Critical Issues in the Methods of Data Collection in Geoinformatics and Environmental Sciences

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Abstract

A successful geographic or environmental research is partly dependent on the sources and methods of data collection, data analysis and result presentation. This study examined two broad sources of data collection to include (i) primary: direct field or in-situ measurements, count, observation, administration of questionnaire, use of check list and Focus Group Discussions, and (ii) secondary: documented materials (including published and unpublished statistics/materials) residents in government and Non-Governmental Agencies (such as World Health and Food and Agricultural organizations), and private geoinformation organizations. Other sources of secondary data collection identified include research institutes such as the National Space Research and Development Agency (NASRDA) for the provision of Satellite Images for landuse and environmental studies, and Universities that deals with science and technology issues such as the Departments of Geography, Environmental Sciences, Urban and Regional Planning and Surveying/Geoinformatics. The study evaluated major materials/tools/equipment used for data collections. The findings revealed that although primary data seems more reliable because of the close watch and methods of their collection, the cost and time it takes to generate them are very expensive hence, most people tend to rely on secondary sources of data for their use. The secondary sources may be relatively cheap but may be fraught with Spatial Data Quality issues. The study demonstrated that both primary and secondary datasets proved very useful in geographic and environmental change studies. A review of an empirical study of 'urbanization impact on climate change in West Africa city of Warri, Delta State, Nigeria' was used to validate this study.

Keywords: *Data Collection, Field, Geographic Data, Primary data, Secondary Data*

1. Introduction

Geoinformatics (or Geographic-Information Science - GIS) can be defined as the art, science or technology dealing with the acquisition, storage, processing, production, presentation and dissemination of Geographic Information (GI) (Ehler, 2008). Geoinformatics has been grouped broadly under technical geography, along with fields like geographic information science (Haidu, 2016). Data collection or gathering is key to effective Geoinformatics analysis and presentation of results. The role of Geoinformatics in Geospatial data modeling, urban studies and environmental management is infinite (Bello & Ikhuoria, 2015). Thus, data collection is the process of gathering information about a subject (Mueller, 2022). Geography as an environmental science is concerned with man's spatial organization and his ecological

relationship with his environment (Onokerhoraye, 1994: 2). Whether built, chemical, biotic or biological environments, Geographers and Environmental scientists are generally interested in studying spatial variations in the distribution of natural and man-made features (Montello & Suttan, 2006).

In geographic and environmental studies, the source of data is a key element in research methodology (Kpalo, 2022). The quality of the environment in terms of variations in environmental quality variables (air, water, and soil) including noise pollution are issues of concerns in environmental studies because of the need for reliable data for mapping and close monitoring (Bello *et al.,* 2022). According to Obadan (2012: 87), research methods generally refer to ways or procedures of conduction a thorough scholarly or scientific investigation or enquiry. Research methods specifically relate to the ways of organising a piece of research in terms of the methods of data collection, data analysis, and report writing (Op. cit.). From time immemorial, Geography has been deriving its data from two broad sources, and these are: documentary and field sources (Akinbode, 1996: 34). Although the field plays a very important role as source for data collection, ground surveying of the entire field is practically impossible hence the shift in modern trend is in favour of micro and macro scale researches in order to achieve a great depth of knowledge using Remote Sensing and Geographic Information System techniques (Bello and Rilwani, 2016). Recently, the scope, coverage and volume of digital geographic datasets are growing rapidly, and public and private sector agencies are creating, processing and disseminating digital data on the environment: landuse, socio-economic and infrastructure at every detailed levels of geographic resolution (Miller & Han, 2009).

It has been argued that Geography, and environmental sciences in general, are concerned with the association among the same or different groups of features thus, how various places resemble or differ from one another is indeed the very core of geographic study (Akinbode, 1996: 2). This is what the Waldo Tobler's First Law of Geography explains, e.g: *everything is related, but closer things are more related than farther things on Earth surface"* (Tobler, 1970). Tobler's First law is regarded as the basis of the underlying concepts of spatial dependence and spatial auto-correlation and is utilized specifically for the inverse distance weighting (IDW) method for spatial interpolation of mass point of samplings and to support the regionalized variable theory for kriging (Kemp, 2008). Therefore, it is important to note that the first law of geography is the fundamental assumption used in all spatial analysis (Miller, 2004; De Smith, Goodchild & Longley, 2004).

