ASSESSMENT OF GEOMETRIC CONSISTENCY OF THE NIGERIAN ADMINISTRATIVE BOUNDARIES DATASETS FROM DIFFERENT SOURCES: THE NEED FOR DATA HARMONY AND STANDARDIZATION

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ABSTRACT

Precise administrative boundaries demarcation facilitates effective governance, policy making, resource allocation and the delivery of public services. The delineation of administrative boundaries in Nigeria has been an ongoing challenge, with several disputes and boundary adjustments over the years. Different sources of datasets on Nigerian administrative boundaries exhibit inconsistencies, leading to discrepancies and misalignment. The aim of this study therefore is to assess the geometric consistency of the Nigerian administrative boundaries datasets from different sources. The datasets were sourced from the Office of Surveyor General of Federation (OSGoF), Geo-Referenced Infrastructure and Demographic Data for Development (GRID3), Global Administrative Areas (GADM) and Divas GIS. These datasets were analyzed in ArcGIS 10.8 for alignment and discrepancy. The findings revealed that the Global Administrative Areas datasets showed general good alignment for the Nigerian national boundary. On the contrary, the datasets from GRID3 and Divas GIS have gross misalignment. Furthermore, the misalignment observed in the datasets is generally prominent in the eastern part where Nigeria shares border with Cameroon. Significant discrepancies were observed between the datasets at all level of boundaries from the various sources compared. The result also revealed that the Nigerian national boundary from the Office of Surveyor General of Federation is 912,153.24 km^2 in area, while datasets from Divas GIS is -1,991.09 km^2 (-0.22%) smaller, GADM is -1,991.09 km^2 (-0.22%) lower and GRID3 is 2,330.75 km^2 (0.26%) higher than OSGoF dataset. The study therefore concluded that these discrepancies could have a significant impact on spatial analysis, resource allocation, and decision-making processes.

Keywords: Administrative boundary, Geometric consistency, Data alignment, Boundary demarcation

INTRODUCTION

In the modern era, geospatial data has become increasingly crucial for a wide range of applications, from urban planning and resource management to disaster response and national security (Tao *et al.,* 2022; UN-GGIM, 2022; Nandakumar *et al.,* 2023). The accuracy and consistency of this data are paramount, as they directly impact the reliability and effectiveness of the decisions and actions taken based on it (Tao *et al.,* 2022). As the reliance on geospatial information continues to increase, addressing data quality challenges and ensuring the availability of reliable and consistent datasets will become even more crucial for informed decision-making, sustainable development, and effective crisis management.

Administrative boundary demarcation is the process of clearly defining and delineating the geographical limits of administrative divisions within a country, such as states, provinces, districts, or municipalities (Ojigi and Eyo, 2014). Clearly defined administrative boundaries help to establish the territorial sovereignty and jurisdiction of a country and its sub-national administrative units. This allows for effective governance, policymaking, and the delivery of public services within the designated administrative areas. Clearly delineated administrative boundaries facilitate the efficient management and allocation of natural resources, infrastructure, and public services within a country. Precise administrative boundary demarcation can help prevent or resolve disputes over territorial claims and land ownership between neighboring administrative units or countries (Rios and Mauro, 2019). For instance, the boundary dispute between Nigeria and Cameroon has a long and complex history, dating back to the colonial era, which has resulted in territorial conflict over the Bakassi Peninsula (Agaptus, 2015). The two countries have since worked to demarcate the maritime and land borders (Ariye, 2015).

In addition, clear boundaries can provide a basis for conflict resolution mechanisms and negotiations. It is also crucial for accurate data collection, such as population censuses, economic surveys, and resource inventories. Administrative boundaries are often used to define electoral constituencies and districts, ensuring fair and equal representation in political processes (EOS, 2023). Despite all these benefits of administrative boundary demarcation if they are not consistent, the reliability of such boundary demarcation becomes questionable.

