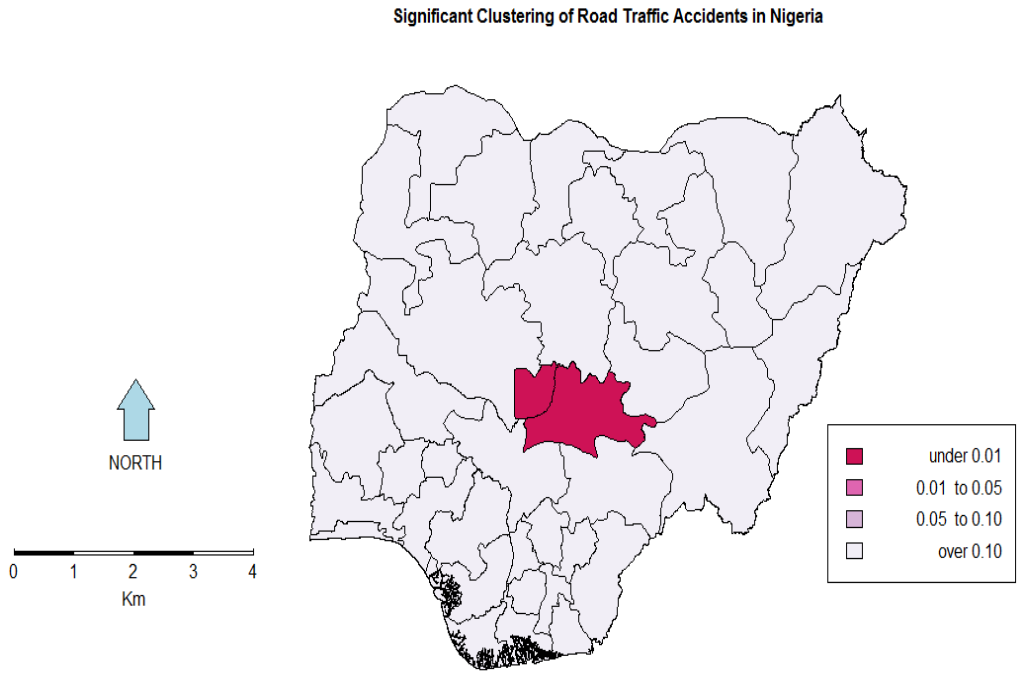


Fig. 5. Significant clustering of road traffic accidents/100,000 population in Nigeria

