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Boundary Mapping and Geodatabase Strategy for National Security Information System in Nigeria

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Abstract

Boundary mapping is the delineation of the territorial limits of a state, country as a sovereign state and its political division and administrative framework under a constitution. The likely consequences of boundary uncertainty, errors and omissions and distortion include: disputes, conflicts and anarchy which are serious brewers of security breakdown if not effectively managed. In recent years, the Office of the Surveyor General of the Federation (OSGoF) and National Boundary Commission (NBC) have been involved in the redefinition and management tasks of International and National boundaries of Nigeria. Some States of the Federation have attempted the demarcations of their local government area boundaries in order to provide the geospatial limits on the ground, but often led to skirmishes over disputed boundaries; whose adjudications are sometimes subjective. This problem exists because there is no definite geodatabase strategy for all boundaries' related information, thereby rendering the physical extent of the country and states an amorphous status to be maneuvered by political leaders. This underscores the importance of boundary infrastructure as a key national security regulatory tool. This paper attempts an examination of boundary mapping and the requisite geodatabase strategy for creating and managing National Security Information System (NSIS) for Nigeria. Key geodatabase fields and records elements were identified and a sample geodatabase structure for managing boundary related security issues in Nigeria was developed using ArcGIS/ArcInfo platform. A total of 111 International boundary pillars distributed among the 20 states in Nigeria that have international borders were proposed. The study recommends the used of sub-meter resolution satellite imagery integrated with the existing NigNet CORS for creating an up-dated boundary, administrative and security base maps and information systems for Nigeria.

Keywords: Geodesy, Boundary Mapping, Geodatabase Strategy, National Security Information System

1.0 Introduction

Boundary mapping is the delineation delimitation on paper of the territorial limits of a state, country as a sovereign state and its political division and administrative framework under a constitution. Karl and Porter, (2006) described boundary mapping as defining the boundary of something in the field (e.g., a patch or population of some species). The main advantage of boundary mapping is that it provides direct information on the spatial distribution and related changes of the patch over time (Karl and Porter, 2006; Pokorney et al, 2006).

The likely consequences of boundary uncertainty, errors and omissions and distortion include: disputes, conflicts and anarchy which are serious brewers of defence and security breakdown if not effectively and sustainably managed. For instance, in 1954, Nigeria was divided into three regions (The Northern, Western and Eastern Regions) by legal notice No. 126 of 1954 and the description of the boundaries of all the three regions was gazetted (Cukwurah, 2008), but no physical beacon with spatial coordinates were put on the ground to define the extent of each region.

Before the advent of GPS technology, boundaries were usually estimated on a topographic map or aerial photograph. A common approach now is to use a GPS to record the vertices of a polygon defining the patch/population. In some cases, patches can be defined from aerial photographs (Karl, (n.d)). Table 1 gives summary of structural and administrative boundary development of Nigeria between 1954 and 1996.

Table1: Structural and Administrative Boundary Development of Nigeria (1954-1996)

S/No.	Structure of the Regions/Sates in Nigeria	Date of Creation	Remarks
1	3 Regions (Northern, Western and Eastern)	1954	Description gazetted, but no physical delineation on the ground
2	12 States	1967	No physical delineation on the ground
3	19 States + Abuja	1976	No Physical Beacon with spatial coordinates, except Abuja (FCT)
4	21 States + Abuja	1989	No Physical Beacon with spatial coordinates, except Abuja (FCT)
5	30 States + Abuja	1991	No Physical Beacon with spatial coordinates, except Abuja (FCT)
6	36 States + Abuja (774 LGAs)	1996	No Physical Beacon with spatial coordinates, except Abuja (FCT)

At the moment most states of the federation, with the exception of the Federal Capita Territory (FCT) have no clearly defined boundaries with concrete beacons of known spatial or positional coordinates known and accepted by the contigual states. Some of the states have attempted the demarcations of their local government area boundaries in order to provide the geospatial limits on the ground, but often led to skirmishes over disputed boundaries; whose adjudications are sometimes subjective. *A major benefit of geo-spatial database for boundary security and national development is that it enhances effective and sustainable decision support system in the physical and socio-economic development of a nation with minimal boundary disputes*.