Nigeria, as the most populous country in Africa, has a complex administrative structure with multiple levels of governance, including federal, state, and local government areas (LGAs). The delineation of administrative boundaries in Nigeria has been an ongoing challenge, with several disputes and boundary adjustments over the years. The current administrative boundaries in Nigeria according to Danjuma and Ismaila (2017) were largely influenced by the colonial era and the post-independence reorganization of the country, and there has been several disputes over the precise location of state and LGA boundaries over the years (Otora, 2022), often leading to legal battles and occasional violence (Mustapha, 2019). Nigeria has experienced several administrative boundary changes, with the creation of new states and LGAs over time (Adebayo, 2002), further complicating the boundary situation. Different sources of datasets on Nigerian administrative boundaries may exhibit inconsistencies, leading to discrepancies in spatial analysis and decision-making. Accurate and consistent delineation of these administrative boundaries is crucial for effective governance, resource allocation, and spatial analysis. However, datasets on the country administrative boundary from different sources have has shown inconsistency and misalignment (Geojay GIS Solution, 2023). This assessment

aims to evaluate the geometric consistency of Nigerian administrative boundary datasets from different sources with the following objectives; comparing the spatial alignment of the boundaries between the datasets; evaluating the level of detail and complexity in the representation of the boundaries, and identifying and quantifying discrepancies in the boundary demarcation.

MATERIALS AND METHODS

Nigeria is located in West Africa, situated along the coast of the Gulf of Guinea. The country shares land borders with Benin, Cameroon, Chad, and Niger, and has a coastline that spans over 800 kilometers. Nigeria's strategic geographic position and diverse terrain, ranging from coastal regions to the Sahel, have significantly shaped its history, culture, and economic development (Adegboyega and Oluwafemi, 2020). The country has a complex administrative level of boundaries comprising three main levels namely: national, state, and local government areas (LGAs) boundaries (with recent political ward boundaries by Geo-Referenced Infrastructure and Demographic Data for Development (GRID3)). Nigeria is divided into 36 states and the Federal Capital Territory (FCT) of Abuja. The 36 states are further grouped into 6 geopolitical zones for administrative and political purposes. The states are further divided into 774 Local Government Areas (LGAs).

The shapefile of Nigerian administrative boundaries were sourced from different sources to achieve the set objectives. These include dataset from the Office of Surveyor General of Federation (OSGoF), Geo-Referenced Infrastructure and Demographic Data for Development (GRID3), Global Administrative Areas (GADM) dataset and Divas GIS Dataset. The international boundary was analyzed to see level of consistency, misalignment and discrepancy with various datasets. Similarly, Kano and the Federal Capital Territory were purposively selected to see the level of alignment and discrepancy at state administrative boundary demarcation, and demarcation of LGAs boundaries were equally analyzed in ArcGIS 10.8 for alignment and discrepancy. The discrepancy observed was quantified. In this study, the datasets from the Office of Surveyor General of Federation (OSGoF) was used as reference data, to which datasets from other sources were compared since it is the official dataset in use in Nigeria.

RESULTS AND DISCUSSION

Spatial alignment of the boundaries between the datasets from different sources

At national administrative boundary level, dataset from Global Administrative Areas (GADM) showed generally good alignment for the Nigerian national boundary. This is evident as GADM boundary directly lying on the boundary from the Office of Surveyor General of Federation (OSGoF). On the contrary, the dataset from GRID3 has the most misalignment almost at every point along the boundary as shown in Figure 1.

