ANALYSIS OF SPATIAL DISTRIBUTION OF GSM BASE STATIONS IN ZARIA URBAN AREA, KADUNA STATE, NIGERIA.

BY

ADAMUGaddafi
M.SC./SCI/20759/2012-2013
(M.Sc., REMOTE SENSING ANG GIS)

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DECLARATION

I declare that the work in this dissertation titled "Analysis of Spatial Distribution of GSM Base Stations in Zaria Urban Area, Kaduna State, Nigeria" was carried out by me in the Department of Geographyunder the supervision of Dr.A.U. Kibon and Dr. U.F. Isa. The information derived from literature has been duly acknowledged in the text and a list of references provided.

GADDAFI ADAMU	**Msc/SCI/20759/2012-2013**	_____
Name	**Reg. No**	**Signature and Date**

CERTIFICATION

This Dissertation titled "ANALYSIS OF SPATIAL DISTRIBUTION OF GSM BASE STATIONS IN ZARIA URBAN AREA, KADUNA STATE, NIGERIA", was written by Gaddafi Adamu and has been read and approved as meeting the requirement for the awardof Master of Science degree in (Remote Sensing and Geographic information system (GIS) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

Dr. U.F. Isa	_____	_____
Chairman, Supervisory Committee	**Signature**	**Date**
Dr. A.U. Kibon	_____	_____
Member, Supervisory Committee	**Signature**	**Date**
Dr. A.U. Kibon	_____	_____
Head of Department, Geography	**Signature**	**Date**
Prof. BalaKabir	_____	_____
Dean, School of Postgraduate Studies	**Signature**	**Date**

DEDICATION

This work is dedicated to my parents Mr. and Mrs. Adamu Aliyu Shika for their encouragements and support during my study.

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ABSTRACT

This studyanalyzed the spatial distribution of GSM base stations (masts) in Zaria Urban area, Kaduna State, Nigeria. The existing base stations(masts) were identified and mapped using World Health Organization (WHO) (2007) regulations for locating a GSM Base Stations, that Mast should be erected ten (10) meters away from the residential areas. Spatial data of the GSM base stations(masts), QuickbirdSatellite image of urban Zaria, field survey, Geographic Positioning System (GPS),Record from various service providers and Nigeria Communication Commission (NCC)was used for the study. The criteria for the location and distribution of the base station masts were also tested using the 10m buffer zone tests. The result revealed 116 GSM Base Stations in the study area, out of which only 16 masts comply with the standards of WHO while the remaining 100 do not comply with the standard of WHO.Proximity analysis was shown as maps within the study area.Most Service providers were found to violate the standards and located their facilities close to where people live, The distribution of GSM Base stationsin urban Zaria are in Random form with Rn value (0.633866) and negative z-score (-7.379585) shows that they are in clustered form. This implies that, masts are sited randomly close to each other when viewed against the background of the area perimeter. Finally the spatial distribution of these facilities within the residential areas also exposed such areas to the effect of electromagnetic radiation and fumes from the generators at the Base Stations and subsequently leading to early grave diseases.

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CHAPTER ONE: INTRODUCTION

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Telecommunication was defined as a technology whose domain is communicating from a distance by Tarmo, (2003). It includes mechanical and electrical communications. The communication system has evolved from traditional mechanical to electrical form using increasingly more sophisticated electrical systems. This is why many authorities such as the National Post, Telegraph, and Telephone (PTT) companies are involved in telecommunications using both forms. This has given birth to the development of Global System for Mobile communication (GSM) in 1982 introduced by European Conference of Postal and Telecommunications Administrations. In Europe, the use of commercial land based cellular mobile telephony has increased dramatically since the first services appeared in the beginning of the 1980's, especially with the introduction of the digital GSM 900/1800 systems in 1990's. Today, GSM has become a global, regional and local system for communications. The system uses a time division multiple accesses which enables more people to communicate simultaneously with a station. Bortkiewitz,Zmyslony and Gadzicka(2004).

The wireless technology relies upon an intensive network of fixed antennas (base stations) of towers, and associated structures which include hill tops because they enable signals to be picked up from and transmitted to a large area. A telecommunication mast tower however, consists of a body structure of steel beams and materials with a concrete base of an approximate height of between 25 and 55meters, whereas antennae, transmitters and receivers are mounted on the body of the structures. These antennae receive high frequency radio waves from cell phones. The ranges of these antennas vary

from distances as short as 1.5km to 2.4km to distances as long as 48km to 56km. A power source is provided with other accessories, all fenced either by block wall or steel poles and wire depending on the preference of the service providers. The land area covered by each mast location is approximately 144m^2 (12m x 12m) (Akin and Margaret 2014). It was estimated that, over 1.4 million base stations exist worldwide, and this number is increasing significantly with the introduction of third generation technology (Nakwawessi, 2010).

GSM communication system was introduced in Nigeria in August 2001. This changed the face of Information and Communication Technology (ICT) in the country. At its launch, there were only two operators in Nigeria, these are: MTN and Econet which metamorphous to Vmobile, Zain and now Airtel. Today, there are several operators across the nation, among the existing ones in Urban Zaria include: Etisalat, Globacom, Startcomms, Visafone, Airtel and MTN. The coming of the GSM in Nigeria brought about economic growth and reduction in unemployment. It also made access to communications easier. The new technology introduces new elements into the built environment of Nigerian cities. There hardly exists a city which does not have erected masts in the country (Punch, 2009).

It was estimated that, more than 120 masts are built monthly on the average by the service providers (Punch, 2009). The service providers as at 2009 have about 3,000 masts each across the country, most concentrating on urban areas (Punch, 2009). As at the year, each provider has more than 14,000 live masts in Nigeria. Today, the number of live masts can only be imagined. If 120 masts per month is anything to go by, then each operator would have added about 4, 800 masts (Nwokoro, 2000).

The effects of mast on city dwellers can be complex. There are silent long term problems that may affect the resident health. In United States for instance, masts have been associated with cancer and other grave illnesses. Occurrence like fatigue, headache, decreased concentration, dizziness, local irritation, tumour induction, sperm motility, morphology and viability, cancer, especially brain tumour and leukaemia, viral and infectious diseases has been blamed on living within 1-5km distance from masts in Dunganon.Abdel, Batanouny and Salem, (2007). There have also been issues related to the fact that some of the mast that are erected are not very strong and there have been cases of towers that have fallen down to cause fatal accident and other nuisance to the environment. The vibration and noise from the generators in the host neighborhood also impair the residents peaceful living. Bortkiewitz,Zmyslony and Gadzicka(2004)

In Nigeria, there are claims that the masts used by telecom providers radiate electromagnetic field (ETF) rays which are injurious to health. The National Radiological Protection Board had said that there is radioactive exposure from mast which may be microwave radiation, electromagnetic radiation and radio frequency radiation. The electromagnetic radiation emitted from masts depends on the height and type of mast but the wave ranges from $50w/m^2$ and $200w/m^2$. Some waves emitted by some masts are not hazardous but most masts emit more than $100w/m^2$ which is said to be hazardous if human being stays around the mast for a long time Abdel, Batanouny and Salem, (2007).

Both the World Health Organization (WHO), and Federal Ministry of Health (2007) confirmed that, research has not been able to provide support for a causal relationship. But given the large number of mobile phone users, it is important to investigate, understand and communicate any potential public health impact from mobile

phones and masts, which work by transmitting radio waves through a network of fixed antennas called base stations.

Consequently, the Nigerian Communications Commission (NCC) in collaboration with the National Environmental Standard Regulatory Enforcement Agency (NESREA) was obliged to adopt the World Health Organization (WHO) (2007) regulations for locating a GSM Base Station in Nigeria, that Mast should be erected 10m from the perimeter wall (fence) of residential, where there is no perimeter wall (fence), a Based Station must be at a minimum of twelve (12) meters and above from the wall of residential, educational, hospital, child care centers and nursing homes. The organization also ascertained that Mast should not be erected on Agricultural lands because of its effect on the crops. These criteria should be met for a GSM Base Stations to assume spatially sound located. Alternatively, a key to the sensitive locating, sighting and design of telecommunications equipment is an understanding of the area landscape, Diaz-Bordenave(1977). The best opportunities for the sighting of masts are: Railway land, Recycling Areas, Waste water treatment works, Industrial/General Business Areas, and so on. Wang (2007).

In the telecommunication world, GIS is used for network planning and development. The ability to layer information onto the earth's surface, complete with attribute data, allows engineers the unique ability to model and assess a network from the office. This saves valuable time and reduces the number of trips Wang(2007). Furthermore, the powerful automation capabilities offered by a GIS increase the speed and accuracy of the network design process and can help reduce, and even eliminate, the downstream impacts of design-phase errors on cost and schedule during the network

deployment phase. The skill level and design time involved in hand-producing comparable designs would be significantly higher. Using a GIS allows the engineer to add existing and competitive coverage to the map to improve the context of the data provided (Demers, 1997; Jones, 2005; and Galati, 2006). Therefore, the purpose of using Remote Sensing and GIS in this study is due to the powerful solutions that the technology brings to the computer desktop in the present day to aid in the database creation, querying, update, and administration of the mentioned facilities.

1.2 STATEMENT OF THE RESEARCH PROBLEM

GSM communication is a popular but new technology of global communication. It makes communication easier because of its mobility nature. This new technology uses a network of towers to enable signals to be picked up from and transmitted in form of waves to a large area, Galati(2006). According to Ayinde, (2012) in Nigeria, owners and operators of masts and towers might have indiscriminately installed these towers all over Nigerian cities without given much thought to the spatial dimension of the facilities erected. It was in due course, Abdel, Batanouny and Salem, (2007) lamented that, short effect of the waves generated in transmitting the signals causes actual burn to the skin, nausea, vomiting and diarrhea while long exposure can cause epilepsy, short term memory loss, sleep disorder, increase in leukemia, and speed of cancerous growth which might lead to death. Consequently, many researchers have contributed immensely to unravel the dilemma both in developed and developing nations.

Although many studies on GSM Base Station have made an appreciable effort, a good example is found in the work of Mladen-Koprivica*et al*. (2013), who examined the statistical analysis of electromagnetic radiation measurements in the vicinity of

GSM/UMTS base station antenna masts in South Africa by conducting extensive electromagnetic field strength measurements. Their result show that the total electric field strength obtained in the vicinity of base station antenna mast in no case exceeded 10 V m^{-1}, which is quite below the International Commission on Non-Ionizing Radiation Protection reference levels. Also At horizontal distances >50 m from the mast bottom, the median and maximum values were <1 and 2 V m^{-1}, respectively.

In Nigeria, Iortile andAgba (2014), examined the radiofrequency radiation distribution around mobile base stations in Makurdi, Benue State, Nigeria using electromagnetic field tester (EMF 827, Lutron) to ascertain the radiofrequency field levels of some selected MTN and AIRTEL base station at a distances approximately 5.00, 10.00, 15.00 and 20.00 metres to the north, south, west and east for each base station respectively. Their result shows that the average magnetic field level of the base station ranged between 0.09*u*t to 0.15*u*t. The mean electric field values for eye, brain and muscles ranged between 18.81 vm^{-1} to 31.55vm^{-1} and the specific absorption rate (SAR) ranged between 0.18 $Wkg^{-1}$to 1.03 $Wkg^{-1}$for the networks. In conclusion, the radio frequency emitted by the GSM base stations are within standards of the regulatory agencies and has no health risk to residence found within the study area.

Likewise Akin and Margaret (2014), studied location adequacy of Telecommunication Masts and residents livability in Osogbo, Nigeria. Their result shows that there were more MTN masts (45.7%) in the area. This is followed by Glo (20%), Airtel (17.14%). Multilinks and Starcommshas 8.57% each has 2.86% of the total masts in the area. The radiations coming from these mastsaccording to radiologist are electromagnetic waves, RF radiation and infrared. These radiations are capable to cause:

epilepsy, leukemia and different types of cancer. This implies that residents living very near these masts are at risk.

Danraka (2010) examined the distribution of Zain base stations in Kano metropolis using GIS technique. The pattern was related to the concept of central place theory. His result shows that, the impact of Zain base station is perceived with high response of people using the network and more business own phone rather than private users. 70 percent of the respondent indicates a regular network provide by Zain and only 30 percent experience a network failure and actions were taken from the network providers for proper and stable network. The study recommended the use of cellular radio communication system due to high cost associated to construction of base stations. Also different telecommunication network companies should share a single base station in a particular geographical area.