Furthermore, Geographers have been at variance in the explanation of the cause of the observed areal differentiation of environmental features. Whether for teaching or for research, a number of sources and methods of data collection generally abound in literature (Kpalo, 2022). The aim of this paper, specifically, is to present the major sources and methods of data collection in geography and environmental sciences. In this paper, the problems associated with primary and secondary data collection are examined and suggestions for a practical approach to a better data collection and use in view of dwindling cost and funding of equipment/instruments in data collection are articulated.

2. Sources of Data Collection in Geoinformatics/Geography and Environmental Sciences

As argued by Goodchild (2009), a geographic (or environmental) data can be described as any unprocessed fact that can be geo-located, in other words; it could be a measured or observed fact that has geographic reference whether absolute (x, y) or relative. The processed data (either manually or using computer) is referred to as geographic information (GI) (Goodchild, 2007).

In Geoinformatics, geographic data can be collected from either primary (field) or secondary (documented or existing) sources as further examined below.

2.1 Primary Sources of Data Collection

Primary data are often referred to as field measurements, observations or statistics (Mueller, 2022) generated from the field, while secondary data are documentary or not directly collected by the researcher (Akinbode, 1996: 34). In environmental studies, for example, one way to characterize data is in terms of whether they were collected specifically for the purpose of a researcher's particular study or not. If so, it is called the primary data. An example would be an environmentalist who is interested in urban pollution and then measures environmental quality indicators (air, water and soil) (Bello & Omoyajowo, 2015). The social environmentalist may also interview people about their attitudes toward increase in indiscriminate waste dump and silting of culverts in urban settlements like in Ekpoma, Keffi or even in the Federal Capital Territory in Nigeria. The major asset of primary data is that they are collected in a way specifically tailored to a particular research question, which means they are probably the data best suited to answering that question. For example, measuring stream flow, stream velocity, water samples for physico-chemial variables, cross profile of eroded area and population census count by a researcher in the field are some of the examples of primary data that can be collected from the field. But all of these take considerable time, planning, money effort and steps to obtain (Bello, Ufuah, Rilwani & Ogah, 2020).

2.1.1 Steps in Primary Data Collection

Depending on the scope and limitations of study (Kpalo, 2022), collection of primary data (Montello & Sutton, 2006) may involve the following steps:

a) Getting ready both mentally as well as physically for collecting primary data from field situations.
b) Keeping a field book/record book or diary for writing relevant information, doing field sketching or writing records of the occurrence of phenomenon at specific time intervals.
c) Making field measurements (including in-situ sample collection), observation, and interview or administering questionnaire schedule to the target groups of people across sampled sites.
d) Verifying the facts through cross checks in the answers and field realities or test standards.
e) Integrating the observations, responses and recorded facts in a systematic and logical framework.

2.1.2 Problems Associated with Direct Field Data collection and Possible Solutions

The field has been identified as the laboratory of the geographers and environmental scientists hence, primary data is credited for its high level of authenticity and reliability because the researcher is directly involved in first hand collection (Rilwani, 2006: 20). However, the major problems associated with direct field data collection, among others, includes: the high cost of data gathering, possible malfunctioning or misapplication of measuring instruments/equipment, some of them may be too heavy to carry, mix-up in data collation, mixed classification and poor recording. The major solution to direct field data collection is adequate preparations in terms of funding and logistics. In specific, it requires appreciable knowledge of field and sample to be taken, proper use of equipment/instruments, their documentation and result interpretations. To achieve the above, one has to test field equipment/instruments before taking them to the field. For instance, the use of questionnaire requires training and retraining of field assistants and possible pilot administration to learn

about likely problems to encounter in the main field work. Same applies to sample collection kits and how samples are stored after collection in order to still give reliable results despite been collected time apart before laboratory test are carried out on them.