The boundary dataset from Divas GIS equally showed misalignment with that of OSGoF at several points as shown in Figure 1, this is however not as prominent as the misalignment of GRID3 boundary demarcation. The misalignment observed in the Nigeria national boundary from different sources is generally prominent in the Northeast down southeast where Nigeria shares border with Cameroon. This inconsistent boundary demarcation with Cameroon as seen in this study may likely be the cause of land dispute between Nigeria and Cameroon some years ago.
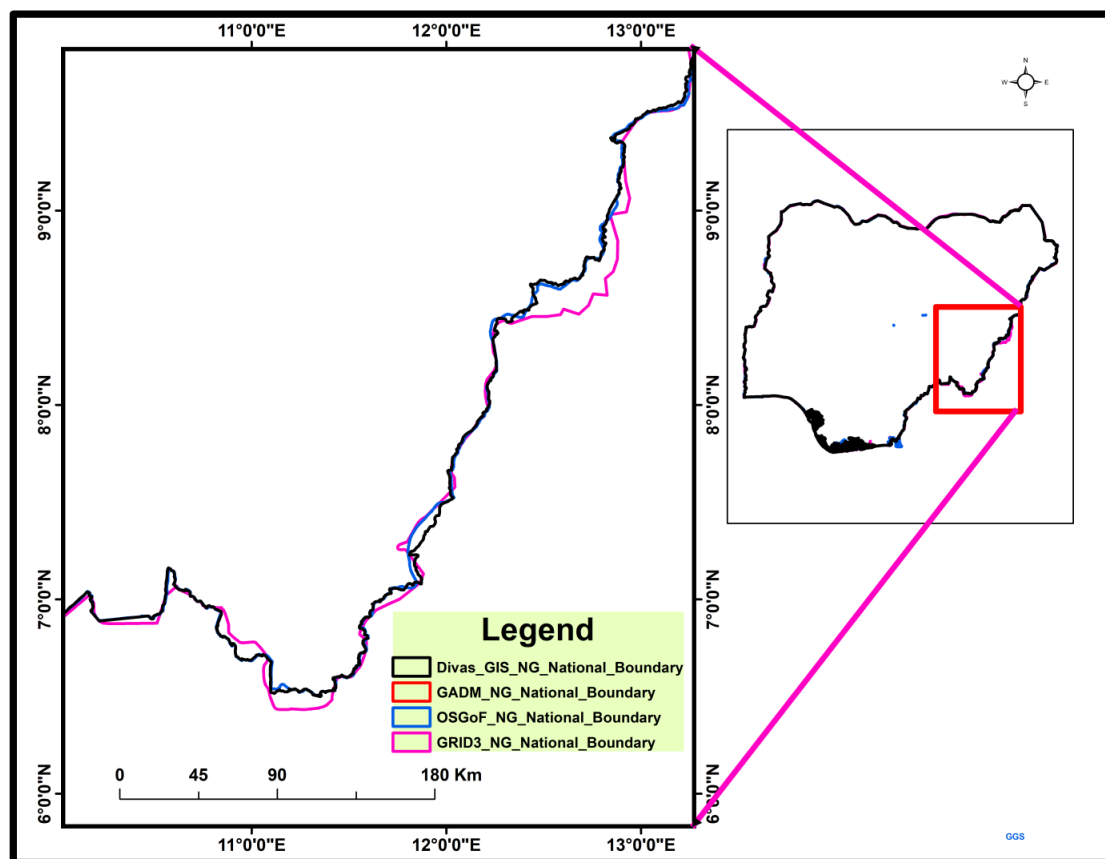

Figure 1: Misalignment of Nigeria national boundary from different sources

At state and Local Government Areas level of boundary demarcation, misalignment and inconsistencies were noticed among the different datasets considered in this study. As shown in Figure 2 and Figure 3 the demarcation of Federal Capital Territory and Kano state has highly of misalignment and inconsistency from different sources. The demarcation of Abuja from Divas GIS is grossly far in alignment with the demarcation from Office of Surveyor General of Federation (OSGoF), both in shape and in location as shown in Figure. Similarly, the demarcation of Abuja by GRID3 also has misalignment when compare with the demarcation by OSGoF. However, the demarcation of Abuja by GADM perfectly aligned with OSGoF
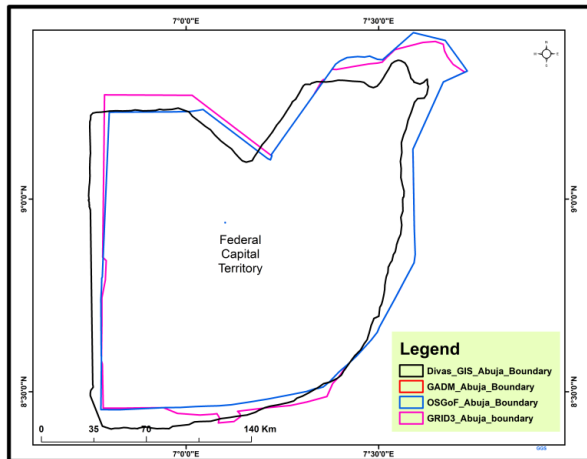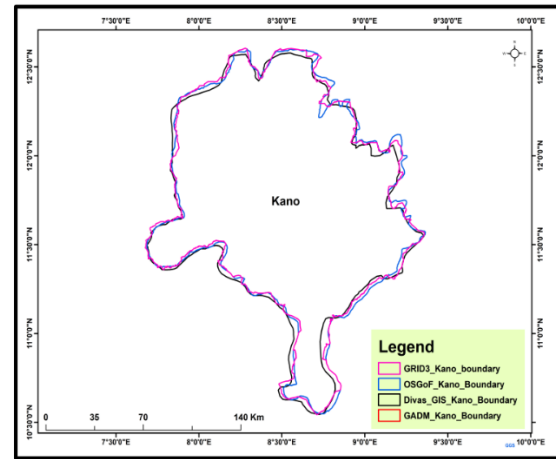