In addressing the regional development policy of Nigeria, the 3rd National Development Plan of 1975-1980 expressed the main weakness of Nigeria's planning effort to be its heavy emphasis on sectoral and financial planning with a total neglect of the physical, which has resulted in in-ordinate spatial and environmental development and paucity of relevant data for decision making purpose (NDP 1975-80). In many countries of the third World and particularly in Nigeria, there is always an immediate action on all development planning issues demanding immediate and impossible solutions even where adequate and background information are not available (Agabi, 2008). Above all, in Nigeria where physical infrastructure such as boundary pillars and data are available they are usually not secured and maintained.

Figure 1: A Typical Inter-State Boundary Beacon (Pillar) between Kwara and Osun States, Nigeria

The major causes of insecurity of boundary pillars (Fig.1), where available in Nigeria include lack of sense of belonging, participatory ownership and management by indigenes within the vicinity of the infrastructure. Ojigi, (2006) suggested the use of Public-Private Partnership (PPP) practice as a new world order for sustainable development, to help reverse the inherent negative attitude of Nigerians in the use and sustenance of geodetic infrastructure.

1.1 Problem Statement

Data is the representation of facts and the task of finding, creating, assembling and integrating any reliable sets of data may be cumbersome. Therefore, the geospatial data required for studying and managing our complex environment and other dynamics in and around it are tasking and cumbersome to generate and manage. Practice and experience have shown that geo-database development for geo-spatial analyses consumes about 80% to 90% of the time and resources available for the implementation of any geospatial mapping and information system project. In view of the foregoing, it is important to initiate and identify the right dimensions of data field and records required for effective boundary mapping and management in a country like Nigeria.

The likely consequences of boundary uncertainty, errors and omissions and distortion include: disputes, conflicts and anarchy which are serious brewers of security breakdown if not effectively and sustainably managed. In recent years, the Office of the Surveyor General of the Federation (OSGoF) and National Boundary Commission (NBC) have been involved in the redefinition and management tasks of International and National boundaries of Nigeria. Individual states attempting to demarcate their boundaries and those of local government areas in order to provide geospatial limits on the ground will certainly result in skirmishes between communities from neighboring states or local government areas. In view of the foregoing, it is important to examine boundary mapping and the requisite geodatabase strategy for creating and managing National Security Information System (NSIS) for Nigeria.

1.2 Aim and Objectives

The aim of the study is to examine the structure of boundary mapping in Nigeria and develop geodatabase strategy for National Security Information System (NSIS). The objectives are to:

1. *Examines the structure of boundary mapping in Nigeria and its contribution to national security*
2. *Identify the key geo-data fields and records elements for sustainable geodatabase structure for managing boundary related security issues in Nigeria*
3. Develop and propose a geodatabase strategy for all boundaries' related information and general *National Security Information System (NSIS) for Nigeria* in order *to minimize the amorphous status and political maneuvering of the physical extent of the Country, States and LGAs.*

1.3 Scope and Limitation of Study

The study is limited to Nigeria, with emphasis on international boundaries between Nigeria and neighboring countries. A control network around the country is envisaged with location address and states in which such international boundaries lie. The study assumes that the same database strategy for international could be stepped down to interstate and inter-local government boundaries respectively; hence the later is not covered in this study. Also the field completion exercise and field validation of the proposed boundary pillars with a team made up of the National Boundary Commission (NBC), OSGoF, Surveyors-General of States and the representatives of government or local communities along the border area in tracing the boundaries on the ground are outside the scope of the study.

1.4 The Study Area (Nigeria)

Nigeria is made up 36 states and the Federal Capital Territory (FCT), and located approximately between latitudes 4^{o}N and 14^{o}N, and longitudes 3^{o}E and 15^{o}E (Fig.2). It lies wholly within the tropics along the Gulf of Guinea, on the west coast of Africa. It is bounded on the west by the Republic of Benin, on the north by the Republic of Niger and on the east by the Republic of Cameroon and on the south by the Atlantic Ocean. The size of Nigeria is about 923,768.64 sq.km and occupies about 14% of West Africa, but supports more than 60% of the population of the region. Nigeria, one of the largest countries in Africa, has 36 states and 774 LGAs and Abuja as the Federal Capital city (NCRS, 2011).