2.2 Secondary Sources of Data Collection

If a geographic or environmental data has been collected by someone else or by a different organization, it is usually called a secondary data (Rilwani, 2006; Akibode, 1996). Put differently, Secondary data are data that researchers do not create themselves but use in their research. Compared to primary data that are generated over the course of fieldwork (that involves, for example, measuring water quality or interviewing respondents for Environmental Sensitivity Index Assessment - ESIA), secondary data are already created by someone else (Martin & Pavlovskaya, 2010). Secondary data providers include government agencies and private companies or such sources as published scientific studies, archives, or collections. Secondary data includes many different kinds of information about natural and human processes that is collected by various government agencies, non - government organizations, or corporations. Examples of such data include Satellite images like SPOT from France, National Space Research and Development Agency (NASRDA) from Nigeria, Landsat from USA, etc; climatic variables, population census data, health statistics, school attainment scores, weather monitoring data, ocean surface temperature variable, fish stock abundance calculations, quantities of hazardous materials released into the environment, results from public opinion polls and other business surveys, as well as data often presented in map form such as pollution or voting patterns, land use, or elevation, among others (Martin & Pavlovskaya, 2010).

Furthermore, an urban geographer who intends to examine the rate of population growth and population density may collect population statistics of Nigeria urban settlements from the National Population Commission. Such statistics is considered as secondary data from a secondary data source. Another example would be a geographer who uses NigeriaSat imageries to study urban growth in Ekpoma, Benin City, Keffi or Jalingo. The imagery was not collected by that researcher, and it was not collected primarily for specific urban growth monitoring purpose but the satellite image datasets can still be used for urban growth and environmental decay or blight monitoring. A number of reasons are responsible for using secondary datasets. For example, secondary datasets are sometimes the only data available to address a particular research question that are even moderately suited to that question. Also, secondary data are almost always less expensive than primary data (in terms of cost, time, and effort). In Geoinformatics, the use of Satellite images covering a large area is very beneficial in terms of cost and ancillary advantages. This includes the extent of earth surface coverage, the time the satellite passes over (temporal resolution), the spatial resolution of the imagery, and the spectral bands recorded (Bello & Rilwani, 2016; Akinbode, 1996: 138-141).

2.2.1 Steps in Secondary Data Collection

Regardless of the type of required datasets, the collection of secondary data (Montello & Sutton, 2006) may involve the following steps:

i) Gather knowledge about the offices/institutions to be visited, if it is going to be physical contact.
ii) Obtain an official referee letter containing the requirements of data and purpose of data collection from the head of your organization. An identity card may also be an essential requirement to get an entry into offices.

iii) Keep a note book/record file to transfer data for the purpose. It could also be done with the help of photo copying systems.
iv) The secondary data collected thus forms the basis for tabulation and processing as per need.

2.2.2 Problems Associated with Secondary Data and Possible Solutions

One of the major arguments for secondary data is that they are relatively cheaper and readily or almost readily available to collect and use when compared to primary data. However, the problem is that they may not be carefully collected following due diligence and approved methods of data collection or well established paradigm (Montello & Sutton, 2006). Likewise, it may have been falsified. Therefore, secondary sources of data must be carefully evaluated from the standpoint of the specific project to determine its adequacy. Assessment should equally be evaluated based on the scale of information contained; when, where, and how the data were obtained and who (individual or agency) was responsible (Rilwani, 2006: 20). This will help judge the authenticity, accuracy and reliability of the data as spatial data quality issue is concerned.

2.3 Why chose a given geographic data (primary or secondary)?

Some geographers or environmentalists use mostly primary data, whereas others use mostly secondary data. This choice depends mostly on the researcher's topical area of study. However, compared to many other scientific disciplines, both human and physical geographers use a great deal of secondary data. This is probably because they so often study phenomena at large spatial and temporal scales (Montello & Sutton, 2006), where it is typically so difficult and costly to collect data that a single study does not warrant it.

The fact that secondary data are not tailored to the researcher's specific research question influences the nature of many environmentalists' research. Problems addressed by census data, for example, are the subject of more geographic research than is necessarily warranted from an intellectual or applied perspective. Financial cost, time, relevance and accuracy of environmental variables should be considered when choosing to use either primary or secondary data in a given research.

3. Methods of Data Collection in Geoinformatics/Geography and Environmental Sciences

Before specifically listing and discussing the various methods of data collection, first we present a broad grouping of data collection in research. According to Montello & Suttan (2006), methods of data collection can be grouped into five (5) sub-groups as follows:

i. Physical measurement
ii. Observation of behaviour
iii. Archives
iv. Explicit reports
v. Computational modeling

i). Physical measurement

According to Montello & Suttan (2006), physical measurement is very popular in geography and environmental studies, especially in physical geography. It generally consists of data collected by measuring and recording physical properties of the earth or its inhabitants. Physical properties include size and number, temperature, chemical makeup, moisture content, texture and hardness, the reflectance and transmissivity of electromagnetic energy (including optical light), air speed and pressure, and more (Bello *et al.*, 2022). One of the key innovations of 20th Century Geography and Environmental Sciences is the use of aerial and satellite remote sensing as ways to efficiently record large amounts of physical measurement data (Bello & Rilwani, 2016; Bello & Ojigi, 2013; Rilwani, 2006).