Lawrence1, Jackson, Akpee and Moka (2012) studied land use planning and Telecommunication facilities locations in Port Harcourt, Rivers state, Nigeria. Their result shows that a total of 251telecommunication facilities of the various service providers were considered. Each facility covers anapproximate area of 144 square meters, which reveals that a total of 3.6144 Hectares of land is occupied in PortHarcourt by these facilities which represent 7.7% of the total land of 470.00 square kilometers. The findings of the study hoped to bring the need for environmental agencies to guide andcontrol the location of these infrastructures through the strengthening of existing institutional capacity. Furthermore, it is recommended that a system to develop an integrated approach

in minimizing land encumbrances of these facilities and the related societal and economic impacts be put in place.

Mohammed (2011) assessed the spatial distribution of MTN base station masts and its implication on health through the use of GIS techniques in Kaduna North LGA, Nigeria. Her result shows that there are 40 MTN base station mast located and distributed in the study area, again most of the inhabitants living where the base stations are located were experiencing some sickness caused by the installation of the mast, and the common environmental problems discovered associated with the location of the mast includes emission of gas pollutants, noise from generators and accidental spill from handling diesel.

Ultimately, the geographic spread of telecommunication masts particularly GSM in urban Zaria has painted a very noticeable aerial picture of the city, yet worried of indiscriminate installation of the base stations and the claims that the masts radiate electromagnetic field (ETF) rays which are injurious to health, could be the result of poor regulation and failure to adapt standards such as those set by the WHO (Emma, 2012), while locating the Base Station.However, increase in population growth and the easier access of communication between individuals has necessitates the increased in number of the facilities across the city to the extent that residential areas have become signal transmitting stations. It is very common to find erected masts located within residential areas in the study area. Sadly, fumes from the generators in form of carbon monoxide which could be harmful to respiratory organs when inhaled in large quantity is being emitted into the environment and this may result to health implications or death. The noise causes pollution to the environment and this causes partial deafening of ear if it

persists. The vibration from the generators may cause headache, sleeplessness and risk of brain tumor for people living around the area (Emma, 2012).

Extensive studies on the spatial distribution of GSM Base station abound, but little is known whether GSM base stations in urban Zaria are distributed in harmony with the recommended standards in anticipation of the claimed effects. With the limited literature on location analysis of telecommunication masts using Remote Sensing and GIS technique the study is set to analyze the spatial distribution of GSM Base stations in urban Zaria area. This is the gap which the proposition of this study intends to fill.

Therefore, the study set to answer the following questions:

i. Where are the locations of the existing Base Stations in the study area?
ii. What is the locational distance of each facility from Residential areas (educational, hospital, and child care centers inclusive)?
iii. What is the spatial pattern of the existing GSM Base Stations in the study area?
iv. How vulnerable are the areas to electromagnetic radiation from GSM Base Stations in the study area;

1.3 AIM AND OBJECTIVES

The aim of this study is to analyze the spatial distribution of GSM base stations (masts) in Zaria Urban area, Kaduna State, Nigeria. To achieve the aim, the specific objectives are set to:

i. identify and map the location of GSM Base Stations in the study area;
ii. examine the locational distance of each base station from Residential areas (educational, hospital, and child care centers inclusive);
iii. examine the spatial pattern of the location of the base stations in the study area;

iv. map out areas vulnerable to the health hazards related to electromagnetic radiation from GSM Base Stations in the study area;

1.4 SCOPE OF THE STUDY

It is within the spatial scope of this research to analyze the locations of the various GSM base stations by means of GPS and Maps in Zaria Urban area, Kaduna State, Nigeria. The study employed identification, mapping, and analysis of the spatial distribution of all the existing telecommunication masts using Remote Sensing and GIS techniques and the locational criteria, such as those recommended standards set by WHO (2007) that masts should be located 10meters away from Residential area. It is however, within the temporal frame of this study to exhaust thirty (29) months to its completion, starting from December, 2014 to May, 2016.

1.5 JUSTIFICATION FOR THE STUDY

The world is fast becoming a Global village and a necessary tool for this is "communication" of which telecommunication is the key player. Cell phone therefore serves as a tool for social connection and managing social relationships among people. This necessitates the need for development of GSM facilities in order to provide the required services, which will at one point or another required planning approval to ensure order and efficiency, Banjo, Hu and Sundar(2008). Consequently, erection of telecommunication masts is practically indispensable for the case of high volume data transfer with guaranteed security and quality, Antonelli, (1991).

No wonder, Zaria urban area and Kaduna State at large have a high density of telecom masts per square kilometer within residential and educational areas regardless of

the dangers involved. These facilities result in emission of radioactive elements that impair the immune system and neurological functions in humans. Though telecommunication has created jobs and given a boost to investments in the study location, it is really a frown at the attitude of the average landlord who put money first in letting out a piece of land before thinking of the health hazard to the community and this callous activities of the telecom firms has proven to capitalize on people's naivety sending them to their early graves. It is pertinent however, to enforce the WHO (2007) regulations concerning the harmful practice so as to resolve the grey areas between the regulatory agencies on issues of operations, infrastructure, and consumer rights and protection. Providentially, this situation may be improved by using reliable data with the GIS. Therefore, there is need to unravel the situation in Urban Zaria of Kaduna State.

The study attempted to analyze the spatial pattern of the distribution of all the erected masts with corresponding land used types of the study area, also analyze the locational distance of each facility from Residential areas (educational, hospital, and child care centers inclusive) base on the WHO (2007) regulations. Thus, filling the gap glossed over by other Researchers. However, inference was drawn and suggestions will then be made to aid decision-making processes and assist Policy formulators in the selection of evidence-based priority interventions where possible; that would stipulate requirements for effective planning. It could also extend the frontiers of knowledge and be used for further researches.

CHAPTER TWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

The chapter presents literature review aimed at facilitating the understanding of the origin and meaning of Telecommunication, Global system for mobile communication (GSM), Base stations (Land Mast) digital Mapping, Google earth and Global Positioning System (GPS) and the debate surrounding the topic within the academic literature. The chapter reviews the definition, concept, evolution, characteristics of GSM base stations and World Health Organization (WHO).

2.2 CONCEPT OF GSM

The concept of cellular service is the use of low power transmitters where frequencies can be re-used within a geographical area. The idea of the first cellular network was brainstorm in 1947; it was intended to be used for military purposes as a way of supplying troops with more advanced forms of communications from1947 till about 1979, several forms of broadcasting technology emerged. The United States began to develop the advanced mobile phone services (AMPS) network, while European countries were developing their own forms of communications (Umar, 2009).

2.3 ORIGIN OF TELEPHONE

Telecommunication may be defined as traditionally referring to the plain old telephone service (POTS), namely the transmission of voice communications using

analogue technologies. Widely defined, it refers to "all two way communication over distance" (Alber, 1991, pp31). It is also defined as the "transmission of signals over distance" (International encyclopedia of communications, 1989, vol. 4 pp 201). Usually the term "telecommunications" refers to the electronic transmission of voice, data graphics and visual information.

Dambroyer (1964), Tornquist (1967) and Johnson (1968) all discussed the commercial, industrial and economic values of the telephone.

Dambroyer (1964) reported that it is a means of communication, the telephone can be used to solve such problems as high cost of coverage and when applied as sales tools in marketing it can help reduce costs, expand market and increases profit. Johnson (1968) said man utilized the telephone for describing contact patterns and spatial interactions. He divided it as follows:

1. Private information from one person to another plays an important role when innovations are diffused there is need to know the contact fields of individuals.
2. Although several investigations have reported social activities, telephones have not been hitherto utilized, despite the fact that they can reveals so much.
3. Telephone operators not only connect callers from far and near, it keeps record of the origin and destinations of calls. Time studies in urban areas show that apart from poor households, business leaders and high ranking executives spend a great deal of their working on personal attendance for problems solving and keeping an eye on the cause of events, such time could be by the telephone.

Telephone as a major element in the telecommunications system has its own geography consisting of locational elements (nodes, networks, transmission media and information flows) as it plays an important role as a transforming agent (Alber, 1970).

The telecommunications as a material entity and spatial artifact and as a major telecommunications transmission medium, the telephone constitutes the traditional medium, being in universal use in both households and businesses. Alber (1970) has traced its origin from the time of Morse who introduced the telegraph in 1937 through the invention of the telephone by Bell in 1876 to the present.

2.4 BRIEF HISTORY OF NIGERIA'S TELECOMMUNICATION

The journey to success in Nigeria's telecommunication milieu has been long and tortuous. Telecommunication facilities in Nigeria were first established in 1886 by the colonial administration. At independence in 1960, with a population of roughly 40 million people, the country only had about 18,724 phone lines for use. This translated to a Tele-density of about 0.5 telephone lines per 1,000 people. The telephone network consisted of 121 exchanges of which 116 were of the manual (magneto) type and only 5 were automatic.

Between 1960 and 1985, the telecommunication sector consisted of the Department of Posts and Telecommunications (P&T) in charge of the internal network and a limited liability company, the Nigerian External Telecommunication (NET) Limited, responsible for the external telecommunications services. NET provided the gateway to the outside world. The installed switching capacity at the end of 1985 was about 200,000 lines as against the planned target of about 460,000. All the exchanges were analogue. Telephone penetration remained poor equaling telephone line to 440

inhabitants, well below the target of 1 telephone line to 100 inhabitants recommended by ITU for developing countries. The quality of service was largely unsatisfactory. The telephone system was unreliable, congested, expensive and customer unfriendly.

Arising from the foregoing, in January 1985, the erstwhile Posts and Telecommunications Department was split into Postal and Telecommunications Divisions. The latter was merged with NET to form Nigerian Telecommunications Limited (NITEL), a limited liability company. The main objective of establishing NITEL was to harmonies the planning and co-ordination of the internal and external telecommunications services, rationalize investments in telecommunications development and provide accessible, efficient and affordable services.

Almost 43 years down the line, the Nigerian Telecommunication Plc, NITEL had roughly half a million lines available to over 100 million Nigerians. NITEL the only national carrier had a monopoly on the sector and was synonymous with epileptic services and bad management. On assumption of office on May 29, 1999 the President Olusegun Obasanjo administration swung to gear to make a reality the complete deregulation of the telecom sector, most especially the much touted granting of licenses to GSM service providers and setting in motion the privatization of NITEL. This proactive approach by the government to the telecom sector has made it possible for over 2.5 million Nigerians to clutch GSM phones today.

2.5 GSM Technology

2G is short for second- generation wireless telephony system. Second generation 2G cellular telecoms networks were commercially launched on the GSM standard in 1991. Three primary benefits of 2G systems were significantly more efficient on the

spectrum allowing for far greater mobile phone penetration levels and 2G introduced data services for mobile phone penetration

Levels and 2G introduced data services for mobile starting with SMS text messages. After 2G was launched, the previous mobile telephone systems wee retrospectively dubbed 1G. while radio signals on 1G networks are analog, and on 2G networks are digital, both systems use digital signaling to connect the radio towards (which listen to the handsets) to the rest of the telephone system. 3G is the third generation of mobile phone standards and technology. 3G networks enable network operators to offer users a wider range of more advanced services while achieving greater network capacity through improved spectral efficiency. Services include wide-area wireless voice telephony video calls, and broadband wireless data, all in a mobile environment the 3G system uses higher frequencies than GSM, which do not travel so well, so it will need three times as many antennas in urban areas and twice as many in the country, Umar (2009).

2.5.1 GSM Network Structure

A GSM network is composed of several functional entities, whose functions and interfaces are specified. The GSM network can be divided into three broad parts:

i. The mobile station is carried by the subscriber
ii. The base station subsystem controls the radio link with mobile station
iii. The network subsystem which consists of the mobile services switching enter (MSC) as its main part, performs the switching of calls between the mobile phone users and then between mobile phone and fixed network users.

2.5.2 The Base Station Subsystem (BSS)

BSS is the section of a GSM network which is responsible for handling traffic and signaling between a mobile phone and the network switching subsystem. The BSS carries out transcending of channels, allocation of radio channels to mobile phones, quality management of transmission and reception over the Air interface and many other tasks relative to the radio network. BSS consist of Base transceivers station (BTS) and the base station controller (BSC).

2.5.3 The Base Transceiver Station (BTS)

BTS contains the equipment for transmitting and receiving of radio signals (transceivers) antennas and equipment for encrypting and decrypting communications with the base station controller (BSC). A group of BTS are controlled by a BSC.

2.5.4 GSM Telecommunication Mast Description

Masts and towers are typically tall structures designed to support antennas (aerials) for telecommunications and broadcasting, they are among the tallest man-made structure. Typical telecommunication mast tower consists of a body structure of steel beams and materials with a concrete base of an approximate height of between 25 and 55meters. Antennae, transmitters and receivers are mounted on the body of the structure. These antennae receive high frequency radio waves from cell phones. The ranges of these antennas vary from distances as short as 1.5 to 2.4km to distances as long as 48 to 56km. A power source is provided with other accessories, all fenced either by block wall or steel poles and wire depending on the service providers. The area covered by each mast location is approximately 144m2 (12m x 12m).