Nigeria is the most populous black nation in the world with a population of over 140 million (National Population Commission, 2006), and can be divided into four distinct geographical regions. Along the coast is a belt of mangrove forests and swamps, stretching some 16 km inland in most places. This region is cut by numerous lagoons and creeks. In the Niger delta region, the coastal belt extends some 100 km inland. Beyond the coast, lowlands follow the valleys of the Niger and Benue, but otherwise the land gives way to a broad, hilly, forested belt that gradually rises to the rocky terrain of the Jos and Bauchi Plateaux. Beyond these Plateaux is a region of savannah, which stretches to the semi-desert Sahelian zone in the extreme north. A great plain, marked by occasional outcroppings of granite, the savannah region is Nigeria's main agricultural area. In the east is the Adamawa Plateau, which borders Cameroon and in which is Dimlang, the Nigeria's highest point standing at about 2,042 m above the mean sea level (Microsoft, 2005; Ojigi, 2006).

Nigeria has two distinct climatic zones; the equatorial maritime air mass along the coast and the dry and dusty tropical continental air mass in the North. Iron-ore deposits are widespread in the savannah region of Nigeria, as are salt deposits. Tin and columbite are found in the plateau area. Great deposits of petroleum and natural gas are

located in the Niger delta and offshore in the bights of Benin and Bonny of the Gulf of Guinea. Nigeria also has large deposits of coal, lead, and zinc, and small deposits of gold and uranium.

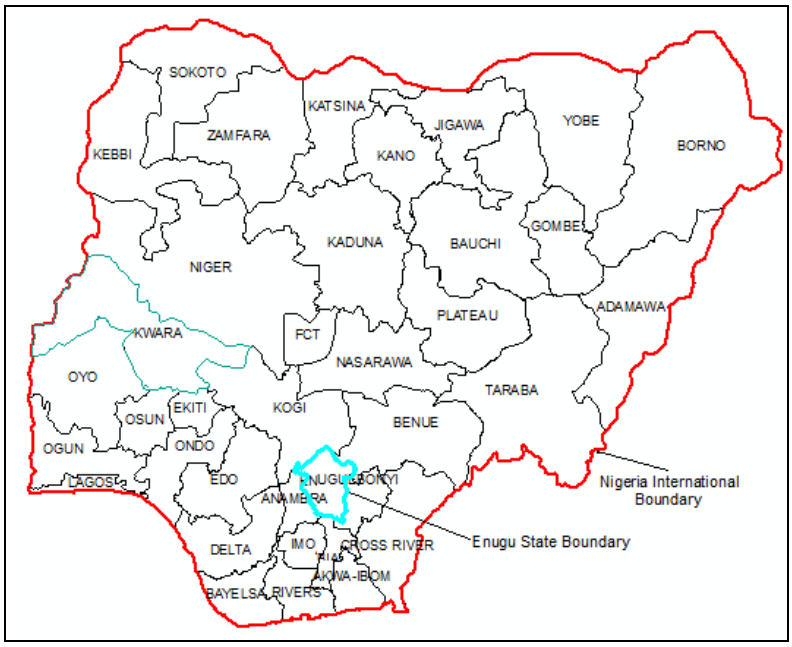


Figure 2: The International and Inter-State Outline of Nigeria

2.0 MATERIALS AND METHODS

2.1 Dataset and Boundary Geodatabase Development

The dataset used include, global earth elevation model (GEEM) and administrative and settlement maps of Nigeria. The international boundary vector file was created and the proposed points of interest for boundary pillars were selected and point data created using prominent nodes along the boundary line. The spatial attributes of importance include the *names of the proposed control pillars, field identifier, the curvilinear coordinates (ϕ, λ, h) of the controls* and *the states of the federation in whose border with other countries in Africa the pillars situate*, etc. The elevation component (h) of the curvilinear coordinates is contained in the visualized national elevation model.

During point creation exercise, the map was made as large as 1:10,000 in order to accurately pick the Geographic Coordinates on WGS84 Ellipsoid to the nearest 3decimal place of second of arc. Note that, the final choice of these proposed pillar positions prior field completion exercise must be subjected to a comprehensive field validation with a team made up of the National Boundary Commission (NBC), OSGoF, Surveyors-General of States and the representatives of government or local communities along the border area in the tracing of the boundary on the ground. The existing boundary pillars around the country are to be added to the strategic geodatabase for easy coordination and NSIS's implementation.