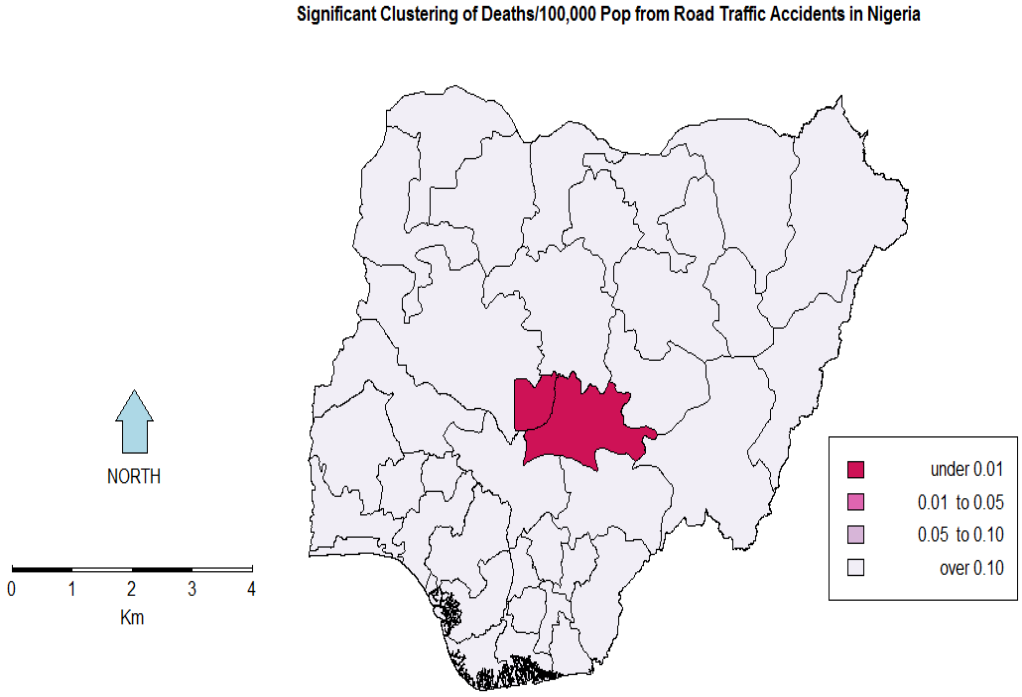


Fig. 6. Significant Clustering of Deaths/100,000 population from road traffic accidents in Nigeria

Table 1 shows the trend of road traffic accidents reported by the 36 states and the Federal capital territory (FCT) from 2007-2015. On the average the Federal Capital Territory had the highest

frequency (844.9) of road traffic crashes while Sokoto state had the lowest frequency (89.6). The rate of change of road traffic accidents was compared between 2007 and 2015. While most states of the country reported a decline in the number of road traffic accident, others reported an increase in the number of road traffic accidents during the period under consideration with the highest being Nasarawa state with an increase of 543%, followed by Ebonyi (+322%) and Kogi (+221) states over what was reported in 2007 as shown in Table 1.

Table 2 shows the mortality associated with road traffic crashes. Kano state had the highest frequency of deaths (535.8) due to road traffic crashes while Bayelsa state had the lowest mortality due to road traffic accidents during the period of under review.

Table 3 shows the Global Moran *I* statistics of road traffic accidents and the mortality associated with road traffic accidents. A significantly positive Global Moran I statistics was observed for road traffic accidents (RTA) which indicated a positive spatial autocorrelation of RTA in the country. This result was sustained both with the Moran test under randomization, normality and Monte Carlo simulation test at $p<0.05$. Similarly, a significant positive spatial autocorrelation was observed for mortality associated with RTA in the country using Global Moran test under randomization, normality and Monte Carlo simulation test conditions at $p<0.05$.

4. DISCUSSION

Spatial analysis is a tool that has the capability to identify, locate and characterize the patterns of road traffic accidents, enable the visual analysis of hot spots and the identification of contributory factors with a view to determine targeted actions necessary to prevent or mitigate the future occurrence of road traffic accidents [16-17].

The study demonstrates a general decline in the rate of road traffic accidents and associated mortality in the country compared with an all-time high of 716.57/100,000 reported in 1990 [18]. In spite of this decline at the national level, there exist wide variations at the subnational level which showed pockets of high rates of road traffic crashes and associated mortality in some states.

The study identified significant clustering in two contiguous locations namely the Federal Capital Territory (FCT) and Nasarawa state. The FCT is a gateway city between the southern and the northern part of the country with major highways namely Abuja-Lokoja, Abuja-Akwanga, Abuja-Jos, Abuja-Suleja and Abuja-Kaduna highways. These highways are characterized by a high volume of traffic, gridlocks and excessive speed by commuters. The FCT is the political capital of Nigeria with a growing influx of people from all over the country which has resulted in an increase in population density and vehicular movement in the city both of which increases the possibility of road traffic accidents. In addition, the rapid developments of economic activity in the FCT may have resulted in higher rates of accidents compared to other states. Some studies have shown significant association between economic development of cities and road traffic accidents [9-19].

Though this study identified the hotspots of RTA in the country, it was limited in identifying the factors associated with the high rate of RTA in the country for lack of data to compare across states. However, the study provides an opportunity for other studies to explore local risk factors that may be associated with high rate of RTA in the identified hotspots. A study conducted in FCT identified some factors that may be responsible for the RTA and associated mortality. The major factor found was the non-compliance with traffic rules by drivers especially over-speeding as a result of a better road network [8,20]. Other studies have also identified poor road infrastructure and maintenance which result in pot-holes on our major highways which are ‘death traps’ to motorist [17,21,22]. Similarly, FCT and Nasarawa state were also identified as hot spots for mortality associated with RTA. The increased mortality could be as a result of poor medical emergency services [23] that can immediately be called upon to respond during road traffic accident conditions.