2.5.5 Types of Masts

Telecommunication towers may be of several types and range in height from 30m to 300m. The general form of telecommunications tower is:

i. Monopoles that consist of tapered steel tubes that fit over each other to form a stable
ii. Guyed towers that are stabilized by tethered wires
iii. Self- supporting towers that are free standing lattice structures.

2.5.6 Cell

The coverage area of one transmitter / receiver bas station is referred to as a cell. Sites for the location of GSM base station are at the intersection of three cells. The shape of cells is hexagonal.

2.5.6.1 Types of cells

There are three types of cells: macro-cells, micro-cells and pico-cells.

i. A macro-cell provides the main coverage in a mobile network, the antennas for macro-cells are mounted on ground based masts, rooftops and other existing structures and are positioned at a height that is not obstructed by surrounding buildings and terrain. The cell ranges from 2-20 km used typically in low traffic areas mostly rural areas and road coverage.
ii. The micro-cell provides infill radio coverage and additional capacity where there are high numbers of uses within macro-cells. Coverage ranges from 0.5 - 2km and it is suitable for high traffic areas mostly used in towns and suburbs.

iii. A pico-cell provides more localized coverage than a micro-cell. They are normally found inside buildings where coverage is poor or where there are a high number of users such as airport, train stations and shopping centers

2.6 EMPIRICAL STUDIES AND THEIR FINDINGS OF GSM BASE STATIONS

Although many studies on GSM Base Stations have made an appreciable effort, a good example is found in the work of Mladen-Koprivica*et al*. (2013), who examined the statistical analysis of electromagnetic radiation measurements in the vicinity of GSM/UMTS base stations antenna masts in South Africa by conducting extensive electromagnetic field strength measurements. Their result show that the total electric field strength obtained in the vicinity of base station antenna mast in no case exceeded 10 V m^{-1}, which is quite below the International Commission on Non-Ionizing Radiation Protection reference levels. Also At horizontal distances >50 m from the mast bottom, the median and maximum values were <1 and 2 V m^{-1}, respectively.

In Nigeria, Iortile and Agba (2014), examined the radiofrequency radiation distribution around mobile base stations in Makurdi, Benue State, Nigeria using electromagnetic field tester (EMF 827, Lutron) to ascertain the radiofrequency field levels of some selected MTN and AIRTEL base station at a distances approximately 5.00, 10.00, 15.00 and 20.00 metres to the north, south, west and east for each base station respectively. Their result shows that the average magnetic field level of the base station ranged between 0.09*u*t to 0.15*u*t. The mean electric field values for eye, brain and muscles ranged between 18.81 vm^{-1} to 31.55vm^{-1} and the specific absorption rate (SAR) ranged between 0.18 $Wkg^{-}$to 1.03 $Wkg^{-1}$for the networks. In conclusion, the radio

frequency emitted by the GSM base stations are within standards of the regulatory agencies and has no health risk to residence found within the study area.

Likewise Akin and Margaret (2014), studied location adequacy of Telecommunication Masts and residents livability in Osogbo, Nigeria. Their result shows that there were more MTN masts (45.7%) in the area. This is followed by Glo (20%), Airtel (17.14%). Multilinks and Starcommshas 8.57% each has 2.86% of the total masts in the area. The radiations coming from these mastsaccording to radiologist are electromagnetic waves, RF radiation and infrared. These radiations are capable to cause: epilepsy, leukemia and different types of cancer. This implies that residents living very near these masts are at risk.

Danraka (2010) examined the distribution of Zain base stations in Kano metropolis using GIS technique. The pattern was related to the concept of central place theory. His result shows that, the impact of Zain base station is perceived with high response of people using the network and more business own phone rather than private users. 70 percent of the respondent indicates a regular network provide by Zain and only 30 percent experience a network failure and actions were taken from the network providers for proper and stable network. The study recommended the use of cellular radio communication system due to high cost associated to construction of base stations. Also different telecommunication network companies should share a single base station in a particular geographical area.

Lawrence, Jackson, Akpee and Moka (2012) studied land use planning and Telecommunication facilities locations in Port Harcourt, Rivers state, Nigeria. Their result shows that a total of 251telecommunication facilities of the various service

providers were considered. Each facility covers an approximate area of 144 square meters, which reveals that a total of 3.6144 Hectares of land is occupied in Port Harcourt by these facilities which represent 7.7% of the total land of 470.00 square kilometers. The findings of the study hoped to bring the need for environmental agencies to guide and control the location of these infrastructures through the strengthening of existing institutional capacity. Furthermore, it is recommended that a system to develop an integrated approach in minimizing land encumbrances of these facilities and the related societal and economic impacts be put in place.

Alenoghena, Emagbetere and Aibinu (2014), developed a comprehensive city structure data base system (CSDS) for the placement of base stations in Minna, Niger state of Nigeria. The researchers developed an effective data collection process for the acquisition and collation of spatial data of the city. The result shows that the created database, radio planners could now be able to access and get hold of relevant map information of the city easily also it serves as a tool required by an intelligent decision making process of base station placement in the city.

Mohammed (2011) assessed the spatial distribution of MTN base station masts and its implication on health through the use of GIS techniques in Kaduna North LGA, Nigeria. His result shows that there are 40 MTN base station mast located and distributed in the study area, again most of the inhabitants living where the base stations are located were experiencing some sickness caused by the installation of the mast, and the common environmental problems discovered associated with the location of the mast includes emission of gas pollutants, noise from generators and accidental spill from handling diesel.

Ike, Adoghe, Abdulkareem (2014) studied the analysis of Telecom Base Stations Powered by Solar Energy in Benin City, Edo State, Nigeria. Their result shows that In order to perform an economic evaluation of grid-connected and stand-alone solar systems for use in cellular base stations, we use PVSYST 6.0.7 software. The specification of solar module used in the experiment is as follows: Mono-crystalline PV cells, Standard Module Design, Flat Roof Mounting, and Ventilated Enclosure. The solar path horizon at Benin City gives the results of the simulations for grid-connected and stand-alone solar power systems for use in base-stations.

It could be seeing that, many studies as cited before now have contributed correspondingly on the subject matter in Nigeria. Yet it is still not known whether GSM base stations in Zaria urban area were distributed harmonized with the recommended standards.

2.7 Impact of Base Stations on Public Health

The wide use of a relatively new technology raises the question of whether there are any implications for human health. Although, there are conflicting reports relating to the probable health effect of GSM mast. The World Health Organization (WHO) defines health as the state of complete physical, mental and social wellbeing, not merely absence of disease or infirmity. Thus it is essential that the probable impact of base stations on the health of residents within their immediate vicinity in particular be assessed. The assessment of any health impact resulting from exposure to radioactive frequency (RF) fields depends on the results of a well planned and executed scientific research (Umar, 2009).

This is germane because any effect of exposure to RF at the levels encountered from telecommunications is likely to be subtle.

2.8 Impact of Base Station on Aesthetics Intrusion

There are many ways which both environment and aesthetic is affected by location of mast. Some of the identified environmental impact associated with GSM mast include but not limited to:

1. Emission of pollutants gases from machineries and power generators
2. Accidental spill from machineries and power generators
3. Spent paints during routine servicing and maintenance checks
4. Falls and injuries arising from maintenance of mast

- Accidental collapse of mast
- Fire and explosion
- Obstruction to flight navigation etc.

According to Kaduna State Urban Planning and Development Authority (2002), the criteria for approval of mast location are:

i. **Evidence of site acquisition**; this involves identifying a suitable site for the proposed mast. Then entering a negotiation for the site for either outright purchase or lease agreement then the lease agreement or sales agreement and all legal document pertaining to the site is attached and formed part of the document to be submitted to the authority for application for permit.

ii. **EIA report**; While telecommunication network can bring substantial benefits to business and social users, such development if insensitively cited can be enormously out of tune from their environment and natural landscape.

The purpose any EIA is to allay the fear that some people wellbeing may be adversely affected by the location of mobile phone stations. These ranges from mobile phone users, those who work and live around base stations. The impact reports will be examining mainly three areas namely: health, Aesthetics (Visual) and public Sensibilities.

iii. **Aviation clearance**; Mobile phones and their base stations transmit and receive signals using electromagnetic waves. All electromagnetic radiation or wave consists of oscillating electric and magnetic field. Frequencies between 100 KH_Z and 300 KH_Z comprises radio frequency (RF) band widely used for telecommunication including radio and television.

iv. **Two years audit report**; Two (2) years audited report of any GSM operator must be submitted with all relevant documents.

v. **Site inspection**; Development control department staff must inspect the site of all mast to ensure that standard are strictly adhered to all relevant permits and clearance has been obtained.

2.9 NIGERIA COMMUNICATION COMMISSION (NCC)

Primarily this act is to create and provide a regulatory framework for the Nigerian communication industry and all matters related thereto and for that purpose and without detracting from the generality of the foregoing. The objectives are but not limited to:

i. Promote the implementation of the national communication or telecommunication policy as may from time to time be modified and amended.

ii. Establish a regulatory framework for the Nigerian communication industry and for this purpose create an effective, impartial and independent regulatory authority

iii. Promoting the provision of modem, universal, efficient, reliable, affordable and easy accessible communication services and the widest range thereof throughout Nigeria.

NCC specified the required approval for network installation as licensee, this may require approval of the State government, Local Government or other relevant authority for installation, placing, laying or maintenance of any network facilities on, though, under or across any land and it shall be the responsibility of such licensees to obtain such approvals.

A licensee shall, in installing its network facilities, take all reasonable steps to ensure that the curse as little determent and inconvenience, and does as little damage, as is practicable. If a licensee engages in an activity under this part in relation to any land, the provider shall take all reasonable steps to restore the land to a condition that is similar to its condition before the activity began.

All licensees shall, in connection with the installation of their respective network facilities, take all reasonable steps to;

a. Act in accordance with good engineering practice.

b. Protect the safety of persons and properties.

c. Ensure that the activity interfere as little as practicable with

i. The operation of public utility.

ii. Public roads and paths.

iii. The movement of traffic.

iv. The use of land.

2.9.1 Standards for Base Station by Nigeria Communication Commission in collaboration with National Environmental Standard Regulatory Enforcement Agency (NESREA)

The maximum height that may be approved for telecommunication tower in Nigeria is 150m. A tower more than 50m in height may be approved by Nigeria Communication Commission (NCC) if the commission is satisfied that the increase height of tower:-

1. Will not be detrimental to the public health, safety or general welfare.
2. Will not have a substantial negative effect upon neighborhood.
3. Is in conformity with the intent and purpose of the planning of the area and the general plan of the community.
4. Will not impair the obligation to comply with any other applicable laws or regulations.

2.9.2 Space Requirement

a) One parking/ loading space shall be required to serve a telecommunication.

b) Any tower site lying 50m or less from a paved road shall be paved.

c) If the site is more than 50m from a paved road, hard surfacing of parking spaces and drive ways shall not be required for those portions of the site lying more than 50m from any paved road.

d) Stealth and camouflage design of towers and antennas are e encouraged to reduce the visual impact of the structure.

2.9.3 Structure

All telecommunications towers as well as guys and guy anchored shall be Located within the buildable area of the property. Telecommunications towers in excess of 150m. in height shall be set back a minimum of 50m from the right of way of all controlled access, federal and state road ways designated as freeways, towers shall be set the greater distance of;

a. 10m from any residential or used property
b. 25% of the height of the tower.
c. The distance specified as a potential hazard area by the designer or the structure.

2.9.4 Residential Areas

Telecommunications towers above 25m in height are as a general rule not permitted within residential areas where they are by exception allowed, they must be placed a minimum ratio of 3:1 distance to height to the nearest residential property.

2.9.5 Non-Residential Areas

Towers or masts in excess of 25m in height are permitted in the non- residential districts.

2.9.6 Tower to Tower Spacing

Tower in excess of 55m in height must be located at a minimum of 1km from any other existing tower in excess of 55m in height.

2.9.7 Nearness to Power-Lines

No tower or masts shall be installed in close proximity to high voltage electrical power transmission lines. The closest distance that equivalent of 120% of the height of the mast**.**

2.9.8 Alternative Mounting Structures

a) Alternative mounting structures 30m or less in height shall be permitted in residential areas.

b) Alternative mounting structures in excess of 30m in height are permitted in non-residential areas.

2.9.9 Antenna Mounts

Antenna mounts must have structural integrity so as to guarantee public safety.

a) Whip and panel antenna mounts

i. Individual telecommunications masts are allowed on existing low tension electrical utility poles, light standards and telecommunication towers in excess of 12m in height, provided that the total length of any antenna does not exceed 15% of the height of the existing structure.

ii. Telecommunication antennas are not permitted on existing high tension transmission towers.

iii. Panel and whip antennas are permitted on billboard structures,

b) Dish antenna mounting standards.

i. Ground mounted dish antennas in excess of 1.5m height shall be screened from road ways and adjacent property by a minimum 1.8m height screening fence.

ii. Building and roof mounted dish antennas of lm or less in diameter, are permitted in all areas.

iii. Building and roof mounted dish antennas in excels of lm in diameter may be permitted after certification from the relevant professionals.