ii). Observation of behaviour

Human geographers often observe the "physical traces" left behind by human behaviour or activity (bio-geographers might study the physical traces of non-human animal activity). They include the house designs in different neighborhoods or cultural regions, crops that have been planted in different fields, or patterns of clear-cut forests left by different harvesting techniques. The second type of data collection is based on the fact that human geographers also observe and record human behaviour directly (again, bio-geographers can observe animal behaviour). Behaviour is the overt and potentially observable actions or activities of individuals or groups of people. It is not their thoughts, feelings, or motivations, although very often behavioural observations provide the data that allow geographers to study thoughts, feelings, and motivations scientifically. Geographers make behavioral observations in person or with the aid of a variety of recording media. Importantly, records of behaviour do not in themselves constitute data; they must be "coded" into categories to become data. Thus, behavioral observations vary greatly in the degree to which they involve people's explicit awareness that they are being studied.

iii). Archives

Geographers and environmental scientists also use existing records that others have collected primarily for non-research purposes (Kpalo, 2022). These secondary records are known as archives. Examples of archives used by Geoinformaticians include archived climate data, birth and death records, newspaper stories, industry and environmental business records, museum records, historical documents, diaries, letters, and more. Often, archives must also be coded in order to produce usable data for reliable analysis and result.

iv). Explicit reports

Explicit reports are beliefs people express about things—about themselves or other people, about places or events, about activities or objects of study in the environment. This type of data collection is quite popular in human geography. Actually, explicit reports are also observations of behaviour; answering a question on a survey is behaving, for instance. But we distinguish reports as distinct types of data collection because they always involve explicit recognition by people that researchers are studying them, and because research participants' explicit beliefs and choices determine the data collected with explicit reports. Explicit reports such as surveys and interviews often consist of questions that have no right or wrong answers, or at least the correctness of the answer is not of chief interest to the environmentalist. When the explicit report consists of questions that do have right or wrong answers, and the correctness of answers is of interest to the researcher, we call the explicit report a test. That is, whereas many types of explicit reports are used to study opinions, attitudes, and preferences, tests are used to study knowledge. These measures are called "explicit" reports because people responding to them

know they are responding to a request for information by a researcher. This turns out to be both an important strength and an important limitation of explicit reports.

v). Computational modeling

This can be applied in both physical and human geography. A model can be defined as simplified representations of portions of reality. Models can be realized in conceptual, physical, graphical, or computational form. Understood in this broad way, models and modeling are pervasive in Geoinformatics. Models can be in the form of statistical models, graphical models (maps are models) and or Conceptual models. As a unique approach to data collection, computational modeling is modeling that evaluates theoretical structures and processes expressed mathematically, typically in a computer. Computational modeling covers research designs, because experts believe it makes sense to think about modeling as an alternative to standard experimental and non-experimental approaches. Models fit portions of reality by comparing outputs of the model to measurements made on the reality to which the model refers. Alternatively, models are sometimes created and thought about as if they were creations of new realities rather than simulations of existing realities. Environmentalists consider how this creation of "artificial realities" may or may not be thought of as scientific research. For example, map is one of the oldest models use in geography and environmental studies and till date, they serve a general purpose: whether topographic or thematic, or even Volunteered Geographic Information (VGI), Crowd Sourcing or Citizen Science (Bello & Ojigi, 2013).

4. Specific Field and Documentary Sources of Geographic Data Collection

4.1 Field Sources and data

This relates to data generated directly from the field. This include: Focus Group Discussions (FGDs), Check List field observation (qualitative), Questionnaire administration, direct field measurements (water, soil, air, noise, etc) in environmental studies, among others.