The results of this study can be used by policy makers for better planning and the use of scarce resources to improve traffic management and decrease the occurrence of RTAs in the identified hotspots for RTA and associated mortality. There is a need for studies at a finer scale for example, the local government areas (which are the lowest administrative areas in the country) within the identified hot clusters to locate where the high rates of RTA occur and explore factors that may be responsible for the high RTA.

Table 1. Trend of road traffic crashes in Nigeria by states, 2007-2015

State	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total	Av. Crash	% Change
Abia	123	209	259	34	76	71	126	87	86	1071	119.0	-30.1
Adamawa	272	153	278	167	57	109	418	288	163	1905	211.7	-40.1
A/Ibom	238	239	395	62	47	56	99	57	50	1243	138.1	-79.0
Anambra	87	121	474	70	36	113	294	272	255	1722	191.3	+193.1
Bauchi	122	183	415	105	180	201	212	493	226	2137	237.4	+85.2
Bayelsa	136	219	93	41	32	44	139	95	69	868	96.4	-49.3
Benue	171	394	801	159	251	196	476	290	388	3126	347.3	+126.9
Borno	125	176	254	78	36	39	78	14	9	809	89.9	-92.8
C/River	201	118	378	53	16	50	169	197	138	1320	146.7	-31.3
Delta	130	284	590	152	105	262	520	290	200	2533	281.4	+53.8
Ebonyi	68	116	0	46	33	57	128	248	287	983	109.2	+322.1
Edo	179	387	558	239	152	344	258	239	274	2630	292.2	+53.1
Ekiti	100	160	220	42	57	118	157	60	55	969	107.7	-45.0
Enugu	176	468	646	80	80	131	301	248	250	2380	264.4	+42.0
FCT	545	690	801	59	475	531	1766	1395	1342	7604	844.9	+146.2
Gombe	110	187	0	536	77	131	207	179	189	1616	179.6	+71.8
Imo	290	198	152	46	102	175	305	241	170	1679	186.6	-41.4
Jigawa	330	241	97	113	38	24	148	101	149	1241	137.9	-54.8
Kaduna	524	1003	1328	92	90	336	1046	525	502	5446	605.1	-4.2
Kano	529	699	553	468	222	228	622	404	269	3994	443.8	-49.1
Katsina	383	167	379	239	54	93	340	159	225	2039	226.6	-41.3
Kebbi	126	146	346	171	40	13	192	149	143	1326	147.3	+13.5
Kogi	103	250	0	103	343	365	535	254	331	2284	253.8	+221.4
Kwara	188	300	288	264	156	200	253	199	207	2055	228.3	+10.1
Lagos	650	503	0	83	68	336	367	321	403	2731	303.4	-38.0
Nasarawa	124	366	95	240	268	218	1158	878	798	4145	460.6	+543.5
Niger	364	349	291	330	88	92	598	602	523	3237	359.7	+43.7
Ogun	502	1037	767	206	227	374	583	298	428	4422	491.3	-14.7
Ondo	218	209	509	386	268	287	314	285	211	2687	298.6	-3.2
Osun	204	422	646	118	260	306	294	266	266	2782	309.1	+30.4
Oyo	195	279	516	94	294	281	336	272	270	2537	281.9	+38.5
Plateau	310	279	454	111	57	85	324	245	236	2101	233.4	-23.9
Rivers	109	133	552	81	95	117	246	137	96	1566	174.0	-11.9
Sokoto	83	104	0	62	70	36	129	158	164	806	89.6	+97.6
Taraba	126	127	271	58	111	89	75	83	106	1046	116.2	-15.9
Yobe	122	246	148	43	52	52	43	70	53	829	92.1	-56.6
Zamfara	214	179	130	99	152	109	327	266	203	1679	186.6	-5.1