2.9.10 Terrain

In making designs for masts and tower structures, the terrain is classified into three broad geographical zones within the Nigerian context.

a) Exposed smooth terrain with virtually no obstruction and in which the height of any obstruction is less than 1.5m, this category includes open sea coasts, lakeshore and flat treeless plains with little vegetation other than short grass.

b) Open terrain with widely spaced obstruction(100m apart) having height and plain dimension generally between 1.5m and 10m, this category includes large airfield, open parklands, or farmlands and underdeveloped outskirts of towns and suburbs with few trees.

c) Terrain having numerous closely spaced obstructions generally they seize of domestic and high rise buildings. This includes wooded areas and suburbs, town and industrial areas fully or substantially developed.

2.9.11 Airports

i. Structures above 30m in height may only be installed with a clearance certificate issued by the Nigerian Airspace Management Authority (NAMA).

ii. No masts (irrespective of the height) may be installed within 15km of any airport without prior approval and a permit from the NAMA.

iii. The requirement also applies to such structures within the proximity of helicopter pads and their approaches.

2.9.12 Co-Location

Masts shall be designed and built to accommodate a minimum of three service providers of the same structure (NCC, 1996).

2.10 World Health Organization Criteria

The World Health Organization (WHO) is a specialized agency of the United Nations (UN) that is concerned with international public health. It was established on 7 April 1948, headquartered in Geneva, Switzerland. The WHO is a member of the United Nations Development Group. Its predecessor, the Health Organization, was an agency of the League of Nations. The constitution of the World Health Organization had been signed by 61 countries on 22 July 1946, with the first meeting of the World Health Assembly finishing on 24 July 1948. It incorporated the Office International Hygiene Public and the League of Nations Health Organization.

According to World Health Organization (WHO) (2007) regulations for locating a GSM Base Station in Nigeria: that Mast should be erected 10m from the perimeter wall (fence) of residential, where there is no perimeter wall (fence), a Based Station must be at a minimum of twelve (12) meters and above from the wall of residential, educational, hospital, child care centers and nursing homes. The organization also ascertained that Mast should not be erected on Agricultural lands because of its effect on the crops. These criteria should be met for a GSM Base Stations to assume spatially sound located. Alternatively, a key to the sensitive locating, sitting and design of telecommunications

equipment is an understanding of the area landscape Diaz-Bordenave(1977). The best opportunities for the sitting of masts are: Railway land, Recycling Areas, Waste water treatment works, Industrial/General Business Areas, and so on. (Wang, 2007).

2.11 QUICKBIRD SATELLITE IMAGERY

Quick Bird was a high-resolution commercial earth observation satellite, owned by Digital Globe launched in 2001 and decayed in 2015 was the first satellite in a constellation of three scheduled to be in orbit by 2008. Quick Bird used Ball Aerospace's Global Imaging System 2000 (BGIS 2000). The satellite collected panchromatic (black and white) imagery at 61 centimeter resolution and multispectral imagery at 2.44- (at 450 km) to 1.63-meter (at 300km) resolution, as orbit altitude is lowered during the end of mission life. At this resolution, detail such as buildings and other infrastructure are easily visible. However, this resolution is insufficient for working with smaller objects such as a license plate on a car. The imagery can be imported into remote sensing image processing software, as well as into GIS packages for analysis. The imagery can also be used as a backdrop for mapping applications, such as Google Earth and Google Maps.

2.12 CONCEPT OF GLOBAL POSITIONING SYSTEM (GPS)

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil and commercial users around the world. It is maintained by the United States government and is freely accessible to anyone with a GPS receiver. (George, Daniel, Micheal, Etiene and Pascal, 2005).

The GPS project was developed in 1973 to overcome the limitations of previous navigation systems, integrating ideas from several predecessors, including a number of classified engineering design studies from the 1960s. GPS was created and realized by the United State Department of Defense (D.O.D) and was originally run with 24 satellites. It became fully operational in 1994. Roger L. Easton is generally credited as its inventor.

Advances in technology and new demands on the existing system have now led to efforts to modernize the GPS system and implement the next generation of GPS III satellites and Next Generation Operational Control System (OCX). Announcements from the Vice President and the White House in 1998 initiated these changes. In 2000, U.S. Congress authorized the modernization effort, referred to as GPS III.

In addition to GPS, other systems are in use or under development. The Russian Global Navigation Satellite System (GLONASS) was developed contemporaneously with GPS, but suffered from incomplete coverage of the globe until the mid-2000s. There are also the planned European Union Galileo Positioning System, Chinese Compass Navigation System and Indian Regional Navigational Satellite System.

2.12.1 Evolution of GPS

The design of GPS is based partly on similar ground-based radio-navigation systems, such as LORAN and the Decca Navigator developed in the early 1940s, and used during World War II. In 1956, the German-American physicist FriedwardtWinterberg proposed a test of general relatively (for time slowing in a strong gravitational field) using accurate atomic clocks placed in orbit inside artificial satellites. (To achieve accuracy requirements, GPS uses principles of general relativity to correct

the satellites' atomic clocks. Additional inspiration for GPS came when the Soviet Union launched the first man-made satellite, Spuntnik in 1957. Two American physicists, William Guier and George Weiffenbach, at Johns Hopkins's Applied Physics Library (APL), decided on their own to monitor Sputnik's radio transmissions. Within hours they realized that, because of the Doppler Effect, they could pinpoint where the satellite was along its orbit from the Doppler shift. The Director of the APL gave them access to their UNIVAC to do the heavy calculations required. The following spring, Frank McClure, the deputy director of the APL, asked Guier and Weiffenbach to investigate the inverse problem – pinpointing the user's location given that of the satellite. (The Navy was developing the submarine-launched Polaris missile, which required them to know the submarine's location.) This led them and APL to develop the Transit system. In 1959, ARPA (renamed DARPA in 1972) also played a role in Transit. (John, 2009).

The first satellite navigation system, Transit, used by the United States Navy, was first successfully tested in 1960. It used a constellation of five satellites and could provide a navigational fix approximately once per hour. In 1967, the U.S. Navy developed the Timationsatellite that proved the ability to place accurate clocks in space, a technology required by GPS. In the 1970s, the ground-based Omega Navigation System, based on phase comparison of signal transmission from pairs of stations, became the first worldwide radio navigation system. Limitations of these systems drove the need for a more universal navigation solution with greater accuracy. (George, Daniel, Micheal, Etiene and Pascal, 2005).

While there were wide needs for accurate navigation in military and civilian sectors, almost none of those were seen as justification for the billions of dollars it would

cost in research, development, deployment, and operation for a constellation of navigation satellites. During the Cold War Arms race, the nuclear threat to the existence of the United States was the one need that did justify this cost in the view of the United States Congress. This deterrent effect is why GPS was funded. It is also the reason for the ultra-secrecy at that time. The nuclear tried consisted of the United States Navy's Submarine-Launched Ballistic Missiles (SLBMs) along with United States Air force (USAF) strategic bombers and Intercontinental Ballistic Missiles (ICBMs). Considered vital to the nuclear deterrence posture, accurate determination of the SLBM launch position was a force multiplier. (George, Daniel, Micheal, Etiene and Pascal, 2005).

Precise navigation would enable United States submarine get an accurate fix of their positions prior to launching their SLBMs. The USAF, with two-thirds of the nuclear triad, also had requirements for a more accurate and reliable navigation system. The Navy and Air Force were developing their own technologies in parallel to solve what was essentially the same problem. To increase the survivability of ICBMs, there was a proposal to use mobile launch platforms (such as Russian SS-24 and SS-25) and so the need to fix the launch position had similarity to the SLBM situation. (George, Daniel, Micheal, Etiene and Pascal, 2005).

In 1960, the Air Force proposed a radio-navigation system called MOSAIC (Mobile System for Accurate ICBM Control) that was essentially 3-D. A follow-on study called Project 57 was worked in 1963 and it was "in this study that the GPS concept was born." That same year the concept was pursued as Project 621B, which had "many of the attributes that you now see in GPS" and promised increased accuracy for Air Force

bombers as well as ICBMs. Updates from the Navy Transit system were too slow for the high speeds of Air Force operation.

The Navy Research Laboratory continued advancements with their Timation (Time Navigation) satellites, first launched in 1967, and with the third one in 1974 carrying the first atomic clock into orbit.(George, Daniel, Micheal, Etiene and Pascal, 2005).

Another important predecessor to GPS came from a different branch of the United States military. In 1964, the United States Army orbited its first Sequential Collation of Range (SECOR) satellite used for geodetic surveying. The SECOR system included three ground-based transmitters from known locations that would send signals to the satellite transponder in orbit. A fourth ground-based station at an undetermined position could then use those signals to fix its location precisely. The last SECOR satellite was launched in 1969. Decades later during the early years of GPS, civilian surveying became one of the first fields to make use of the new technology, because they could reap benefits of signals from the less-than-complete GPS constellation years before it was declared operational. GPS can be thought of as an evolution of the SECOR system where the ground-based transmitters have been migrated into orbit. (George, Daniel, Micheal, Etiene and Pascal, 2005).

2.12.2 Basic Concept of GPS

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include

i. the time the message was transmitted
ii. satellite position at time of message transmission

The receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite using the speed of light. Each of these distances and satellites' locations define a sphere. The receiver is on the surface of each of these spheres when the distances and the satellites' locations are correct. These distances and satellites' locations are used to compute the location of the receiver using the navigation equation. This location is then displayed, perhaps with a moving map display or latitude and longitude; elevation information may be included. Many GPS units show derived information such as direction and speed, calculated from position changes, Agnewand Larson (2007).

In typical GPS operation, four or more satellites must be visible to obtain an accurate result. Four sphere surfaces typically do not intersect. Because of this we can say with confidence that when we solve the navigation equations to find an intersection, this solution gives us the position of the receiver along with accurate time thereby eliminating the need for a very large, expensive, and power hungry clock. The very accurately computed time is used only for display or not at all in many GPS applications, which use only the location. A number of applications for GPS do make use of this cheap and highly accurate timing. These include time transfer traffic signal timing, and synchronization of cell phone base stations Agnew and Larson(2007).

Although four satellites are required for normal operation, fewer apply in special cases. If one variable is already known, a receiver can determine its position using only three satellites. For example, a ship or aircraft may have known elevation. Some GPS receivers may use additional clues or assumptions such as reusing the last known altitude, dead reckoning inertial navigation or including information from the vehicle computer, to

give a (possibly degraded) position when fewer than four satellites are visible Agnew and Larson(2007).

2.12.3 Structure

The current GPS used worldwide consists of three major segments. These are the space segment (SS), a control segment (CS), and a user segment (US). The U.S. Air Force develops, maintains, and operates the space and control segments. GPS satellites broadcast signals from space, and each GPS receiver uses these signals to calculate its three-dimensional location (latitude, longitude, and altitude) and the current time. (George, Daniel, Micheal, Etiene and Pascal, 2005).

The space segment is composed of 24 to 32 satellites in medium earth orbit and also includes the payload adapters to the boosters required to launch them into orbit. The control segment is composed of a master control station, an alternate master control station, and a host of dedicated and shared ground antennas and monitor stations. The user segment is composed of hundreds of thousands of U.S. and allied military users of the secure GPS Precise Positioning Service and tens of millions of civil, commercial, and scientific users of the Standard Positioning Service.

2.12.4 User Segment

GPS receivers come in a variety of formats, from devices integrated into cars, phones, and watches, to dedicated devices such as Garmin GPS. Secure GPS Precise Positioning Service, and tens of millions of civil, commercial and scientific users of the Standard Positioning Service. In general, GPS receivers are composed of an antenna, tuned to the frequencies transmitted by the satellites, receiver-processors, and a highly stable clock (often a crystal oscillator). They may also include a display for providing

location and speed information to the user. A receiver is often described by its number of channels: this signifies how many satellites it can monitor simultaneously. Originally limited to four or five, this has progressively increased over the years so that, as of 2007, receivers typically have between 12 and 20 channels.

2.12.5 Applications

While originally a military project, GPS is considered a *dual-use* technology, meaning it has significant military and civilian applications. GPS has become a widely deployed and useful tool for commerce, scientific uses, tracking, and surveillance. GPS's accurate time facilitates everyday activities such as banking, mobile phone operations, and even the control of power grids by allowing well synchronized hand-off switching.

