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Two-Way Contingency Table Analysis for Casualty Due to Road Traffic Crashes

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ABSTRACT

Road traffic crash is an event on the road that is wished never to occur. Much more scared and worrisome is casualty due to road traffic crash. As a nation it is important to know where casualty due to road traffic crash occurs the most for appropriate interventions. This study aimed at investigating whether there is significant relationship between geo political regions in Nigeria and outcome of road traffic crash, where the target outcome is the casualty due to road traffic crashes. Data on number of casualties and non-casualties for each geopolitical region of Nigeria from the year 2016 to 2022 was collected and presented in a 6×2 contingency table. Pearson Chi Square test and Likelihood Ratio Chi Square test for independence were used to determine whether there is relationship between the geopolitical region and outcome of road traffic crash. Result revealed that there is significant relationship between the two categorical variables. To determine significant associations in the 6×2 contingency table, 15 possible local 2×2 tables were derived from the 6×2 contingency table, and odds ratio as a measure of association was employed. Results revealed that significantly, the odds ratio for each of the 15 possible local 2×2 tables are not equal to 1. Conclusively, the geopolitical region with the least casualties due to road traffic crashes in Nigeria is South East. Higher than South East region is South South region. Higher than South South region is South West Region. Higher than South West region is North West region. Higher than North West region is North East Region. The geopolitical region with the greatest casualties due to road traffic crash in Nigeria is North Central. Generally, the Northern region of Nigeria suffered higher casualties than the Southern region. More attention needs be given to stop the higher casualties suffered in the Northern region of Nigeria and particularly, in the North Central region.

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Introduction

Generally, road traffic crash is an event that is desired never to occur, and much more desired is casualty as an outcome of road traffic crash, never to occur even where road traffic crash occurs. In traffic management and road safety, it is important to understand the dynamics of casualties resulting from road traffic crash. Two-way contingency table analysis emerges as a powerful statistical tool in unraveling the underlying patterns and associations between various factors contributing to casualties in road traffic crashes.

Literatures on Two-way contingency table analysis for casualty due to road traffic crashes is expanding, with an increasing number of publications exploring its application in road safety research. The growth in research activity and citation rates indicates a growing interest and recognition of the importance of this analytical technique in understanding and addressing road traffic crashes. This is a promising sign for the future development of research in this area.

Bhalla and Naghavi, in their paper provides a comprehensive analysis of the global burden of road traffic injuries and projects future trends up to 2030 [1]. They used two-way contingency table analysis to examine the factors contributing to road traffic crashes and casualties. In their conclusion, they highlighted the significant impact of road traffic injuries on public health globally and emphasize the need for effective interventions to reduce casualties and improve road safety. Elvik, in their paper explores non-linear relationship between risk factors and road traffic crashes, with a focus on promoting environmentally sustainable transport options [2]. They used Two-way contingency table analysis to assess the effectiveness of the different interventions in reducing casualties. In their conclusions, they highlighted the importance of considering non-linear risk factors in road safety interventions and suggest that promoting sustainable transport can contribute to reducing road traffic casualties. Wang and Kockelman, in their paper investigated the relationship between roadway design characteristics and traffic safety outcomes using Two-way contingency table analysis [3]. Their study examined how different design features impact the likelihood of road traffic crashes and casualties. In their conclusions, they suggested that roadway design plays a significant role in influencing traffic safety outcomes, and specific design elements can be targeted to reduce the risk of crashes and improve overall road safety. Zhang and Lindsay, in their paper presented a detailed road safety evaluation using two-way contingency table analysis to identify the factors associated with road traffic crashes and casualties [4]. Their study aimed to provide insights for developing effective road safety strategies. Their main conclusions emphasized the importance of considering multiple factors in road safety evaluations and highlight the potential of two-way contingency table analysis in identifying risk factors and informing targeted interventions. Bhalla et al., in their paper focused on building national estimates of the burden of road traffic injuries in developing countries, using