The study generated geodatabase using ArcGIS 9.3 platform for only Nigeria's international boundaries. Nigeria's international boundaries are boundaries that pertain to its land and maritime borders with neighboring countries. In the event of fieldwork or field data gathering, OSGoF is to provide the team leadership (Diggi, 2008). On the other hand, interstate boundaries are the internal boundaries within the country meant to create convenient administrative structure for governance and resource allocation and distribution.

The proposed border control pillars were selected and plotted within the data frame of the NigNet CORS for effective coordination during field implementation. The existing 11 NigNet CORS co-plotted within common data frame of the proposed International boundary pillars include Abuja (OSGoF), Port Harcourt (RUST), Gembu (HATC), Lagos (UNILAG), Kebbi (WUFP), Zaria (ABU), Yola (FUTY), Enugu (UNEC), Calabar (UNICAL), Toro (CGG) and Maiduguri (RAMPOLY). The CORS have now assumed status of Primary Triangulation Pillars for national and International boundary management.

2.2 Boundary Mapping and Geodatabase Matrix

The geodatabase matrix for boundary mapping and NSIS to include the following among others:

1. The beacon positions of International, State and LGA boundaries;
2. Border villages and towns;
3. Land marks such as rivers, footpaths, immigration and custom posts, fishing terminals, vegetations types, land use;
4. The size of the area under dispute (if any);
5. Incursions made by neighboring countries and states;
6. Number of litigation and dates of application of litigations;
7. Frequency of surveillance using high resolution satellite remote sensing;
8. Number of boundary crises/IVA and dates;
9. Available local/national security operatives ;
10. Methods of border mapping: GNSS/CORS, classical geodetic surveys, photogrammetric means, Laser/LiDAR, etc
11. Record of arbitration and Court Judgments;
12. Mineral resources along border corridors

2.3 Geodatabase Design

The fields and records are to be carefully designed, generated and structured to enhance complete geodatabase development for reliable geospatial information system products. The complete appropriation and use of the above fields depend largely on the availability of the records (data) for the identified fields; which in reality takes years to build or develop. However, what is most important is the design (conceptual, logical, and physical) of the desired geodatabase, which is a pre-requisite for a good and well structured database.

Through the use of data management tools in ArcMap-ArcCatalog, a simple personal geodatabase, which required no extra programming, was created for the study. The querying, editing and creation of boundary map and its overlay on base global image data was made easy with the data and behavior in the geodatabase without any customization. The basic steps in building geodatabase, as prescribed by ESRI (2008), include organizing the data in ArcCatalog, importing data into the geodatabase, creating subtypes and attributes domains, creating relationships between objects, building a geometric network, creating annotation, creating layers for the geodatabase data, creating a topology, and loading coverage data into the geodatabase topology.

3.0 RESULTS AND DISCUSSION

3.1 Results

Figure 3 represent the overlay of administrative and 1: 100,000 index map sheet of Nigeria; while figure 4 is the Nigerian States' Attribute Database (field and records). The attributes data for the state boundary shown in figure 4 is made up of fields such as state name, capital, code, date of creation, major mineral resources, population in 1991 and 2006, population density and growth rate, number of local government areas, area (sq.km), perimeter (km), number of adjoining states and geopolitical zone.