The following tools or equipment may be used when collecting field data:

a) **Stationery:** Writing and drawing equipment i.e. paper, pencil, pens etc. for recording or sketching.

b) **Field Compass/Prismatic Compass:** To determine or find out direction or bearing while in the field

c) **Questionnaires:** These are forms of printed questions to be filled in by appropriate persons at their own time and pace. It should be all-encompassing whether close ended or open ended. It should however not be bias in administration and questions should be targeted at research questions or set objectives. It may take time, but is very good in social and environmental user-centered design research. This approach is widely used in Human geography and environmental sciences when dealing with human and environmental impact assessment and perception of possible change in environmental variables due to exploitation (Bello and Omoyajowo, 2015).

d) **Aerial Photos/Satellite Image Data**. They are mainly used for augmenting map information and can be used as base data for generating different layers of land cover use for environmental dynamics studies such as climate and Vegetation change, Landuse/landcover change studies, urban growth analysis, disaster studies, among others (Bello & Rilwani, 2016; Rilwani, 2006; Akinbode, 1996).

e) **Maps:** Whether large or small scale, Survey maps may be used for map reading and base maps could be used for filling in observable features in the field. Maps are useful for tourism and travels. They are also use for modeling environmental resource such as

solid mineral (e.g. gold). They serve as reference guide and with the advent of web-maps, smart phone can now be used as navigation guide and with available data mashup, vector layers (point, line, polygons) and raster layers (images/pictures) can be overlayed on satellite images and viewed simultaneously as image map as made possible in recent time with the aid of Web 2.0 in VGI and Collaborative Web Mapping (CWM) (Bello & Ojigi, 2013).

f) **Cameras:** For example, video cameras/camcorders and still photograph cameras can be used for filming or recording pictures of geographical features and activities in the environment.
g) **Audio Tape Recorders or Cassette Recorders:** These can be used for recording interviews.
h) **Measurement equipment:** Such as 4-in-1 Environment Meters for measuring air quality (Bello *et al.*, 2022), tape measures, meters rulers etc. for obtaining information about distance are essential in data collection.
i) **Weather instruments:** Such as a rain gauge, sixth's thermometer, hygrometer, sunshine recorder etc. for the measurement and recording of the elements of weather in the environment (Odjugo, 2011).
j) **Binoculars/Telescopes:** To observe distant objects or features in the field. This includes Astrology/Astronomical Instruments such as Refracting Astronomical Telescope.
k) **Excavation Tools:** Tools like hand hoes, spades and mattocks for digging in order to reveal the soil profile. Others include Soil Auger. Auger is used for taking soil samples for soil quality analysis.

4.2 Documented (archived) data

Documented (and archived) data include both published and unpublished data obtained from Government, None-Governmental Organization (NGOs) and private sectors. Some of the major sources of documented secondary data in Nigeria according to Obadan (2012: 89) include the following:

i. National Bureau of Statistics (NBC) for official government planning statistics,
ii. National Population Commission (NPopC) for census data,
iii. Nigerian Geological Survey Agency for sub-surface and solid mineral data
iv. Nigerian Meteorological Agency (NIMET) for weather data,
v. National Museum and Monuments (NMM) for historical data and information,
vi. Independent National Electoral Commission (INEC) for electoral data,
vii. Nigerian Custom Service (NCS) for import and export data,
viii. Nigerian Ports Authority (NPA) for water transportation data,
ix. Nigeria National Petroleum Corporation (NNPC) for data on crude oil and its by-products,
x. Central Bank of Nigeria (CBN) for data on official government earnings and spending,
xi. Manufacturing Association of Nigeria (MAN) for data on locally manufactured products ready for exports,
xii. Nigerian Stock Exchange (NSE) for data on foreign exchange (FOREX) trade,
xiii. Office of the Surveyor General of the Federation (OSGOF) for topographic maps.
xiv. National Association of Chambers of Commerce (NACC) for data on general trade deals,
xv. Research Institutes such as the Nigerian Institutes for Oil Palm Research (NIFOR) for oil palm data and the National Space Research and Development Agency (NASRDA) for Satellite imagery provisions. Others include:

xvi. Universities (especially Surveying, Geography and Planning Departments),
xvii. Ministries, Departments, Agencies/Parastatals of Governments such as the state Ministry of Lands, Survey and Urban Development,
xviii. International organizations such as the World Bank, International Monetary Fund (IMF), World Health organization (WHO), World Trade organization (WTO), United Nations and her various agencies, organization for Petroleum Exporting Countries (OPEC), Food and Agricultural organization (FAO), etc.