Iran as a case study [5]. They utilized Two-way contingency table analysis to analyze data from various sources and provide a comprehensive assessment of road traffic crash casualties in Iran. Their study concluded that the burden of road traffic injuries in Iran is substantial, highlighting the need for effective interventions to reduce casualties. Bhalla et al, in their paper presented an estimation of road traffic fatalities and injuries in Iran using capture-recapture methods [6]. They employed Two-way contingency table analysis to account for underreporting and provide more accurate estimates of casualties. Their study found that the incidence of road traffic fatalities and injuries in Iran is higher than previously reported, emphasizing the importance of improving data collection and reporting mechanisms. Wu and Zhang, in their paper, focused on analyzing road traffic crash injury severity using ordered probit models, considering various factors that influence the severity of injuries [7]. They applied Two-way contingency table analysis to examine the relationship between different variables and injury outcomes. Their study found that factors such as vehicle type, road conditions, and driver behavior significantly impact the severity of injuries in road traffic crashes, highlighting the need for targeted interventions to improve road safety. Zhang and Fraser, in their paper explored road traffic crash analysis using a data mining approach to identify patterns and factors contributing to crash casualties [8]. The authors utilized Two-way contingency table analysis to analyze a large dataset of crash data and extract meaningful insights. Their study concluded that data mining techniques can effectively identify risk factors for road traffic crashes, aiding in the development of targeted interventions to reduce casualties.

So, the collective body of literature on Two-way contingency table analysis for casualty due to road traffic crashes adds value to society by providing insights into the casual relationships between various factors and the occurrence of crashes resulting in casualties. In this study, the aim is to investigate whether there is significant relationship between geo political regions in Nigeria and outcome of road traffic crash, where the target outcome is the casualty due to road traffic crashes.

Method

Data for this study is collected from the Federal Road Safety Corp (FRSC) Nigeria, a secondary source. The data is on frequency of casualty and non-casualty due to road traffic crash in the six geopolitical regions in Nigeria.

The data is expressed in a 6×2 contingency table shown in Table 1 below.

Table 1: Two-Way Contingency Table for Outcomes of Road Traffic Crash in Nigeria

	Casualty	Non-Casualty
North East	22255	19758
North West	32183	38860
North central	40068	33206
South East	11385	44491
South West	27616	32456
South South	9990	21532

To analyse the data in Table 1 above, the assumed generating probability mechanism is unrestricted sampling method which is Poisson distribution. This is so since the sampling size is not fixed both at the marginals of the outcome of the road traffic crashes and the grand total. The occurrence of road traffic crash as well as the outcomes are all Poisson distributed.

Two-way contingency tables show the behavior of two categorical variables. The interest is to determine whether the two categorical variables (say X and Y) are independent. Supposed they are independent, then their joint probabilities π_{ij} is the same as the product of their marginal probabilities ($\pi_i + \pi +_j$). That is, $\pi_{ij}=P(X=i,Y=j)=P(X=i)\ P(Y=j)=\pi_i + \pi +_j$ for all pairs of i,j.

The hypothesis of independence between the two categorical variables can well be tested by using Chi-Square method of goodness of fit.

H_0:Independence model is true ($\pi_{ij}=\pi_i + \pi +_j$,for all pairs of i,j)
H_1:Saturated is true ($\pi_{ij}\neq\pi_i + \pi +_j$,for at least one pair of i,j).

Pearson Chi-Square goodness of fit test statistic is given as:

$$X^2 = \sum_{i=1}^{I}\sum_{j=1}^{J}\frac{(n_{ij}-n\pi_{0ij})^2}{n\pi_{0ij}}$$

were,

n_{ij} is the observed frequency of cell i,j,

π_{0ij} is the hypothesized joint probability for cell i,j ,

n is the grand frequency,

$n\pi 0_{ij}$ is the expected frequency of cell i,j.

Also, Deviance (or likelihood-ratio) Chi-Square goodness of test statistic which can be used alongside with Pearson Chi-Square is given as $G^2 = 2\sum_{i=1}^{I}\sum_{j=1}^{J} n_{ij}\log\left(\frac{n_{ij}}{n\pi_{0ij}}\right)$.