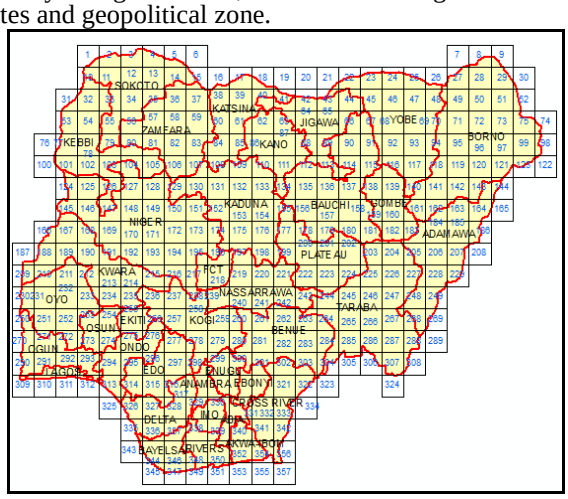
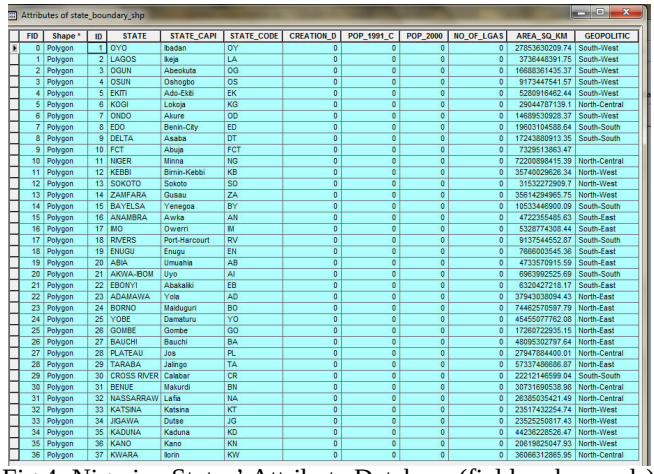


Figure 3: Overlay of Administrative and 1: 100,000 Index Map of Nigeria



FID	Shape *	ID	STATE	STATE_CAPI	STATE_CODE	CREATION_D	POP_1991_C	POP_2000	NO_OF_LGAS	AREA_SQ_KM	GEOPOLITIC
0	Polygon	1	OYO	Ibadan	OY	0	0	0	0	27053630209.74	South-West
1	Polygon	2	LAGOS	Ikeja	LA	0	0	0	0	3736448391.75	South-West
2	Polygon	3	OGUN	Abeokuta	OG	0	0	0	0	16688361435.37	South-West
3	Polygon	4	OSUN	Oshogbo	OS	0	0	0	0	9173447541.57	South-West
4	Polygon	5	EKITI	Ado-Ekiti	EK	0	0	0	0	5280916462.44	South-West
5	Polygon	6	KOGI	Lokoja	KG	0	0	0	0	29044787139.1	North-Central
6	Polygon	7	ONDO	Akure	OD	0	0	0	0	14689530928.37	South-West
7	Polygon	8	EDO	Benin-City	ED	0	0	0	0	19603104588.64	South-South
8	Polygon	9	DELTA	Asaba	DT	0	0	0	0	17243880913.35	South-South
9	Polygon	10	FCT	Abuja	FCT	0	0	0	0	7329513863.47	
10	Polygon	11	NIGER	Minna	NG	0	0	0	0	72200896415.39	North-Central
11	Polygon	12	KEBBI	Birnin-Kebbi	KB	0	0	0	0	35740029626.34	North-West
12	Polygon	13	SOKOTO	Sokoto	SO	0	0	0	0	31532272909.7	North-West
13	Polygon	14	ZAMFARA	Gusau	ZA	0	0	0	0	35614294965.75	North-West
14	Polygon	15	BAYELSA	Yenegoa	BY	0	0	0	0	10533446900.09	South-South
15	Polygon	16	ANAMBRA	Awka	AN	0	0	0	0	4722355485.63	South-East
16	Polygon	17	IMO	Owerri	IM	0	0	0	0	5328774308.44	South-East
17	Polygon	18	RIVERS	Port-Harcourt	RV	0	0	0	0	9137544552.87	South-South
18	Polygon	19	ENUGU	Enugu	EN	0	0	0	0	7666003545.36	South-East
19	Polygon	20	ABIA	Umuahia	AB	0	0	0	0	4733570915.59	South-East
20	Polygon	21	AKWA-IBOM	Uyo	AI	0	0	0	0	6963992525.69	South-South
21	Polygon	22	EBONYI	Abakaliki	EB	0	0	0	0	6320427218.17	South-East
22	Polygon	23	ADAMAWA	Yola	AD	0	0	0	0	37943038094.43	North-East
23	Polygon	24	BORNO	Maiduguri	BO	0	0	0	0	74462570597.79	North-East
24	Polygon	25	YOBE	Damaturu	YO	0	0	0	0	45455077762.08	North-East
25	Polygon	26	GOMBE	Gombe	GO	0	0	0	0	17260722935.15	North-East
26	Polygon	27	BAUCHI	Bauchi	BA	0	0	0	0	48095302797.64	North-East
27	Polygon	28	PLATEAU	Jos	PL	0	0	0	0	27947884400.01	North-Central
28	Polygon	29	TARABA	Jalingo	TA	0	0	0	0	57337486686.87	North-East
29	Polygon	30	CROSS RIVER	Calabar	CR	0	0	0	0	22212146599.04	South-South
30	Polygon	31	BENUE	Makurdi	BN	0	0	0	0	30731690538.98	North-Central
31	Polygon	32	NASSARRAW	Lafia	NA	0	0	0	0	26385035421.49	North-Central
32	Polygon	33	KATSINA	Katsina	KT	0	0	0	0	23517432254.74	North-West
33	Polygon	34	JIGAWA	Dutse	JG	0	0	0	0	23525250817.43	North-West
34	Polygon	35	KADUNA	Kaduna	KD	0	0	0	0	44236228526.47	North-West
35	Polygon	36	KANO	Kano	KN	0	0	0	0	20619825047.93	North-West
36	Polygon	37	KWARA	Ilorin	KW	0	0	0	0	36066312865.95	North-Central