5. Empirical Application: Africa Perspective on Data Collection: *'Urbanization Impact on Climate Variation: The Case of Warri, Delta State, Nigeria'*

5.1 Preambles

In this study, Odjugo (2011) examined urbanization impact on climate variation in Warri, first, by reviewing the causes of climate change to include (i) natural causes such as continental drift, volcanoes, ocean current, the earth's tilt, and comets and meteorite, and (ii) human causes which specifically gain prominence with the 19th Century Industrial revolution that saw large scale use of fossil fuels for industrial activities. The study emphasized that as more and more industries grew and increased in terms of geographic locations, the need to improve on urban development for housing and other infrastructure gave rise to the cutting down of trees thus, altering the natural ecosystem of the environment. In specific, the discovery of crude oil, its exploration and exploitation in Warri led to oil spill and urban encroachment into water ways and forested areas. To examine the impact of climatic variation occasioned by urban growth, the source, type and method of data collection and analysis is presented in sub-section 5.2 and 5.3 respectively.

5.2 Source and Type of Data Collected

To examine the impact of urbanization in climate variation in Warri, Odjudo (2011) used secondary data collected from the Nigerian Meteorological Agency, Lagos. The climate data obtained comprises of air temperature, rainfall amount, and relative humidly for 40 years (1970-2009). According to Odjugo (Op. Cit.), the study limits itself to 1970 – 2009 because, one, climate change signals actually became stronger as from the 1970s, and two, the rate of physical expansion of Warri also became rapid from the 1970s and 1980s.

5.2 Methods of Data Collection and Analysis in the Africa Case Study

Odjugo (2011) stated that the temperature traverse of Warri was taken weekly at 2pm in the month of March, 2010 using the thermometer. This 2pm used was based on the fact that human activities in Warri are at their peak between 12 noon to 4pm and this period also record the highest daily temperatures. The data collected were further analysed using statistical tools like the percentages, time series analysis, graphs and tables. The study thus shows an increase in average temperature from 26^0C to 28.3^0C. The study concluded that the observed increasing temperature and rainfall and decreasing relative humidity in Warri over the past 40 years (1970 – 2009) was attributed to the altered physical and chemical properties of the city occasioned by urbanization process.

Thus, from the above Africa case scenario herein examined in this paper, it is abundantly clear that, although generating data directly is more reliable, there are situations where the Geographer or Environmentalist would want to study events over a long period of time. In this case, the researcher can not manufacture past historical dataset other than to rely on existing data from trusted secondary sources like the Nigerian Meteorological Agency (NIMET) for

Climate data, the National Space Research and Development Agency (NASRDA) for satellite images, among others. With proper analysis, reliable results can still be obtained from secondary sources of data collection for informed decision making and relevant planning. This sums up the very essence and hallmark of this paper - *Emerging Issues in the Methods Of Data Collection In Geography And Environmental Sciences: Africa case perspectives.*

6. Conclusion

Research cannot be undertaken without data, whether from primary or secondary sources. However, depending on what is required in the research, Geographers or Environmentalists have to take into consideration the study aim, objective, research questions and hypothesis that needs to be satisfied by weighing the strength and weaknesses of the primary and secondary sources and types of data before embarking on using them. The cost, time and accuracy of the data should equally be factored into the decision making. And as demonstrated in examining an Africa case study on 'urbanization impact on climate change in Warri by Odjugo (2011), both primary and secondary data proves useful in geographic and environmental studies if well analyzed empirically. It is, therefore, recommended that proper verification and validation of secondary data and their sources be carried out before using them in research by Geographers or Environmentalists as this will help to re-assure users of the quality requirements for further use.

References

Akinbode A. (1996): *Research Methods in Geography*. Ekpoma: Edo State University Publishing House.

Bello, I. E. & Omoyajowo, A. O. (2015): Geospatial Modeling and Analysis of Environmental Quality Indicators in Sub-Saharan African Mining Community of Evbonogbon, Nigeria. *International Journal of Development and Sustainability (Japan),* 4(4): 381-397. (Online): available at http://isdsnet.com/ijds-v4n4-3.pdf

Bello, I. E. & Ikhuoria, I. A. (2015). 3D Cartographic Model and Animation of As-built Educational landuse of UNIBEN, Nigeria. *International Journal of Scientific Research in Science and Technology*, 1(5), 204-212 (Online): available at DOI:15.11/IJSRST151540

Bello, I. E., Ufuah, M.E., Rilwani, M.L. & Ogah,A.T. (2020): A Paradigm Synthesis Of The Relevance Of Fieldwork In Geographic Research. *American Journal of Geographical Research and Reviews*, 2020; 3(16), 1-12. (Online): available at https://escipub.com/ajgrr-2019-09-2705/

Bello, I.E. & Ojigi, L.M. (2013): Collaborative web mapping and volunteered geographic information: a study in Nigeria. *Applied GIS,* 9(2): 1-17.19.