Under the independence model, the expected frequency is estimated as

$$E_{ij} = n\hat{\pi}_{ij} = n\hat{\pi}_{i+}\,\hat{\pi}_{+j} = \frac{n_{i+}n_{+j}}{n_{++}}$$

Both the Pearson Chi-Square and Likelihood ratio tests are to be tested at 0.05 level of significance. The null hypothesis will be rejected when p-value (the probability that the null hypothesis is correct, computed from the data) is less than the level of significance of the test. Otherwise, the null hypothesis will not be rejected.

The Local Odds Ratio is a measure of association between two variables for a specific cell in a 2×2 contingency table. It compares the odds of an outcome of interest (casualty) in a region with the odds of the same outcome of interest (casualty) in another region.

The odds are ratios of probabilities of 'casualty' and 'non casualty' for a given a given row.
Odds of casualty (Y=1) occurring versus non casualty (Y=2) occurring in a region (X=1) can be

given as: $Odds_1 = \frac{P(Y=1|X=1)}{P(Y=2|X=1)}$.

The second odds (given that another region is considered (X=2)), $Odds_2 = \frac{P(Y=1|X=2)}{P(Y=2|X=2)}$ The odds ratio is now the ratio of the odds1 and odds2 (or vice-versa),

$$\theta = \frac{P(Y=1|X=1)}{P(Y=2|X=1)} \Big/ \frac{P(Y=1|X=2)}{P(Y=2|X=2)}$$

The natural point estimate of the odds ratio is sample cross-product ratio given as $\hat{\theta} = \frac{O_{11}O_{22}}{O_{12}O_{21}}$

The confidence interval is obtained on the log scale, the natural log. The estimated variance of is given as $Var(log(\hat{\theta})) = \frac{1}{O_{11}} + \frac{1}{O_{12}} + \frac{1}{O_{21}} + \frac{1}{O_{22}}$

And therefore, the 95% confidence interval for by exponentiating the endpoints is given as $log(\theta) \pm 1.96\sqrt{\frac{1}{O_{11}} + \frac{1}{O_{12}} + \frac{1}{O_{21}} + \frac{1}{O_{22}}}$.

The null hypothesis is $H_0 : \theta = 1$.

Results and Discussion

Testing for independence between geopolitical regions and the outcome of road traffic crash, Pearson Chi-square test statistic and Likelihood Ratio Chi-square test statistic are used. Table 2 below shows the crosstabulation of the six geopolitical regions in Nigeria and the outcome of road traffic crashes in each of the regions. In each cell of the table, first presented is the observed frequency, followed by expected frequency and lastly, the cell percentage. Just below the table are the results of the Pearson Chi-square test statistic value (= 19000), its degree of freedom (= 5) and corresponding p-value (=0.000). Also, below the table is the Likelihood Ratio Chi-square test statistic value (= 21000), its degree of freedom (= 5), and its corresponding p-value (= 0.000).

Table 2: Crosstabulation of Regions and Outcome of Road Traffic Crash

Keys: Observed frequencies Expected frequencies Cell percentage			
Region	**Casualty**	**Non casualty**	**Total**
North East	22255 18060.9 6.67	19758 23952.1 5.92	42013 42013.0 12.59
North West	32183 30540.6 9.64	38860 40502.4 11.64	71043 71043.0 21.28
North Central	40064 31499.7 12.00	33206 41774.3 9.95	73274 73274.0 21.95
South East	11385 24020.5 3.41	44499 31855.5 13.33	55876 55876.0 16.74
South West	27616 25824.3 8.27	32456 34247.7 9.72	60072 60072.0 18.00
South South	9990 13551.0 2.99	21582 177971.0 6.45	31522 31522.0 9.44
Total	143497 143497.0 42.99	190303 190303.0 57.01	333800 333800.0 100.00

Pearson chi-squared at 5 d.f =19000
Chi-squared p-values =0.000
Likelihood ratio chi-squared at 5 d.f =21000
Likelihood -ratio chi-squared p-values = 0.000
Since the p-values for both the Pearson Chi-square and Likelihood ratio Chi-square are less than 0.05 level of significant, the null hypothesis of independence between the geopolitical regions and outcome of road traffic crash is rejected. There is significant relationship between the geopolitical regions and the outcome of the road traffic crashes in Nigeria.