2.12.6 Restrictions on Civilian Use

The U.S. Government controls the export of some civilian receivers. All GPS receivers capable of functioning above 18 kilometers (11 mi) altitude and 515 meters per second (1,001 kn) or designed, modified for use with unmanned air vehicles like e.g. ballistic or cruise missile systems are classified as munitions (weapons) for which State Department export licenses are required. This rule applies even to otherwise purely civilian units that only receive the L1 frequency and the C/A (Coarse/Acquisition) code and cannot correct for Selective Availability (SA), etc.

Disabling operation above these limits exempts the receiver from classification as munitions. Vendor interpretations differ. The rule refers to operation at both the target altitude and speed, but some receivers stop operating even when stationary. This has caused problems with some amateur radio balloon launches that regularly reach 30 kilometers (19 mi). These limits only apply to units exported from (or which have

components exported from) the USA – there is a growing trade in various components, including G.P.S units, supplied by other countries, which are expressly sold as ITAR-free.

2.13Roles of Google Earth

Google Earth is a virtual globe and geographical information program that was originally called Earth Viewer 3D. This technology was developed by Keyhole Inc, a Central Intelligence Agency (CIA) and acquired by Google in 2004. Earth surfaces are mapped by the superimposition of images obtained from satellite images, aerial photograph and GIS 3D globe.

The product, re-released as Google Earth in 2005, is currently available for use on personal computer running Windows 2000 and above, Mac OS X 10.3.9 and above, Linux Kernel: 2.6 or later (released on June 12, 2006), and Free BSD. Google Earth is also available as browser plug-in which was released on May 28, 2008. It was also made available for mobile viewers on the iPhone OS on October 28, 2008, as a free download from the App store, and is available to Android users as a free app in the Google play store. In addition to releasing an updated Keyhole based client, Google also added the imagery from the Earth database to their web-based mapping software, Google Maps. The release of Google Earth in June 2005 to the public caused a more than tenfold increase in media coverage on virtual globes between 2004 and 2005, driving public interest in geospatial technologies and applications. As of October 2011 Google Earth has been downloaded more than a billion times. (Google Inc.).

For other parts of the surface of the Earth 3D images of terrain and buildings are available. Google Earth uses Digital Elevation Model (DEM) data collected by NASA's

Shuttle Radar Topography Mission (SRTM). This means one can view the whole earth in three dimensions. Since November 2006, the 3D views of many mountains, including Mount Everest, have been improved by the use of supplementary DEM data to fill the gaps in SRTM coverage (ibid).

Many people use the applications to add their own data, making them available through various sources, such as the Bulletin Board System (BBS) or blogs. Google Earth is able to show all kinds of images overlaid on the surface of the earth and is also a Web Map Service client. Google Earth supports managing three-dimensional Geospatial data through Keyhole Markup Language (KML).

Google Earth is simply based on 3D maps, with the capability to show 3D buildings and structures (such as bridges), through model program software. In prior versions of Google Earth (before Version 4), 3D buildings were limited to a few cities, and had poorer rendering with no textures. Many buildings and structures from around the world now have detailed 3D structures; including (but not limited to) those in the United States, Canada, Australia, Ireland, India, Japan, United Kingdom, Germany, Pakistan and the cities, Amsterdam and Alexandria. In August 2007, Hamburg became the first city entirely shown in 3D, including textures such as façades. The 'Westport3D' model was created by 3D imaging firm AM3TD using long-distance laser scanning technology and digital photography and is the first such model of an Irish town to be created. As it was developed initially to aid Local Government in carrying out their town planning functions it includes the highest resolution photo-realistic textures to be found anywhere in Google Earth. Three-dimensional renderings are available for certain buildings and structures around the world via Google's 3D Warehouse and other

websites. In June 2012, Google announced that it will start to replace user submitted 3D buildings with auto-generated 3D mesh buildings starting with major cities. Although there are many cities on Google Earth that are fully or partially 3D, more are available in the Earth Gallery. The Earth Gallery is a library of modifications of Google Earth people have made. In the library there are more than just modifications for 3D buildings there are models of earth quakes using the Google Earth model, 3D forests, and much more (Google Inc.).

In 2009, Google added a feature that enable users monitor traffic speeds at loops located every 200 yards. In version 4.3 released on April 15, 2008, Google Street View was fully integrated into the program enabling the program to provide an on the street level view in many locations.

On January 31, 2010, the entirety of Google Earth's ocean floor imagery was updated to new images by SIO, NOAA, US NAVY, NGA, and GEBCO. The new images have caused smaller islands, such as some atolls in the Maladies, to be rendered invisible despite their shores being completely outlined.

2.13.1 Uses of Google Earth

Google Earth has variety of uses among which are:

i. Viewing areas subjected to widespread disasters. This was how the January 12, 2010 Haiti Earthquake images of Haiti were made available on January 17.

ii. Application by teachers to improve on teaching strategies which are adopting Google Earth in the classroom for lesson planning, such as teaching students geographical themes (location, culture, characteristics, human interaction, and movement) to creating maps.

iii. Exploring and placing bookmarks on the Moon, Mars and other cosmic territories.

iv. Guiding directions, street names, objects, cities and establishments.

v. Providing catalogue of information pertaining to the user's location. Example, spotting gas stations, restaurants, museums and other public establishments in their vicinity.

vi. Google Earth can also function as a hub of knowledge, pertaining the user's location. By enabling certain options, one can see the location of gas stations, restaurants, museums, and other public establishments in their area. Google Earth can also dot the map with links to images, YouTube videos, and Wikipedia articles relevant to the area being viewed.

vii. Enabling the creation of custom image overlays for planning trips, hikes on handheld GPS units.

viii. Facilitating researches by scholars.

2.14 TOPOLOGICAL STRUCTURE

Topological structure is use to define the location and the shape of feature using x-y co-ordinate pairs (Burrough, 1986). Topology is a mathematical procedures used to store 3 space relationships features i.e. the relationship between points, lines and polygon making up a feature can be describe as the principle of topology.

Hence, topological relationship is needed for spatial analysis. Estees (1991) set forth the idea that a topology structure is inherently a product of topological data. These means that, in other to understand topological structure clearly, there is need to understand the basic concept of space.

2.14.1 Component of Geo Spatial Object

Component of geo-spatial object is very important in topologic structure. There are two basic components namely:

1. Thematic data
2. Geometric data: is further divided into three:
    i. Location: - location of the object can be determined during data acquisition, they may be acquired either by using object based approach (vector) or using G.P.S or analytical photogrammetry (field based approach) raster using digital image processing.
    ii. Shape and size of the object: - this is determined through observation of the object, involving measurement.
    iii. Spatial relationships between one object and the other can be demonstrated using three dimensional main components:-
        a. Topological relationship
        b. Metric relationship
        c. Spatial orders relationship
3. Metric relationship: - this can be determined from the location of the object distance and directions of points.
    a. Topological relationship; - This is based on mathematical topology, it is the type of relationship that remains invariant under certain topologic transformation. This type of relationship is needed for spatial analysis for customized map. Through research has proved that they do change trough scaling and they are related to neighborhood relationship.

b. Spatial order relationship: - this is based on lattice geometry, for example A is contained in B. given relationship at coarse level, it does not give relationship as detailed as topologic relationship.

2.14.2 GEO-SPATIAL DATA

Topologic structure and spatial analysis requires that every piece of information be tied to a specific geographic unit (space). Therefore it is important to know something about Geo-Spatial data. Geo-spatial object refer to things that are distributed over the earth. Each object geo spatially has three types of data that are explicitly required to store especially in vector based (object based) conception they include:-

a) Location data: it defines the position of space, usually expressed by a set of x, y or z co-ordinates. In other word location is usually specified along 2 or 3 axes. Usually, we recognized three types or clan of geo-spatial data. I.e. object are distributed as points along line or with an area.

2.14.3 DIGITAL MAPPING

This is the process of producing maps from spatial data in numeric form rather than in graphical or analogue form. It also refers to a computerized compilation and production of maps or plans using information in a digital format, Ndukwe(2001). Digital mapping (also called digital cartography) is the process by which a collection of data is compiled and formatted into a virtual image. The primary function of this technology is to produce maps that give accurate representations of a particular area, detailing major road arteries and other locations of interest. The technology also allows the calculation of distances from places and the area coverage of spatial entities. Though digital mapping can be found in a variety of computer applications, such as Google Earth, the main use of

these maps is with the Global Positioning System (GPS) satellite network, used in standard automotive navigation system, Ndukwe(2001).

2.14.4 Digital mapping comprises three options, namely:

i. Data capture or data acquisition involves converting the data into digital forms.

ii. Data processing is the transformation of data into structures for different functions.

iii. Data presentation transmits data to users through or visual displays.

Digital mapping is a technique in Geographic Information System (GIS) and Remote Sensing.

2.15 CONCEPT OF GIS

2.15.1 Data Input

This involves entering or transferring the analogue or digital geographical data (map aerial photograph, or satellite imagery) and statistical (attribute) data into the GIS. The data input function thus enables GIS to convert the original input data into a machine-readable GIS-compatible format, Oluochaand Ogbale(2007). Data input operate at three levels; geo-referencing, registering the source materials, and analogue data conversion which this study adopted.

2.15.1.1 Geo-referencing:

It is also known as geo-rectification, geo-locating, geo-coding or geo-registering is the process of assigning spatial location identity to pieces of information. It is a process of giving cartographic materials such as digital satellite imagery, aerial photograph, and map or a statistical data real world coordinate systems and map projections. Geo-

referencing is commonly achieved by using coordinate systems. Examples of coordinate system are the spherical (geographic) coordinate system and the rectangular coordinate system. Non-coordinate systems include Postal Address and Postal Codes (or ZIP codes in use), Telephone Codes, Place Names, Enumeration Areas (EAs), House Numbering or Street Addresses, etc.

2.15.1.2 Registering the source materials:

This is the process of indicating to the computer the specific portion of the earth's surface. The source materials pertain to by entering the coordinate values of a minimum of three or four known locations (Control Points) on the source material. Before digitizing a cartographic source material or data for use in GIS environment, (geo-rectify) the data, whether in analogue or digital format, registered or geo-rectified.

2.15.1.3 Analogue data conversion:

Is a process of data capture or conversion of analogue geographic data to computer compatible format achieved through input devices such as digitizer, scanner and joy stick? The choice of the devices used depends on certain availability, the volume or scale of work to be digitized, nature of the input data, the kind of data processing to be executed, and the type of output expected, Oluochaand Ogbale(2007).

2.15.2 Data Storage:

Data storage is a function GIS. A typical GIS is equipped with commands and facilities to store both spatial and non-spatial in a number of formats or file structures. GIS data are normally stored in any of the common computer storage devices available. Geographic data are often large; hence a storage device with a large storage capacity is often required for GIS operations according to Oluochaand Ogbale(2007).

2.15.3 Data Manipulation

Geographical (map) data and the attribute (tabular) data held in GIS is subjected to manipulative operations, to generate results. Some of the standard data manipulative functions perform in GIS are: data integration, map overlay analysis, cartographic functions, buffering, network analysis, feature measurement, database querying or searching, and geospatial analysis.

2.15.3.1 Map overlay analysis:

GIS map overlay analysis is often accomplished through map algebra techniques. Map algebra is an operation in which new maps are calculated using mathematical or statistical formula or expressions. With the aid of map algebra a number of thematic map layers are combined in overlay operations and new information that was not present in the individual map is derived (Western and Farifteh, 1997). Each of the map layer used in an overlay function represents the spatial distribution of a particular attribute of feature over a common study area. The map overlay operations are used to transform the map layers into new map layers in order to extract information useful to the user, Takeyama and Couchlelis, (1997).

2.15.3.2 Cartographic functions:

The range of cartographic functions a GIS may perform includes changing map scale, co-ordinate conversion, transformation of projections, map annotation (lettering,

map embellishment (e.g. adding legends, neat lines, north arrow, title, etc). map composition and cartographic modeling, Oluochaand Ogbale(2007).

2.15.3.3 Buffering:

A buffer is a polygon created around a point or polygon feature on a map. The polygon could be of constant width (equidistant) or variable – width from the feature being buffered. Usually, buffer zones form new polygons, and these could be used in conjunction with other map layers of the same area for overlay operations. The buffering function of GIS enables the users to accomplish some other manipulative tasks, including proximity analysis.

2.15.3.4 Proximity Analysis:

Proximity tools can be divided into two categories depending on the type of input the tool accepts: features or raster's. The feature-based tools vary in the types of output they produce. For example, the Buffer tool outputs polygon features, which can then be used as input to overlay or spatial selection tools such as Select Layer by Location. The Near tool adds a distance measurement attribute to the input features. The raster-based Euclidean distance tools measure distances from the center of source cells to the center of destination cells. The raster-based cost-distance tools accumulate the cost of each cell traversed between sources and destinations.