Fig 4: Nigerian States' Attribute Database (field and records)

The portion of the attribute table in figures 5 and 6 show the names of the proposed control pillars, field identifier, the curvilinear coordinates (ϕ, λ, h) of the controls and the states of the federation in whose border with other countries in Africa the pillars situate, etc.

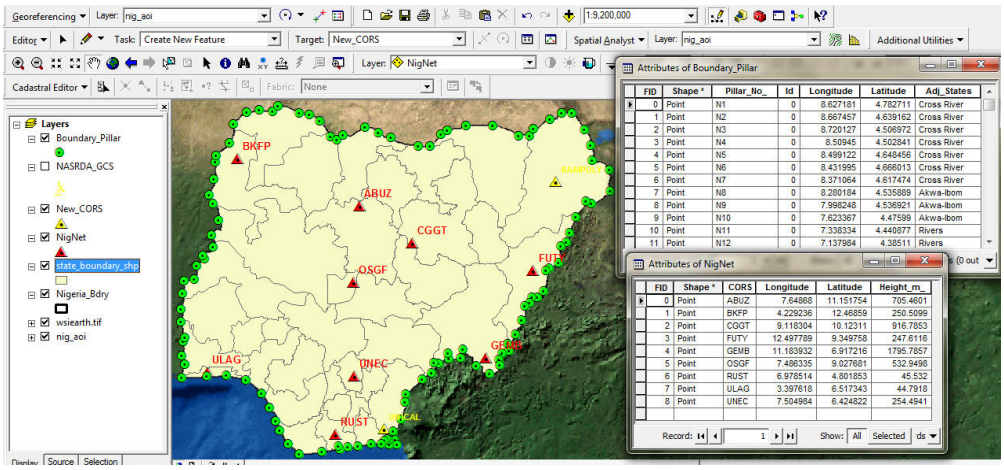


Figure 5: The Proposed International Boundary Pillar, Inter-state boundary and NigNet CORS overlayed on Regional Elevation Model for Nigeria