Since the null hypothesis testing for independence between the geopolitical regions and the outcome of road traffic crash is rejected, next is to determine where the association exist. Local odds ratio is used to determine the associations existing in the all possible 2 x 2 tables derived from the global 6x2 contingency table. Table 3 to Table 17 shows 15 local possible 2 x 2 tables from which odds ratio for each are computed with their confidence limits.

Table 3: NE-NW Regions RTC Outcome

Region	Casualty	Non casualty	Total
NE	22255	19758	42103
NW	32183	38860	71043
Total	54438	58618	112056

Table 4: NE-NC Regions RTC Outcome

Region	Casualty	Non casualty	Total
NE	22255	19758	42103
NC	40068	33206	73274
Total	62323	52964	115377

Table 5: NE-SE Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NE	22255	19758	42103
SE	11385	44491	55876
Total	33640	64249	60086

Table 6: NE-SW Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NE	22255	19758	42103
SW	27616	32456	60072
Total	49871	42013	102175

Table 7: NE-SS Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NE	22255	19758	42103
SS	9990	21532	22522
Total	32245	41290	64625

Table 8: NW-NC Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NW	32183	38860	71043
NC	40068	33206	73274
Total	72251	72066	144317

Table 9: NW-SE Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NW	32183	38860	71043
SE	11385	44491	55876
Total	33368	83351	126919

Table 10: NW-SW Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NW	32183	38860	71043
SW	27616	32456	60072
Total	59799	71316	131115

Table 11: NW-SS Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NW	32183	38860	71043
SS	9990	21532	22522
Total	42173	60392	93565

Table 12: NC-SE Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NC	40068	33206	73274
SE	11385	44491	55876
Total	51453	77697	129150

Table 13: NC-SW Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NC	40068	33206	73274
SW	27616	32456	60072
Total	67684	65662	133346

Table 14: NC-SS Regions X RTC Outcome

Region	Casualty	Non casualty	Total
NC	40068	33206	73274
SS	9990	21532	22522
Total	50058	54738	95796

Table 15: SE-SW Regions X RTC Outcome

Region	Casualty	Non casualty	Total
SE	11385	44491	55876
SW	27616	32456	60072
Total	39001	76947	115948

Table 16: SE-SS Regions X RTC Outcome

Region	Casualty	Non casualty	Total
SE	11385	44491	55876
SS	9990	21532	22522
Total	21375	66023	78398

Table 17: SW-SS Regions X RTC Outcome

Region	Casualty	Non casualty	Total
SW	27616	32456	60072
SS	9990	21532	22522
Total	37606	53988	82594

The estimated odds ratios, 95% confidence intervals of the odds ratios, Chi-Square test for independence (testing odds ratio equals 1) statistic and corresponding p-values computed for each of the local 2 x 2 tables are displayed in Table 18. Measuring the association in Table 3, from Table 18, the odds ratio of casualty due to road traffic crash in North East region and casualty due to road traffic crash in North West region is 1.3601. The odds of casualty occurring in road traffic crash in North East region is 1.3601 times the odds of casualty occurring in road traffic crash in North West region. The chi-square test statistic value and its corresponding p-value are 622.25 and 0.000, respectively. Since the p-values is less than 0.05 level of significant, the null hypothesis of independence is rejected. Significantly, the casualty due to road traffic crash occurring in North East region is more likely than in North West Region. The 95% lower and upper confidence limits of the estimated odds ratio are 1.3275 and 1.3935 respectively. Since this confidence interval does not contain 1, casualty due to road traffic crash occurring in North East region of Nigeria is significantly more likely than in North West region.