Python Window

This is a geo-processing command in the software interface that employ the use of "Clip Analysis" in order to extracts input features (Base Stations) that overlay the clip features (Land used types).

2.15.3.5 Clip Analysis:

This tool usually cuts out a piece of one feature class using one or more of the features in another feature class as a "cookie cutter". This is particularly useful for creating a new feature class also referred to as study area or area of interest that contains a geographic subset of the features in another larger feature class.

2.15.3.6 Nearest Neighbor Analysis" (NNA):

Nearest Neighbor Analysis is the method of exploring patterns in the location data by comparing mean distance (Do) of the phenomena in question to the same expected mean distance (De) usually under a random distribution. A negative Z score indicates clustering, while a positive score means dispersion or evenness.

2.15.3.7 Address Matching:

It is also called geo-coding, is the process by which GIS automatically links an address record in a tabular file to corresponding street section in a map file. The address matching provides useful information about the location of point features. For instance, through address matching, the street address of a building such as its street number, street name, street type, the side of the road it is located, etc. could be known.

2.15.3.8 Feature Measurement:

One common measurement exercise is feature enumeration, which involves counting or totaling the number of a discrete feature within a definite geographical area.

Another feature measurement operation is measuring the distance (horizontal and vertical) between two objects. GIS can be used to compute the perimeter as well as area (size) and shape index of polygon features, Oluocha and Ogbale(2007).

2.15.3.9 Database Querying or Searching:

Probes database for specified relationships or conditions among features or data items. A query is represented in a way that DBMS are organized and processed. Querying operates on spatial and non-spatial data. Spatial query involves locating features within a spatial database using spatial search criteria, Pratt and Adamski(2005). Querying could be conducted on or among points, lines and areas (polygon) features. Non spatial query does not entail the use of latitude and longitude or other location information in answering the search question, Oluochand Ogbale(2007) reported in answering the search question. Non-spatial querying or searching functions one feature or place is snot queried in relation to another.

2.15.3.10 Geospatial Analysis:

Is a unique of statistics that describe spatial relationships among sample data? Several geo-statistic operations involve spatial interpolation which is the process of using sample points which known values at other points, Myers(2006). The basic concept of geo-statistics is that of scales of spatial variation. It has common characteristics with GIS and spatial statistics in general, Myers (2006).

2.15.4 Data Output:

The data sub-system in GIS is used to obtain copies of the result of a data manipulation operation. Based on the choice of the user, the output may be in form of soft copy or hard copy. The output could be graphic displays or tabular reports. The data

output sub-system should be capable of allowing the user to prepare or format the document for the final printing or plotting.

This study was also guided by these processes in data presentation. GIS helps in making the presentation of data more attractive than traditional static maps. Projecting tabular data onto maps helps in recognizing unexpected situations which, now noticed, call for closer examination. When considering geographical (spatial) factors, the analysis becomes finer and more precise, increasing the likelihood that ensuing strategies will be more pertinent. More flexible assistance can be provided in prospective planning at multiple levels or units of analysis: national, regional, provincial/district, and local. Expanded holistic representation and exploration of the contexts of schooling through the direct and dynamic use of multiple sources of influential data such as those found in census, utilities, land use, and databases which are otherwise very difficult to include in education planning and management but are needed for essential considerations for school progress and increased public appeal and utility. Extensive control of scale of complexity: extensive flexibility in how much data are displayed or explored at a given time, with changes in unit analysis are among the immediate considerations of this study. This task can be achieved through employing techniques in Geographic Information System, Aronoff(1989).

Geographic Information is characterized with measurements, mapping, monitoring and modeling which are enhanced through GIS, Olaleye (2005). Geographic Information System is also a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. GIS is a highly dynamic field, growing at very rapid pace of technological change and increasing

number of applications, Davis(2001). Wiegand (2001) extended that GIS allows the user to visualise and analyse spatial information in ways that, reveal hidden relationships, patterns and trends. In the strictest sense, it is a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, maps, and present the results of all these operations. GIS technology can be used for scientific investigations, resource management, asset management, environmental impact assessment, urban planning, cartography, criminology, history, sales, marketing, and regional or school mapping.The use of Geographical Information Systems (GIS) has become an increasingly important element in schools in recent years and spatial understanding is a key factor of using GIS, Biebrach, (2005).

Analysis of school microclimate fieldwork would involve creating graphs on a spreadsheet and commenting on patterns. Using GIS, students are able to rapidly create spatially located graphs which led to significantly improved analysis and geographical interpretation. Many spatial temporal works would have been laborious and time consuming without GIS, thus reducing the time available for detailed analysis. GIS Use varied resources, including maps, visual media and Geographical Information Systems' (QCA, 2007).

The concept of space or spatial awareness is a key concept which Lambert (2008) defines as the ability to recognise, interpret and understand spatial patterns, distributions and relationships. GIS, is used to interpret and analyse different maps to select information and identify relationships between spatial patterns, Dells(2007). GIS is

structured around seven key concepts (place, space, scale, interdependence, environmental interaction, changing physical and human processes and diversity).

CHAPTER THREE: THE STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This chapter establishes the study area and methodology of the research. It presents the study area, research design, data sources, instrumentation and data collection procedure. Characteristics of the study area were also summarized.

3.2 THE STUDY AREA

3.2.1 Loctation

Urban Zaria Area is located on latitude 11^0 15' N and 11^0 3' N and longitude 7^0 3'E and 7^0 50'E and is about 686m above sea level. In terms of total land area, it covers about 45,567Km^2, with a population of 6,066,562 people as at 2006 (NPC 2009). It consists of two Local Government Areas; Zaria Local Government and Sabon-Gari Local GovernmentThe area spread from Shika sub-settlement in the North to Dutsen Abba sub-settlement in the south west and from Dambo sub-settlement in the east to Wusasa sub-settlement in the west (figure 3.1).

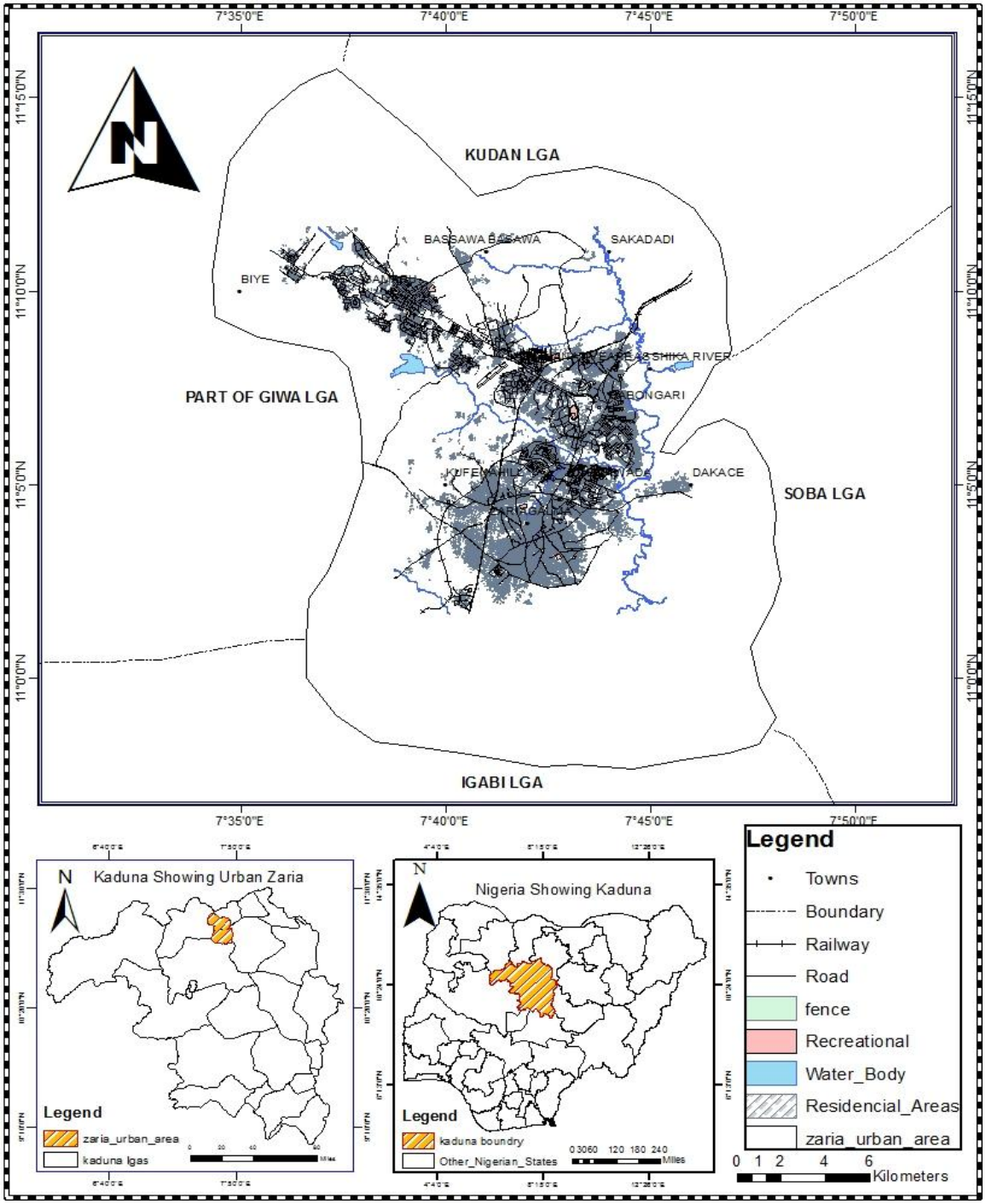


Fig 3.1: Administrative Map of the Study Area

Source: Adopted and Modified FromMinistry of Land and Physical Planning, Bamaiyi House, No. 30. Sokoto Road, Kwangila, Zaria - Kaduna Nigeria. 2016.

3.2.2 Climate

The study area falls within the Tropical Continental climate type with pronounced dry season, lasting up to seven months (October-May). It falls within the tropical savannah (Aw) climate, according to Koppen's World Climate Classification. During the dry season, a cool period is usually experienced between November and February. This emanates from the influence of the North-easterly (NE) winds (the Harmattan) which control the tropical continental air mass coming from the Sahara. This weather prevails over most parts of the country. The NE winds are characterized by hazy to dusty conditions and low temperatures, as low as 10^0C at night. In the afternoons, up to 42^0C is sometimes recorded. The humidity also drops to less than 15% in December/January. The study area also experience a brief period of hot and dry weather in March and April, followed by a progressive incursion of Tropical Maritime air mass of Atlantic Ocean which displaces the NE (Harnattan) winds. During this short period, the mean daily maximum temperatures are fairly stable, and they range from 38^0C to 42^0C. After that, the South Westerly (SW) Monsoon winds laden with moisture bring the rain in thunderstorms and squalls with heavy fall of high intensities. The rainy season lasts from May to September/October with long-term annual rainfall of 1040 mm in about 90 days. (www.abu.edu.ng).

3.2.3 Vegetation

The vegetation of Zaria falls within the guinea savanna zone which is characterized by grassland with scattered trees and woody shrubs vegetation. Artificial vegetation in some parts of the study area like Zaria and Sabon Gari are created. . It lies in the natural vegetation of the Northern Guinea Savannah, some 80 km North of Kaduna

town, along the major high way from Kaduna to Kano State. There are farms, gardens, mangoes trees, silk cotton and baobabs, shrubs and a number of grasses. However, increase in human population with its concomitant demands for housing; fuel wood and poor land management have great impact on the natural vegetation thereby reducing it drastically, Lawal(2008).

3.2.4 Soil

The soil in Zaria region is relatively deep red-brown to red-yellow tropical ferruginous soils. Most of the soil contains 30-40 percent clay. It is good moisture retention land and very poor in sustaining intensive agriculture for a long period. Fadama is the term used to explain this type of soil. In some cases, it persists to supply water even during the dry season while in other areas shaduf method of irrigation has to be used even along the river banks (www.abu.edu.ng).

3.2.5 Drainage

The river Galma forms the main focus of the drainage systems in Zaria region. Although Galma carries water throughout the year, most of its tributaries such as River Samaru dry up between January and May. The main tributary of Galma; Kubanni, is another river of economic importance in the region. The valleys of the streams are generally wide, shallow and not incised especially in the northern part of Zaria. To the west and north-west, the valley bottoms are alleviated and are singularly flat, wide and level. Udo, (1970).