Bello, I.E. & Rilwani, M. L. (2016): Quantitative Assessment of Remotely Sensed Data for Landcover Change and Environmental Management. *Indonesian Journal of Geography (Indonesia),* 48(2): 135 – 144. (Online): https://jurnal.ugm.ac.id/ijg/article/view/17629.

Bello, I.E., Bello, A.A., Edobor, W.W. and Kabiru, D.M. (2022): GIS-based modeling and assessment of noise pollution in the Nnamdi Azikiwi International Airport, Abuja, Nigeria. *Nigerian Journal of Cartography and GIS*, 15(1&2), 20-33.

De Smith, M.J., Goodchild, M.F., & Longley, P. (2007): *Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools.* Troubador Publishing Ltd, p44

Ehlers, M. (2008): Geoinformatics and digital earth initiatives: a German perspective. *International Journal of Digital Earth*, 1:1, 17-30, DOI: 10.1080/17538940701781975

Goodchild, M.F. (2007) Citizens as Sensors: The World of Volunteered Geography. *GeoJournal*. 69: pp. 211-221.

Goodchild, M.F. (2009): NeoGeography and the nature of geographic expertise. *Journal of Location Based Services*, 3(2), 82-96.

Haidu, I. (2016). What is Technical Geography – a letter from the editor. *Geographia Technica.* 11: 1–5. *doi:10.21163/GT_2016.111.01*.

Kemp, K. (2008): Encyclopedia of Geographic Information Science, *SAGE,* 2008, Pp 146–147.

Kpalo, S. Y. (2022): *Introduction to Research Methodology: A Guide for beginners.* Abuja, Bar and Bench Publishers Limited. p 228

Martin, K. & Pavlovskaya, M. (2010): Secondary Data in: B. Gomez & J.P. Jones. III (eds.). *Research Methods in Geography*. USA, Wiley, Blackwell. pp. 173 – 193.

Miller, H. (2004): Tobler's First Law and Spatial Analysis. *Annals of the Association of American Geographers.* 94 (2), 284–289. doi:10.1111/j.1467-8306.2004.09402005.x. S2CID 19172678.

Miller, H.J. & Han, J. (2009): Geographic Data mining and knowledge Discovery: An overview in: H.J. Miller and J. Han (eds.): *Geographic Data Mining and knowledge Discovery*. Bristol, PA, USA, Taylor and Francis, pp. 1 – 26.

Montello, D.R. & Sutton, P.C. (2006): Data Collection in Geography: Overview in: DR Montello & PC. Sutton (eds.): *An Introduction to Scientific Research Methods in Geography*. Pp. 35 – 45. Thousand Oaks, CA: Sage, Retrieved June 23, 2015 from http://www.sagepub.com/sites/default/files/upm-binaries/10919_Chapter3.pdf

Mueller, H. (2022): Understanding Different Data Collection Strategies & Techniques. (Online): Accessed January 23, 2023 from https://study.com/learn/lesson/data-collection-techniques-methods.html

Obadan, M.I. (2012): *Research Process, Report Writing and Referencing: A Guide for Researchers and Scholars in all disciplines*. Abuja, Goldmark Press limited.

Odjugo, P.A.O. (2011): Urbanization Impact on Climate Variation: The Case of Warri, Delta State, Nigeria in: F. C. Okafor (ed.) *Critical Issues in Nigeria's Development: Environment, Economy and Social Justice*. Essays in Honour of Professor Emeritus Andrew G Onokerhoraye. Ibadan, Spectrum Books limited. pp. 551 - 569.

Onokerhoraye, A.G. (1994): *Geographic Thought, Philosophy and Methodology.* Benin Social Science for Africa. Ibadan, Intec Printers Limited.

Rilwani, M. L. (2006): *Field Studies in Geography and Planning*. Benin City, Donald publisher.

Tobler, W. (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography*, 46(Supplement): 234–240.