Table 18: Odds Ratio Results for the 15 Possible Local 2 x 2 Tables

The Two Compared Regions	Odds-Ratio	Chi-square	P-value	95% CI		Rank Order
NE-NW	1.3601	622.25	0.0000	1.3275	1.3935	10th
NE-NC	0.9335	31.47	0.0000	0.9113	0.9562	12th
NE-SE	4.4017	11296.68	0.0000	4.2721	4.5353	2nd
NE-SW	1.3238	484.84	0.0000	1.2910	1.3574	11th
NE-SS	2.4277	3312.10	0.0000	2.3532	2.5047	5th
NW-NC	0.6863	1269.91	0.0000	0.6722	0.7008	13th
NW-SE	3.2364	8619.28	0.0000	3.1526	3.3225	3rd
NW-SW	2.1194	26193.84	0.0000	2.1002	2.1388	6th
NW-SS	2.0624	31756.45	0.0000	2.0460	2.0789	7th
NC-SE	4.7154	15567.38	0.0000	4.5904	4.8439	1st
NC-SW	1.4181	1002.14	0.0000	1.3876	1.4493	9th
NC-SS	2.6008	4669.07	0.0000	2.5278	2.6759	4th
SE-SW	0.3007	8496.39	0.0000	0.2927	0.3090	15th
SE-SS	0.5515	1396.92	0.0000	0.5344	0.5693	14th
SW-SS	1.8339	1741.85	0.0000	1.7817	1.8877	8th

Measuring the association in Table 4, from Table 18, the odds ratio of casualty due to road traffic crash in North East region and casualty due to road traffic crash in North Central region is 0.9335. The odds of casualty due to road traffic crash occurring in the North East region is 0.9335 times the odds of casualty due to road traffic crash occurring in North Central region. Inversely, the odds of casualty occurring due to road traffic crash in the North Central region is $\frac{1}{0.9335}$ =1.0712 times the odds of casualty occurring due to road traffic crash in North East region. The chi-square and the corresponding p-value are 31.47 and 0.000 respectively. Since the p-value is less than 0.05 level of significant, the null hypothesis of independence is rejected. Significantly, the of casualty due to road traffic crash occurring in North East region is less likely than in North Central region. The 95% lower and upper confidence limits of the estimated odd ratio are 0.9113 and 0.9562 respectively. Also, since the confidence intervals did not contain 1, casualty due to road traffic crash occurring in North East region is significantly less likely than in North Central region.

Measuring the association in Table 5, from Table 18, the odds ratio of casualty due to road traffic crash in North East region and casualty due to road traffic crash in South East region is 4.4017. The odds of casualty due to road traffic crash occurring in the North East region is 4.4017 times the odds of casualty due to road traffic crash occurring in South East region. Chi-square statistic value and its corresponding p-values are 11296.68 and 0.000 respectively. Since the p-values is less than 0.05 level of significant, the null hypothesis of independence is rejected. Significantly, the casualty due to road traffic crash occurring in North East region is more likely than in South East region. The 95% lower and upper confidence limits of the estimated of odds ratio are 4.2721 and 4.5353 respectively. Since the confidence intervals did not contain 1, casualty due to road traffic crash occurring in North East region is significantly more likely than that of South East region.

Measuring the association in Table 6, from Table 18, the odds ratio of casualty due to road traffic crash in North East region and casualty due to road traffic crash in South West region is 1.3238. The odds of casualty due to road traffic crash occurring in the North East region is 1.3238 times the odds of casualty due to road traffic crash occurring in South West region. Respectively, Chi-square and its corresponding p-values are 484.84 and 0.000. Since the p-values is less than 0.05 level of significant, the null hypothesis of independence is rejected. Significantly, casualty due to road traffic crash occurring in North East region is more likely than in South West region. The 95% lower and upper confidence limit of the estimated odds ratio are 1.2910 and 1.3574 respectively. Since the confidence intervals did not contain 1, casualty due to road traffic crash occurring in North East region is significantly more likely than in South West region.

Measuring the association in Table 7, from Table 18, the odds ratio of casualty due to road traffic crash occurring in North East region and casualty due road traffic crash occurring in South region is 2.4277. The odds of casualty due to road traffic crash occurring in the South region is 2.4277 times the odds of casualty due to road traffic crash occurring in South West region. The Chi-Square test statistic and its corresponding p-values are 3312.10 and 0.000 respectively. Since the p-value is less than 0.05 level of significant, the null hypothesis of independence is rejected. Significantly, casualty due to road traffic crash occurring in North East region is more likely than in South region. The 95% lower and upper confidence limits of the odds ratio are 2.3532 and 2.5047 respectively. Since the confidence intervals did not contain 1, casualty due to road traffic crash occurring in North East region is significantly more likely than in South region.