Figure 2: Abuja boundary

Figure 3: Kano state boundary

Another state consider in this study was Kano. As shown in Figure 3 Kano state boundary demarcation from both GRID3 and Divas GIS have gross misalignment with that of OSGoF. As the case with Abuja boundary demarcation, only the Kano boundary from GADM perfectly aligned with OSGoF (Figure 3).

Furthermore, for the alignment and consistency examination, the boundaries were considered at Local Government Areas (LGAs) level using Osun state LGAs and the result is presented in Figure 4. It was found that the demarcation of Local Government Area boundaries were totally different from one data source to the other. All the boundary datasets considered in this study demarcated LGAs boundaries totally different from the demarcation of the Office of Surveyor General of Federation (OSGoF)
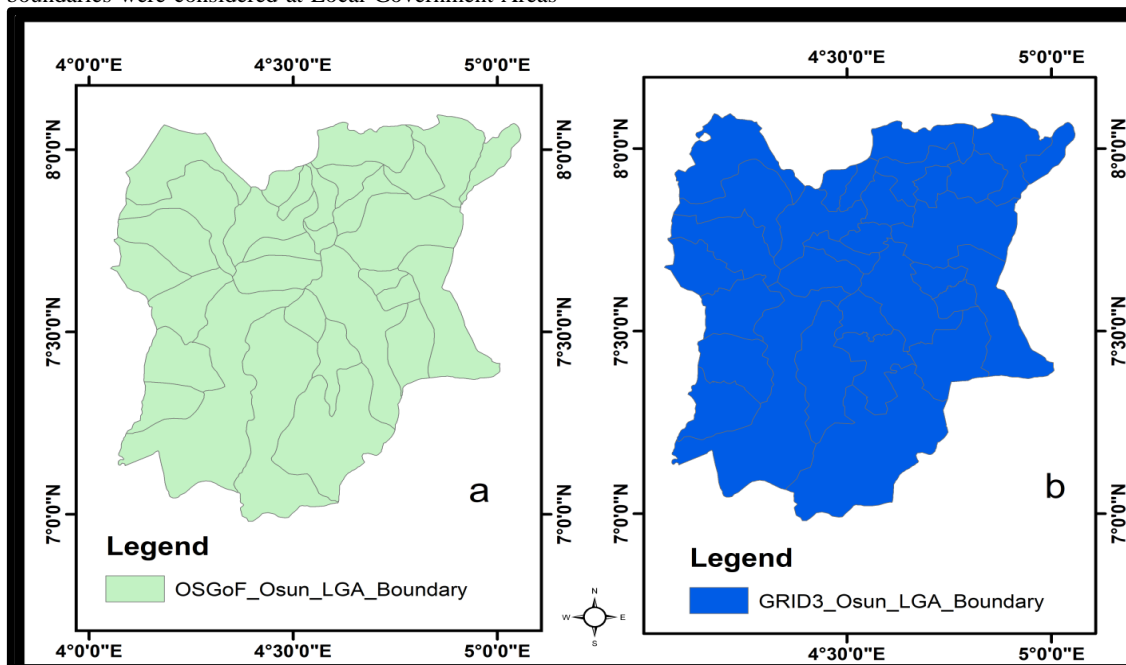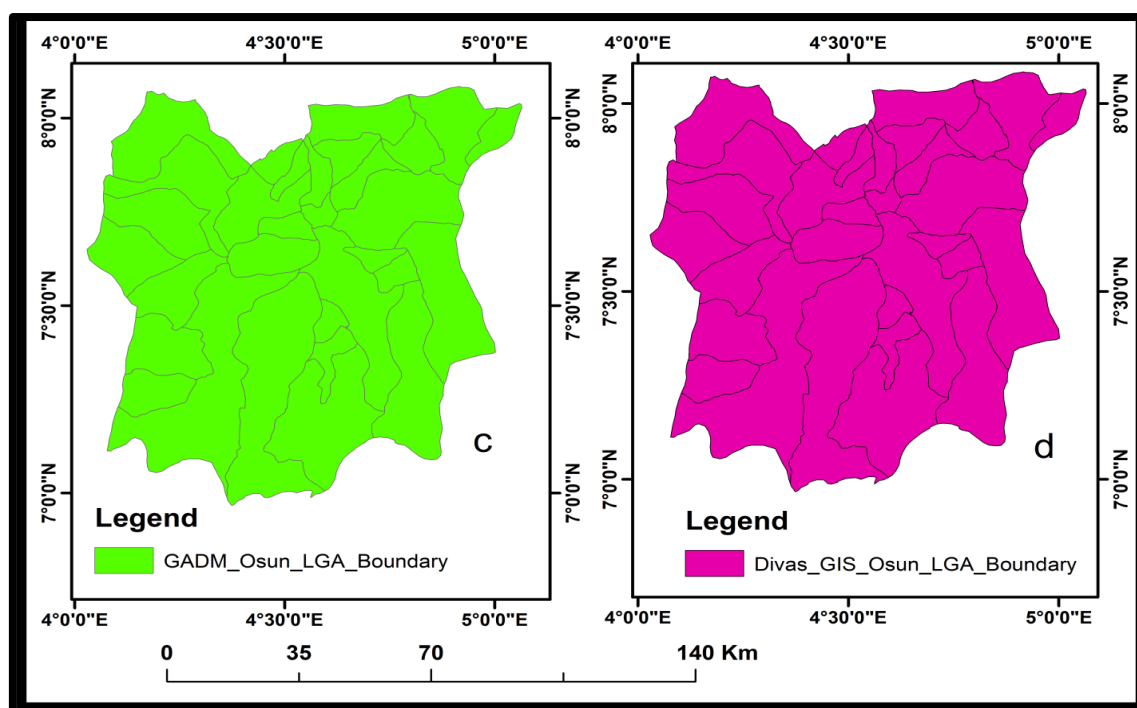
Figure 4: Osun state Local Government Areas boundary demarcation from different sources (a = OSGoF demarcation, b = GRID3 demarcation, c = GADM demarcation and d = Divas GIS demarcation)

Level of detail and complexity in the representation of the boundaries

As shown in Figure 1 the Global Administrative Areas (GADM) datasets has a similar level of detail, capturing the complex geometry of the Nigerian administrative boundaries similar to the dataset from the Office of Surveyor General of Federation (OSGoF). The GADM datasets also showed generally good alignment for the Nigerian state boundaries and a little bit different for LGA boundaries. The GRID3 and Divas GIS datasets, in comparison, had a more generalized representation of the boundaries, with a lower level of detail. In addition, the GRID3 and Divas GIS datasets, exhibited noticeable misalignments, particularly along the international borders, between state and LGA boundaries.

Identifying and quantifying discrepancies in the boundaries

Significant discrepancies were observed between the datasets at all level of boundaries from the various sources compared. The differences in boundary locations ranged from a few hundred meters to several kilometers, depending on the specific region. To further quantify the discrepancies area national state and LGAs boundaries were calculated and the difference from the reference dataset was determined.