3.2.6 Relief

The bedrock geology is predominantly metamorphic rocks of the Nigerian basement complex consisting of biotite, gneisses and older granites. There are rocky granitic residuals form inselbergs of varying shapes and sizes, and constitute the main local relief (relative relief is less than 150m) here and there with, Madarkaci and Jushi hills with Kufena hill standing out very prominently. The valleys are shallow but wide, stretching several tens of kilometers into the headwater areas with gentle sloping valley sides; imperceptibly grading into moist to marshy alleviated bottomlands or floodplains, called Fadama in Hausa. Although stream valley incisions and dissections of the high plains are evident in several areas, they are due more to anthropogenic influences and climatic factors than regional geologic instability, Udo(1970).

3.2.7 Economy

Zaria's economy is a combination of primary, secondary and tertiary. Staples are guinea corn and millet, and cash crops include cotton, groundnuts and tobacco. The study area is considered by some to be a main centre of Hausa agriculture, not only is Zaria a market town for the surrounding area, it is the home of numerous artisans, from traditional crafts like leather work, dyeing and cap making, to tinkers, print shops and furniture makes. It is also the centre of textile industry that for over 200 years has made elaborately hand embroider robes that are worn by men throughout Nigeria and West Africa. There are a number of commercial activities from trading, hawking, commercial cycling but to mention a few Banking, educational, recreational, hotels are some of the tertiary economic activities found, Gihring(1984).

3.2.8 Transportation

Because Zaria is north of the rail junction at Kaduna, it has equal rail access to the seaports at Lagos and Port Harcourt. However, currently only the railway to Lagos is functional, as the eastern line of Nigeria's rail network is not operational. This means the study area has access to Lagos and Kano to the north, not Port Harcourt. The study area is also accessible from Jos, Sokoto, Katsina and Kaduna by road. This means the study area has access to the northern and southern parts of the country. Gihring(1984). Intercity transport is conducive with commercial buses, tricycles and motor cycles available.

3.3 METHODOLOGY

One of the main tasks that should be looked at carefully during the building of any GIS application is regarding creating the required data and then integrating these data within the GIS environment. For this application, the required data was sourced and built upon the following.

3.3.1 Reconnaissance Survey

A reconnaissance was carried out as the first step in the execution of this project so as to have an insight into the work to be done and to aid accurate decision making during execution of the project.

3.3.2 Types of Data Used

i. Quick bird Satellite image.

ii. Coordinates of the GSM base stations' locations. The Geographic Positioning System (GPS) was used to collect the coordinates

iii. Data on GSM Base Stations Record from various service providers and Nigeria Communication Commission (NCC). The data include the following:

a) Name of the various GSM Base Station.

b) The address and location of the Base Stations.

c) Number of the Base Stations in the study Area.

d) Ownership and characteristics of each Facility.

3.3.3 Sources of Data

The data was sourced from primary and secondary sources:

i. **Primary Data:** The primary data that was sourced via Ground Truth Observations (GTOs) in the field. The research method employed pre-field work such as: Collection of the coordinate of the GSM Base Stations using Global Position System (GPS). Hence, validity and reliability was ensured during measurement.

ii. Secondary Data: Quick bird Satellite image of the area was collected from Planners and Development Consultants Zaria, Kaduna State Nigeria. The image was used to identify and extract the relevant features.

3.3.4 Data processing

This involved the processing, extraction and analysis of relevant spatial and attribute information about the study area from satellites images. The following steps were employed:

i. **Image Geo-referencing:** The Quick bird Satellite image of the area was geo-referenced with the aid of Ground control points, the places were visited to confirm their location and positions using GPS. The image was then geo-registered by

creating a geographical coordinate system using zone 32 North of Minna datum to facilitate geo-spatial processing and analysis.

ii. **Vector Data Creation:** The image covering the study area was utilized after Vectorization was performed through ArcGIS version 10.2 windows operating environment. The purpose is to transform the raster image into vector Shape files, where the image was digitized under the following themes: the Road networks, Railways and water bodies as Lines. Residential areas, as polygon data (i.e. lines, and polygon features) contained separate attribute tables.

iii. **Geo-spatial Database:** A Geo-Spatial database of all the facilities was created for relevant Query Statements and subsequent analysis. Thus, all the necessary information for each facility was entered into its layer's attribute table and stored. This was achieved by adding required number of fields (columns) to the table and entering the data for all the facilities in their corresponding records (rows) in Microsoft Excel and imported into the ArcGIS 10.2 software environment. The GSM Base Stations were labeled with their Names, X and Y location, Number of the Facilities, Addresses, Types, Area, and Ownership of the facilities in the study Area.

3.3.5 Methods of Data Analysis

Objective 1: To identify and map the location of GSM Base Stations in the study area,the database was imported into Arc GIS environment and the data containing the relevant vector Shape files were checked in ArcGIS environment to create a visual map of point and polygon features classes. The X and Y coordinate of the facilities has then automatically displayed the locations of all the base stations on the map. This shows the distribution of the facilities across the study location.

Objective 2: Analyze the locational distance of each Base Station from Residential areas (educational, hospital, and child care centers inclusive); As such, the WHO (2007) standard for locating GSM Base Stations in Nigeria was adopted that masts should be located 10m away from residential areas. The analysis was therefore performed as follows:

a. "Buffer Analysis": The buffering of 10m was created around the Base Stations within the software environment, so that proximity analysis to the Residential areas is done.
b. "Proximity Analysis": The database was then queried to check the proximity of the Base Stations to the Residential areas. The following "Query Analysis" was then engrossed for better appreciation of the facts on ground:
    i. Select by location Residential areas within 5m Buffer of Base Stations.
    ii. Select by location Residential areas within 10m Buffer of Base Stations.
    iii. Select by location Residential areas within 12m Buffer of Base Stations.
    iv. Select by location Residential areas within 20m Buffer of Base Stations.

Objective 3: To analyze the spatial pattern of the location of the base stations in the study area; ultimately, the vectorized map of the study location was imported and all the relevant Shapefiles was spatially overlaid. Subsequently, the "Nearest Neighbor Analysis" (NNA) inferential statistical tool in ArcGIS 10.2 was computed to establish the spatial pattern that may exists in the data. Nearest Neighbor Analysis is the method of exploring patterns in the location data by comparing mean distance (Do) of the phenomena in question to the same expected mean distance (De) usually under a random distribution. Analysis produce a Nearest Neighbor Ratio (Rn) result between 0 – 2.15. If the Rn value result fall between

a range of 0 – 0.49 the pattern is said to be significantly clustered, while a range of 0.5 – 1.5 indicates a significant random distribution. If the Rn value falls within 1.56 – 2.15 the pattern is said to be significantly dispersed or regular depending upon the number of points per pattern. A negative Z score indicates clustering, while a positive score means dispersion or evenness (Getis and Ord 1998).

Objective 4: To map out areas vulnerable to health hazards related to electromagnetic radiation and health implications from GSM Base Stations in the study area; all the facilities was 10m bufferedwithin the software environment, so that proximity analysis to the Residential areas were done to show the residential areas that fall within 10m radius away from the Based Stations so as to adopt the World Health Organization (WHO 2007) regulations for locating a GSM Base Station in Nigeria: that Masts should be erected 10 meters away from residential areas.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results of the analysis of the data collected during the field work. The variables analyzed include coordinates of the Land Masts, analysis on the locational characteristic and the names and types of the service providers of GSM Base Stations in Zaria Urban Area. This also has information like the address of the location of the Base Station, residential type. The raster and vector Maps for the study area were also presented.

4.2 IDENTIFYING AND MAPPING THE LOCATION OF GSM BASE STATIONS.

Below are the coordinates and the generic map for the study area at a glance. This showing the spatial distribution of GSM Base stations in Zaria urban.

Table 4.2.1: Geographical Location/Coordinates of Airtel GSM Base Station in Zaria Urban Area.

SERVICE PROVIDER	COORDINATE		LOCATION
AIRTEL	EASTING	NORTHING	
A1	358331	1225165	Along KofarDoka - Dan Magaji Road Behind 7up
A2	358634	1222501	KauraRimiDoko
A3	359108	1222653	Amaru behind former magajin Gari house
A4	356809	1222015	Durumi Zaria city
A5	358018	1220651	KofanGayan
A6	359291	1222839	Anguwar Liman Zaria city
A7	357918	1222618	Durumi Zaria city
A8	359863	1223544	Banzazzau near child care hospital
A9	359245	1224457	KofarDoka
A10	357931	1222343	Kan Fage Zaria city

A11	358330	1222639	Babban Dodo TurakiIsmaila Road
A13	360404	1226038	Kongo near GarajinJaji
A14	357605	1228656	Benz Shop
A15	361578	1224762	WTC
A16	356854	1225459	Dan - Magaji behind Mamuda Garage
A17	362132	1228438	Dogon Bauchi Sabon Gari
A18	360302	1227377	Behind PZ Building
A19	360357	1227695	Total premises PZ area
A20	353277	1233332	ABU main Campus
A21	352783	1233748	Behind Mr. Biggs
A22	385338	124114	Near Energy Research Gate
A23	385462	123987	Zango

The data in table 4.2.1 is the Geographical Location/Coordinates of 23 Airtel land masts which were spread across Zaria Urban area. The Coordinates was used to create the spatial distribution of Airtel base station in figure 4.1

4.2.1. Spatial Distribution of Airtel Land Masts in Zaria Urban Area.

This has displayed the distribution of Airtel land masts as seen in figure 4.1

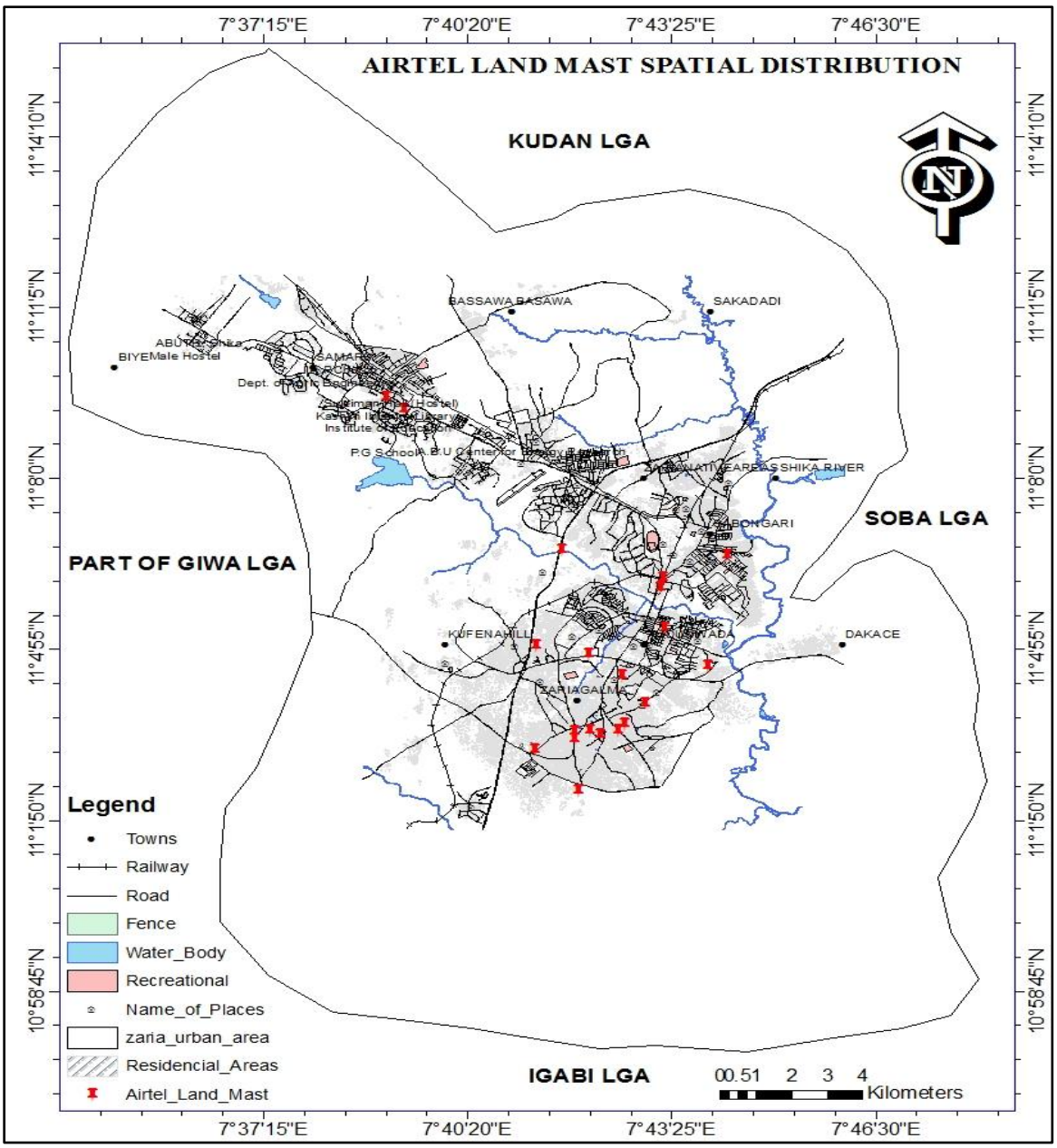


Fig 4.1: Spatial Distribution of Airtel Land Masts in Zaria Urban Area.