Table 2. Mortality from road traffic crashes by states in Nigeria, 2007-2015

State	2007	2008	2009	2010	2011	2012	2013	2014	2015	Deaths	Average deaths
Abia	77	131	351	126	56	17	55	38	41	892	99.1
Adamawa	52	70	364	589	38	75	88	72	71	1419	157.7
A/ Ibom	78	188	447	156	18	31	55	23	41	1037	115.2
Anambra	33	59	574	283	34	36	129	110	193	1451	161.2
Bauchi	84	80	594	608	257	293	78	269	187	2450	272.2
Bayelsa	70	150	156	73	15	10	34	21	16	545	60.6
Benue	98	279	1,874	437	187	117	232	169	176	3569	396.6
Borno	53	90	344	307	69	81	49	2	2	997	110.8
C/River	138	39	523	199	23	37	115	147	113	1334	148.2
Delta	43	171	544	739	96	154	315	210	151	2423	269.2
Ebonyi	25	63	0	140	16	22	30	113	180	589	65.4
Edo	130	247	492	1,131	184	228	290	216	184	3102	344.7
Ekiti	57	88	222	140	18	86	42	48	24	725	80.6
Enugu	91	331	491	425	84	77	123	178	95	1895	210.6
FCT	284	390	630	324	253	238	446	335	328	3228	358.7
Gombe	62	97	0	2,203	108	90	115	107	101	2883	320.3
Imo	73	129	57	216	63	79	114	103	70	904	100.4
Jigawa	170	126	147	379	53	41	99	115	79	1209	134.3
Kaduna	277	692	864	279	173	281	588	539	474	4167	463.0
Kano	356	446	643	1,924	279	158	461	358	197	4822	535.8
Katsina	295	34	1,196	791	139	135	150	247	190	3177	353.0
Kebbi	25	82	448	851	36	34	114	77	97	1764	196.0
Kogi	113	165	0	341	231	211	335	304	310	2010	223.3
Kwara	170	199	475	1,562	174	114	108	130	133	3065	340.6
Lagos	332	90	0	370	70	110	113	110	117	1312	145.8
Nasarawa	131	264	154	681	113	134	324	314	197	2312	256.9
Niger	144	226	570	1,013	182	97	327	227	199	2985	331.7
Ogun	412	517	1,029	763	166	247	309	232	307	3982	442.4
Ondo	144	123	714	1,486	234	239	190	173	198	3501	389.0
Osun	127	286	0	703	189	178	226	190	223	2122	235.8
Oyo	113	168	489	571	303	245	368	277	222	2756	306.2
Plateau	84	209	536	846	97	52	109	106	77	2116	235.1
Rivers	54	64	569	326	47	59	82	67	69	1337	148.6
Sokoto	45	43	0	223	86	50	41	108	102	698	77.6
Taraba	35	68	458	340	30	44	30	27	14	1046	116.2
Yobe	71	160	398	197	109	71	83	127	114	1330	147.8
Zamfara	127	97	363	418	142	89	177	107	148	1668	185.3

Table 3. Global Moran *I* statistics of road traffic accidents and deaths associated with RTA in Nigeria 2007-2015

	Road traffic crashes		Mortality associated with RTA	
	Moran *I* Statistic	**P value**	**Moran *I* Statistic**	**P value**
Moran I test under randomisation	0.16	0.0001	0.14	0.02
Moran I test under normality	0.16	0.0367	0.14	0.04
Monte-Carlo simulation of Moran I	0.16	0.001	0.14	0.001

5. STUDY LIMITATION

The major limitation is that the data utilized for this study is from the Federal Road Safety Commission (FRSC) in Nigeria which may not adequately represent the true burden of RTA in the country because some other organ of governed such as the traffic division of the Nigerian Police Force also have records on road traffic crashes in the country. However, the data from the FRSC is the most credible and reliable data on RTA in the country. The lack of reliable information especially mortality associated with RTA may be as a result of lack of active surveillance and follow up to report the outcome of injuries associated with road crashes. There is need for interagency collaboration to improve the data system on RTA in the country.

6. CONCLUSION

The study found a decline of RTA over the years under study. There was significant clustering of RTA occurrence and death in the Federal capital territory and Nasarawa state. The findings can provide evidence based information to policy makers to better plan and deploy scarce resources to hot spot states by improving traffic management and thereby decrease the occurrence of RTA and associated mortality in the identified hotspots.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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