Table 1: Discrepancies in the Nigerian national boundary demarcation from different sources

S/N	Data source	Area (km^2)	Discrepancy (km^2)	% of discrepancy
1	Divas GIS NG National Boundary	910162.16	-1991.09	-0.22
2	GADM NG National Boundary	910162.16	-1991.09	-0.22
3	GRID3 NG National Boundary	914484.00	2330.75	0.26
4	OSGoF NG National Boundary	912153.24	0	0

NB: OSGoF NG National Boundary is the reference dataset

As shown in Table 1, the total area of the Nigerian national boundary from the Office of Surveyor General of Federation (OSGoF) dataset is 912,153.24 km^2 in area (this value is also different from values found on the internet as the Nigeria land mass). Comparing the area of other dataset with this, it was found that Divas GIS Nigerian national boundary was -1,991.09 km^2 (-0.22%) lower, GADM Nigerian national boundary was -1,991.09 km^2 (-0.22%) lower and GRID3 Nigerian national boundary was 2,330.75 km^2 (0.26%) higher than OSGoF national boundary.

At the state level, discrepancies were also observed in all the state among the various datasets. The results of Discrepancies in state boundaries as measured in the area coverage of each state and compared with that of OSGoF is presented in Table 2

Table 2: Discrepancies in the Nigerian states boundary demarcation from different sources (area in km^2)

S/N	State	OSGoF	GRID3	Diff.	%	GADM	Diff.	%	Divas GIS	Diff.	%
1	Abia	4858.88	4795.74	-63.14	-1.30	4723.46	-135.43	-2.79	4723.46	-135.43	-2.79
2	Adamawa	37924.99	40049.51	2124.53	5.60	34386.66	-3538.33	-9.33	34386.66	-3538.33	-9.33
3	Akwa Ibom	6723.20	6866.09	142.89	2.13	6733.39	10.18	0.15	6733.39	10.18	0.15
4	Anambra	4807.93	4818.74	10.80	0.22	4592.54	-215.39	-4.48	4592.54	-215.39	-4.48
5	Bauchi	48496.40	49575.13	1078.73	2.22	49040.19	543.79	1.12	49040.19	543.79	1.12
6	Bayelsa	9546.42	9406.59	-139.83	-1.46	9781.47	235.05	2.46	9781.47	235.05	2.46
7	Benue	31462.23	30860.06	-602.17	-1.91	31303.88	-158.35	-0.50	31303.88	-158.35	-0.50
8	Borno	75949.95	72471.70	-3478.25	-4.58	71725.84	-4224.11	-5.56	66487.53	-9462.42	-12.46
9	Cross River	21417.61	20981.07	-436.54	-2.04	21287.75	-129.86	-0.61	21287.75	-129.86	-0.61
10	Delta	17113.00	16998.13	-114.87	-0.67	16658.29	-454.71	-2.66	16658.29	-454.71	-2.66
11	Ebonyi	6336.48	6483.84	147.35	2.33	6185.83	-150.66	-2.38	6185.83	-150.66	-2.38
12	Edo	19555.55	19600.10	44.55	0.23	19631.54	75.99	0.39	19631.54	75.98	0.39
13	Ekiti	5773.24	5800.81	27.57	0.48	5253.97	-519.27	-8.99	5253.97	-519.27	-8.99
14	Enugu	7635.72	7625.21	-10.51	-0.14	7702.29	66.56	0.87	7702.29	66.56	0.87
15	FCT	7388.14	7621.28	233.14	3.16	7353.16	-34.98	-0.47	7353.16	-34.99	-0.47
16	Gombe	17438.00	16650.01	-787.99	-4.52	18203.56	765.57	4.39	18203.56	765.57	4.39
17	Imo	5075.46	5103.49	28.03	0.55	5312.16	236.70	4.66	5312.16	236.70	4.66
18	Jigawa	23201.55	23427.28	225.73	0.97	23985.63	784.08	3.38	23985.63	784.08	3.38
19	Kaduna	44146.82	45051.94	905.12	2.05	44306.36	159.53	0.36	44306.36	159.53	0.36
20	Kano	20310.40	20216.01	-94.39	-0.46	20069.22	-241.18	-1.19	20069.22	-241.18	-1.19
21	Katsina	23957.92	24230.19	272.26	1.14	23700.25	-257.67	-1.08	23700.25	-257.67	-1.08
22	Kebbi	36788.02	37395.99	607.97	1.65	36159.94	-628.09	-1.71	36159.94	-628.09	-1.71
23	Kogi	28925.88	28896.65	-29.23	-0.10	28967.94	42.06	0.15	28967.94	42.06	0.15
24	Kwara	33838.42	33596.21	-242.21	-0.72	35627.95	1789.53	5.29	35627.95	1789.53	5.29
25	Lagos	3701.45	3793.15	91.70	2.48	3815.64	114.20	3.09	3815.64	114.20	3.09
26	Nassarawa	26750.46	26242.30	-508.16	-1.90	26313.59	-436.87	-1.63	26313.59	-436.87	-1.63
27	Niger	72143.47	71159.17	-984.29	-1.36	71222.05	-921.42	-1.28	71222.05	-921.42	-1.28
28	Ogun	16810.67	16878.12	67.44	0.40	16230.84	-579.83	-3.45	16230.84	-579.83	-3.45
29	Ondo	15132.20	15105.43	-26.77	-0.18	14581.10	-551.10	-3.64	14581.10	-551.10	-3.64
30	Osun	8644.30	8588.46	-55.84	-0.65	9238.09	593.80	6.87	9238.09	593.80	6.87
31	Oyo	27824.83	27928.57	103.74	0.37	27617.83	-207.00	-0.74	27617.83	-207.00	-0.74
32	Plateau	26490.35	26009.33	-481.01	-1.82	27562.53	1072.18	4.05	27562.53	1072.18	4.05
33	Rivers	10188.80	10171.80	-17.01	-0.17	8539.08	-1649.73	-16.19	8539.07	-1649.73	-16.19
34	Sokoto	32257.59	31141.74	-1115.85	-3.46	31844.56	-413.03	-1.28	31844.56	-413.03	-1.28
35	Taraba	58561.23	58810.09	248.85	0.42	60313.93	1752.69	2.99	60313.93	1752.69	2.99
36	Yobe	41414.37	45797.12	4382.74	10.58	45613.91	4199.54	10.14	45613.91	4199.54	10.14
37	Zamfara	33561.96	34336.96	775.00	2.31	34575.76	1013.80	3.02	34575.76	1013.80	3.02
		912153.90	914484.00	2330.09	0.26	910162.16	-1991.75	-0.22	904923.84	-7230.06	-0.79