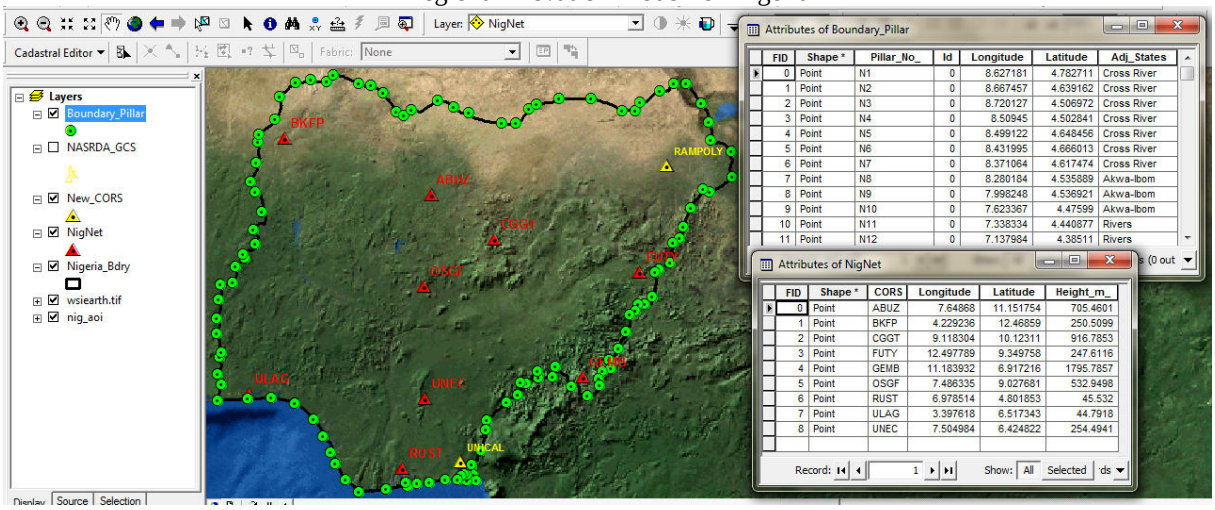


Figure 6: The Proposed International Boundary Pillars, NigNet CORS and the Regional Elevation Model in Nigeria

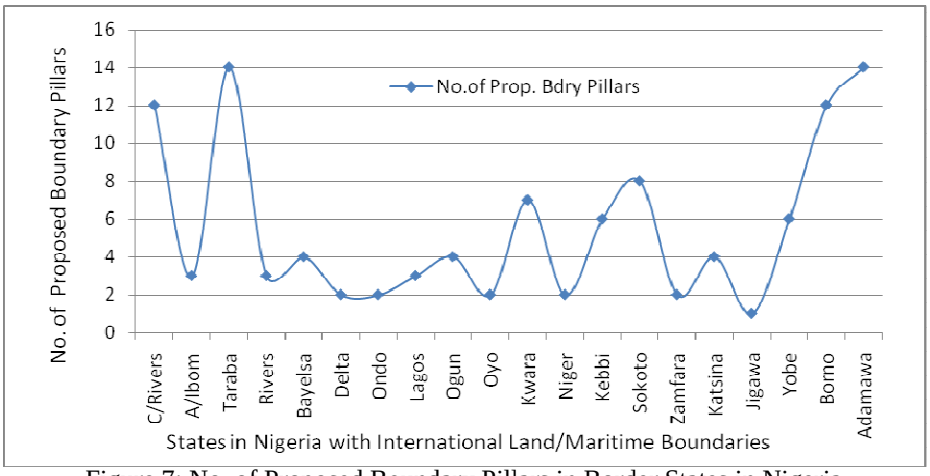


Figure 7: No. of Proposed Boundary Pillars in Border States in Nigeria

3.2 Discussion

In this study, a total of 111 International boundary pillars were proposed and basic geodatabase was created for them (figures 5 and 6). The pillars were distributed among the 20 states in Nigeria that have international borders in which majority of the points of interest were on arc or curve nodes along the boundary line. The reason for choosing more points of interest from prominent curve or arc nodes than straights along Nigeria International boundary line is to preserve the shape of the country and to avoid self ceding of own country land mass along the border region. Figure 7 is the graphic summary of the number of pillars for states along Nigeria international borders with Taraba and Adamawa having the highest number of 14 each, while Jigawa has the least of one number of International boundary pillar.

The elastic geodatabase themes for the pillars include *names of the proposed control pillars, field identifier, the curvilinear coordinates (ϕ, λ, h) of the controls* and *the states of the federation in whose border with other countries in Africa the pillars situate*, etc. The elevation component (h) of the curvilinear coordinates is contained in the visualized national elevation model. It is important to note that the geodatabase strategy suggested in this study is a pre-condition for effective field completion exercise through comprehensive field validation with technical team made up of the National Boundary Commission (NBC), OSGoF, Surveyors-General of States and the representatives of government or local communities along the border area in the tracing of the boundary on the ground.