Measuring the association in Table 8, from Table 18, the odd ratios of casualty due to road traffic crash occurring in North West region and casualty due to road traffic crash occurring North Central region is 0.6863. The odds of casualty due to road traffic crash occurring in the North West region is 0.6863 times the odds of casualty due to road traffic crash occurring in the North Central. Inversely, the odds of casualty occurring due to road traffic crash in the North Central region is $\frac{1}{0.6863} = 1.4571$ times the odds of casualty occurring due to road traffic crash in North West region.

Chi-Square statistic value and its corresponding p-value are 1269.91 and 0.000 respectively. Since the p-value is less than 0.05 level of significance, the null hypothesis of independence is rejected. Significantly, casualty due to road traffic crash occurring in North West is less likely than in North Central region. The 95% lower and upper confidence limits of the odds ratio are 0.6722 and 0.7008 respectively. Since the confidence limits did not contain 1, it shows further that casualty due to road traffic crash occurring in North West is significantly less likely than in North Central.

Measuring the association in Table 9, from Table 18, the odds ratio of casualty due to road traffic crash occurring in North West region and casualty due to road traffic crash occurring in South East region is 3.2364. The odds of casualty due to road traffic crash occurring in North West region is 3.2364 times the odds of casualty due to road traffic crash occurring in South East region. Chi-Square test statistic value and its corresponding p-value are 8619.28 and 0.000 respectively. Since the p-values is less than 0.05 level of significant, the null hypothesis of independence is rejected. Significantly, casualty due to road traffic crash in North West region is more likely than in South East region. The 95% lower and upper confidence limits of the odds ratio are 3.1526 and 3.3225 respectively. Since the confidence limits did not contain 1, casualty due to road traffic crash in North West region is significantly more likely than in South East region.

Measuring the association in Table 10, from Table 18, the odds ratio of casualty due to road traffic crash occurring in North West region and casualty due to road traffic crash occurring in South West region is 2.1194. The odds of casualty due to road traffic crash occurring in North West region is 2.1194 times the odds of casualty due to road traffic crash occurring in South West region. Chi-Square test statistic value and its corresponding p-value are 26193.84 and 0.000 respectively. Since the p-values is less than 0.05 level of significant, the null hypothesis of independence is rejected. Significantly, casualty due to road traffic crash in North West region is more likely than in South West region. The 95% lower and upper confidence limits of the odds ratio are 2.1002 and 2.1388 respectively. Since the confidence limits did not contain 1, casualty due to road traffic crash in North West region is significantly more likely than in South West region.

Measuring the association in Table 16, from Table 18, the odds ratio of casualty due to road traffic crash occurring in South East region and casualty due to road traffic crash occurring in South region is 0.5515. The odds of casualty due to road traffic crash occurring in South East region is 0.5515 times the odds of casualty due to road traffic crash occurring in South region. Inversely, the odds of casualty occurring due to road traffic crash in the South region is $\frac{1}{0.5515} = 1.8132$times the odds of casualty occurring due to road traffic crash in South East region. Chi-Square test statistic value and its corresponding p-value are 1396.92 and 0.000 respectively. Since the p-values is less than 0.05 level of significant, the null hypothesis of independence is rejected. Significantly, casualty due to road traffic crash in South East region is less likely than in South region. The 95% lower and upper confidence limits of the odds ratio are 0.5344 and 0.5694 respectively. Since the confidence limits did not contain 1, casualty due to road traffic crash in South East region is significantly less likely than in South region.

Conclusion

Significantly, the geopolitical region with the least casualties due to road traffic crashes in Nigeria is South East. Higher than South East region is South region. Higher than South region is South West Region. Higher than South West region is North West region. Higher than North West region is North East Region. The geopolitical region with the greatest casualties due to road traffic crash in Nigeria is North Central.

Generally, the Northern region of Nigeria suffered higher casualties than the Southern region.

Recommendation

Based on this study, it is recommended that Two-way contingency table analysis is reliable to investigating significant differences in the casualties due to road traffic crashes suffered among the six geopolitical regions in Nigeria.

It is also recommended that more attention be given to stop the higher casualties suffered in the Northern region of Nigeria, and particularly, in the North Central region.

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