CONCLUSION

This study assessed the geometric consistency of the Nigerian administrative boundary datasets from different sources with the following key findings: global Administrative Areas (GADM) datasets showed generally good alignment for the Nigerian national boundary. On the contrary, the dataset from Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) and Divas GIS have gross misalignment almost at every point along the boundary, the misalignment observed in the Nigeria national boundary from different sources is generally prominent in the Northeast down southeast where Nigeria shares border with Cameroon, significant discrepancies were observed between the datasets at all level of boundaries from the various sources compared, Nigerian national boundary from the Office of Surveyor General of Federation (OSGoF) dataset is 912,153.24 km^2 in area. Comparing the area of other dataset with this, it was found that Divas GIS Nigerian national boundary was -1,991.09 km^2 (-0.22%) lower, GADM Nigerian national boundary was -1,991.09 km2 (-0.22%) lower and GRID3 Nigerian national boundary was 2,330.75 km2 (0.26%) higher than OSGoF national boundary. Based on these findings the study therefore concluded that these discrepancies could have a significant impact on spatial analysis, resource allocation, and decision-making processes. Based on the findings of this study and to ensure the reliability and utilization of Nigerian administrative boundary datasets, the following recommendations were made; there should be collaboration between the Office of Surveyor General of Federation, relevant government agencies like the Nigerian Geological Survey Agency, NGOs and international organizations to ensure the regular update and maintenance of these datasets; there should be harmony, consistency and standardization of Nigerian boundaries datasets to promote the use of the most geometrically consistent datasets for spatial analysis, resource allocation, and decision-making processes in Nigeria, and further research is recommended to look at encroachment of neighboring countries into the Nigerian national boundaries and within state and LGA boundaries

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