A very important feature of International boundary infrastructure is the quality of the survey and data used in its determination. Appropriate data collection and structuring to suit or serve the purpose and scale of a geospatial information system is very fundamental to its enterprise application. Therefore, in the data matrices and strategies identified for national boundary mapping, the integrity of the data plays great role in the implementation of a reliable and dependable decision support. Therefore, it is expected that for boundary related-based NSIS, the population of the data fields identified are made elastic. However, care should be taken not to over blot the dimension of data matrix (row and column records), so long as the basic data fields have been covered. This will enhance tidy and unambiguous structured query language (SQL) for drawing conclusion on specific threshold in the final geodatabase(s).

3.3 Geodatabase Development strategy for NSIS

The following strategies are identified as the most formidable integrated step towards the effective use of the geodatabase matrix for the implementation of a National Security Information System (NSIS) in Nigeria.

i. Comprehensive and structured design (conceptual, logical, and physical) of the desired geodatabase, as a pre-requisite for an effective database.
ii. Integrated periodic mapping with sub-meter resolution satellite imagery or digital aerial photography and Global Navigation Satellite System.
iii. Establishment and development of local government survey departments to monitor respective borders and limits within their own territories.
iv. Keeping geospatial data and metadata records of boundary itineraries.
v. Pulling together of national data in central databank called ‘National Geospatial Data Infrastructure’ and disseminating the same for border geo-intelligence monitoring and national development
vi. Effective use of Intensity Value Analysis (IVA) of Boundary Problems. The IVA technique is used to estimate the number of boundary disputes in the immediate vicinity of a location or along specific international, inter-state, and local boundaries. However, this technique requires the construction of

buffers that extends a predetermined distance from the point or line under examination (a distance termed a *bandwidth*) and count the number of boundary disputes falling within that bandwidth. For example, a buffer of 10km and 5km around Nigeria-Cameroon border for all kinds of boundary skirmishes over a period of time will characterize the ***tolerance level*** of the two countries within the buffer-zone.

4.0 CONCLUSIONS

This study has proposed a geodatabase strategy for boundary-related NSIS that will serve as a hub for the sustainable management of security of the physical and economic structure of the country. The use of sub-meter resolution satellite imagery integrated with the existing NigNet CORS in Nigeria to select and populate the boundary pillars along the nation's international border and create a robust geospatial information system for sustainable development has become imperative.

It is a fact that the geospatial data required for studying and managing our complex environment and other dynamics in and around it are tasking and cumbersome to generate and manage. Nonetheless, geospatial information system remains the most integrated and harmonized way of generating decision support that truly reflect the events and abstractions from the real world around us. All boundary and security challenges in Nigeria occur at different geographical locations, dates, time, causing different effects and casualties, with litigation or response processes that are not the same.

Therefore, the geodatabase strategy suggested in this study is a pre-condition for effective field completion exercise of a comprehensive national boundary database development through comprehensive field validation with technical team made up of the National Boundary Commission (NBC), OSGoF, Surveyors-General of States and the representatives of government or local communities along the border area in the tracing of the boundary on the ground. At the end of it all, and with appropriate structured query language (SQL), the database will provide relevant boundary information for national security decision support system.

4.1 Recommendations

Recommended strategies for the boundary mapping and geo-database management for NSIS are:

1. Sub-meter resolution imagery integrated with the existing NigNet CORS should be adopted for creating an up-dated boundary, administrative and security based maps and information systems for Nigeria;
2. Digital compendium of geo-database (showing spatial and attributes) of all boundary pillars for International, national and local boundaries should created and constantly up-dated;
3. National Geospatial Database Infrastructure (NGDI) for Nigeria should strive to generate time series data on national defence and security for the Nigerian Military and civil security management;
4. Local Government Area Boundary Unit to be put in place and developed for effective and quick responses to boundary disputes;
5. IVA should be used to understudy the tolerant level of border communities in and around Nigeria.

Acknowledgments

We appreciate the Office of the Surveyor General of the Federation (OSGoF) for initiating and establishing the GNSS/NigNet CORS Infrastructure in Nigeria, which will serve as a strategic framework and platform for national boundary mapping and security information system in Nigeria. Our Special thanks to ESRI and GoogleEarth.com for the open source availability of ESRI ArcGlobe data and global imagery respectively. We wish to thank the National Space Research and Development Agency (NASRDA), Abuja for the satellite data management and space applications infrastructure, which provided the enabling environment for this research.

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