Source: Field Survey and Arc GIS, 2016.

The data in table 4.2.1 was used todisplay the spatial distribution of Airtel GSM Base Station in figure 4.1. There are more Airtel land masts in the southern part of the study area and little were distributed towards the northern part of the study area.

Table 4.2.2: Geographical Location/Coordinates of MTN GSM Base Station in Zaria Urban Area

SERVICE PROVIDER	COORDINATE		LOCATION
MTN	EASTING	NORTHING	
M1	356658	1221679	lowcost opposite police station
M2	358543	1222427	Anguwar Liman
M3	359354	1223417	Kwarbai near Nabara house
M4	358841	1223105	Emir's Palace
M5	359655	1223271	Madarkachi near Mai Anguwa house
M6	357587	1222774	AnguwarJuma Zaria city
M7	356929	1221356	Lowcost opposite central Mosque
M8	357035	1221759	KofarKuyambana Zaria city
M9	358373	1222663	Babban Dodo Zaria city
M10	358631	1222149	Kaura Kwan Kira
M11	360156	1223886	Ban-Zazzau Zaria City
M12	359424	1225590	Near Albarkawa Estate property agency Tudun Wada
M13	359939	1226611	Agoro, behind Baba trader house
M14	358286	1226347	Emir Road Gaskiya Layout
M15	361589	1226233	Gyallesu
M16	358979	1226357	Gaskiya Cooperation
M17	361426	1224770	WTC
M18	361688	1224327	Jos Road
M19	356851	1225461	Danmagaji Behind MamaduGarege

M20	361076	1229542	BATC (Tobacco)
M21	360481	1230987	Dogarawa
M23	360544	1231353	Dogarawa
M24	356339	1232396	NITT
M25	355645	1235379	NARICT
M26	361775	1228321	Sabon Gari Jafaru Road
M27	359847	1229896	MTD
M28	362145	1229735	Sapele Road Sabon Gari
M29	358577	1230156	Hanwa highcost
M30	360163	1227831	Behind police Head Quarters
M31	352766	1233789	Opposite North Gate
M32	351504	1234645	DAC Agric
M33	350713	1236516	Bomo Samaru
M34	352752	1234217	Samaru
M35	349816	1235242	Area G
M36	353242	1233395	Main Campus
M37	385014	124286	Agric police station
M38	385431	124063	Zango Filling Station

The data in table 4.2.2 is the Geographical Location/Coordinates of 38 MTN land masts which were spread across Zaria Urban area. The Coordinates was used to create the spatial distribution of MTN base station in figure 4.2

4.2.2. Spatial Distribution of MTN Land Masts in Zaria Urban Area.

Figure 4.2 displays the spatial distribution of MTN GSM Base Station in the study Area.

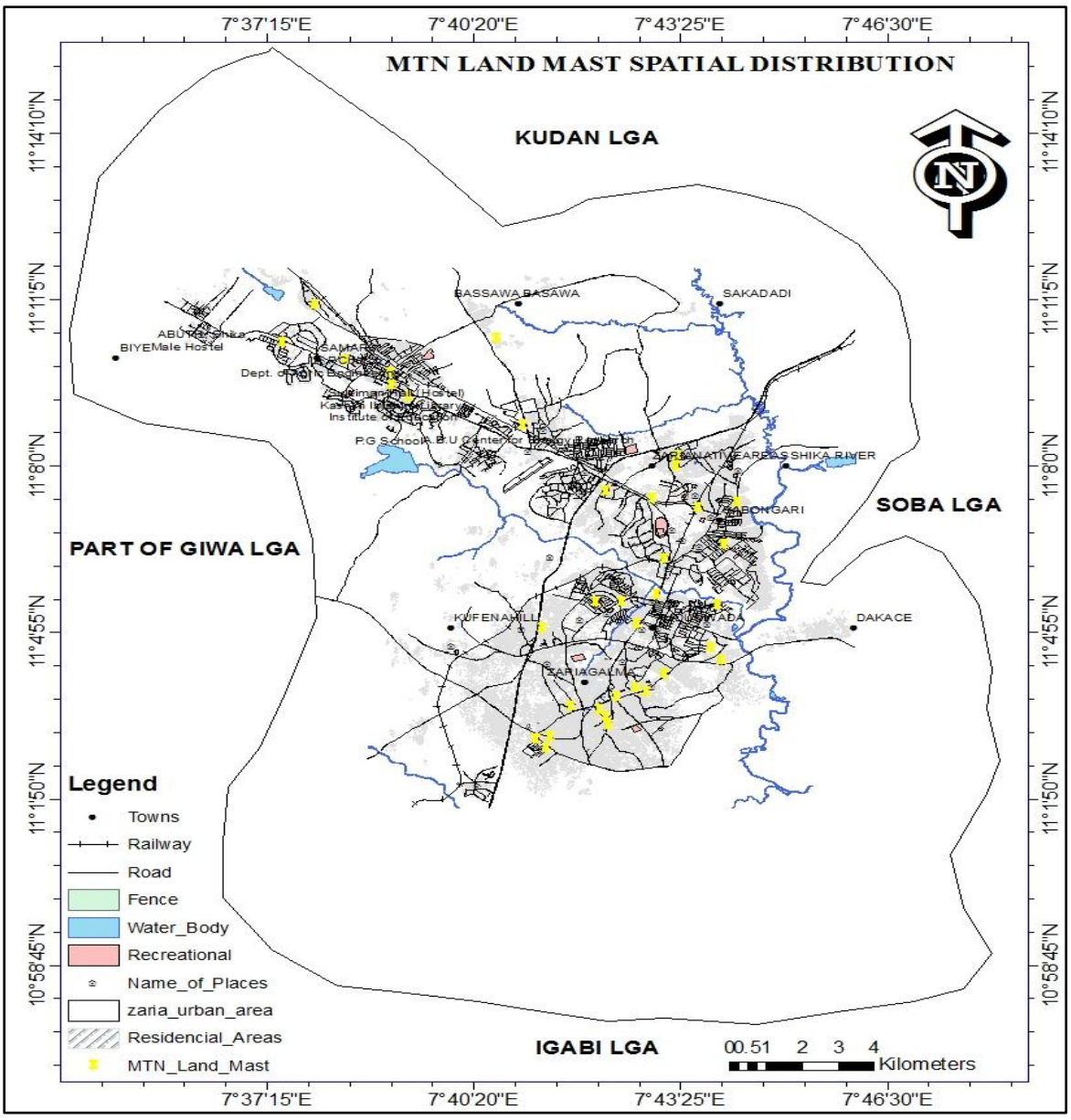


Fig 4.2: Spatial Distribution of MTN Land Masts in Zaria Urban Area.

Source: Field Survey and Arc GIS, 2016.

The data in table 4.2.2was used todisplay the spatial distribution of MTN GSM Base Station in figure 4.2. They are clustered distributed in the study area, because they are found everywhere in the area which helps to provide network services in the area.

Table 4.2.3: Geographical Location/Coordinates of Starcomms GSM Base Station in Zaria Urban Area

SERVICE PROVIDER	COORDINATE		LOCATION
STARCOMMS	EASTING	NORTHING	
S1	359943	1221761	Anguwar Liman Zaria City
S2	359805	1224751	New Jos Road near HEBN Publisher PLC
S3	359073	1226401	Gaskiya Cooperation
S4	359188	1228221	Road D, off western way GRA
S5	361315	1226201	Gyellesu
S7	361496	1229322	Kings Road Sabon Gari
S8	357663	1228907	Hanwa by Express, near Maslaha Seed.
S9	358324	1230114	New Extension Opposite NNPC Mega Station
S10	353061	1234219	Samaru
S11	352946	1233900	Samaru

The data in table 4.2.3 is the Geographical Location/Coordinates of 11 Starcomms land masts which were spread across Zaria Urban area. The Coordinates was used to create the spatial distribution of Airtel base station in figure 4.3

4.2.3. Spatial Distribution of Starcomms Land Masts in Zaria Urban Area.

This has displayed the distribution of Starcomms land masts as seen in figure 4.3

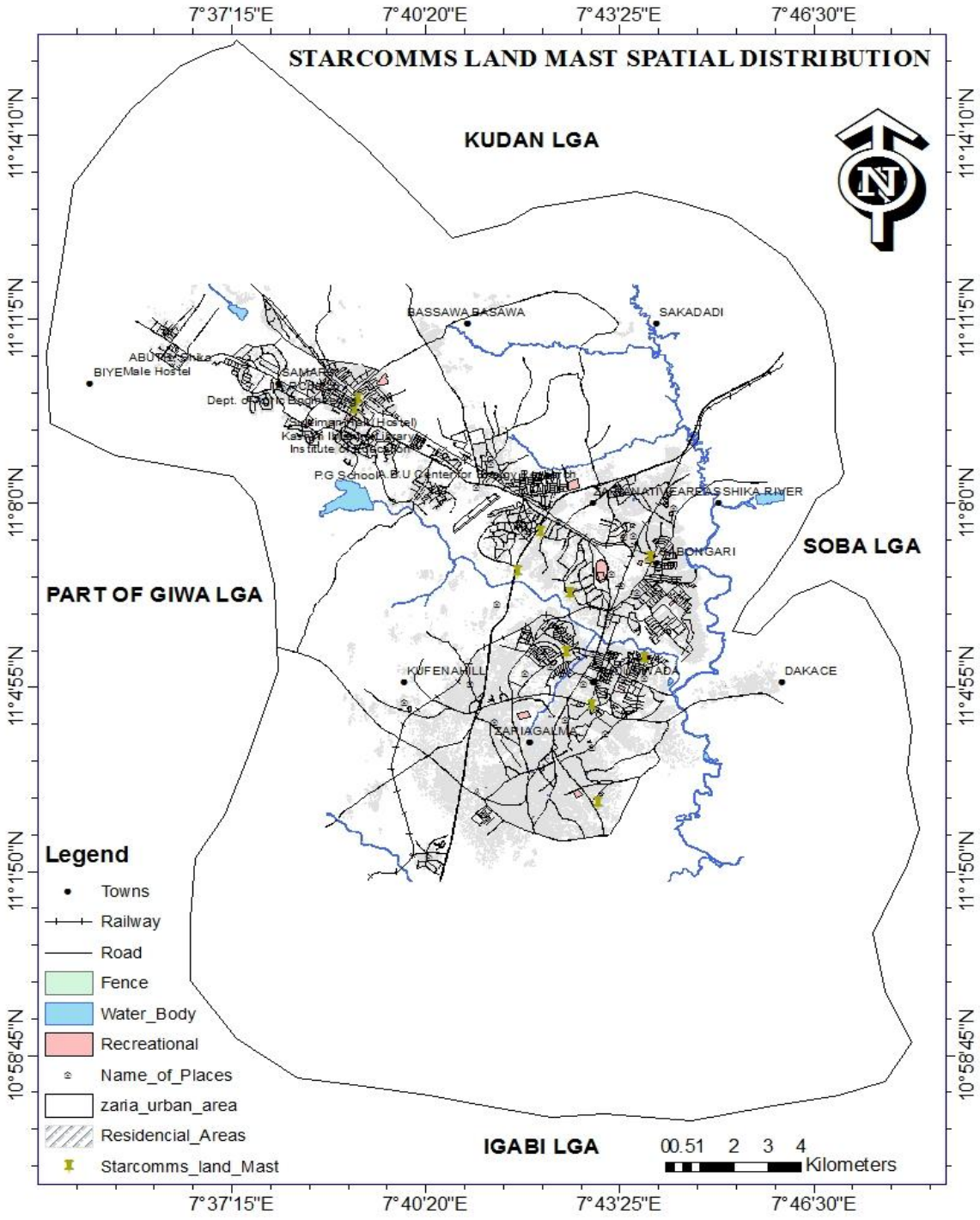


Fig 4.3: Spatial Distribution of Starcomms Land Mastsin Zaria Urban Area.

Source: Field Survey and Arc GIS, 2016.

The data in table 4.2.3 was used todisplay the spatial distribution of Starcomms GSM Base Station in figure 4.3. They are only concentrated at the center of the study area with just 11 land mast, which provide network service in the study area.

Table 4.2.4: Geographical Location/Coordinates of Visafone GSM Base Station in Zaria Urban Area.

SERVICE PROVIDER	COORDINATE		LOCATION
VISAFONE	EASTING	NORTHING	
V1	356928	1226950	TukurTukur
V2	359399	1225787	LayinPumpoTudun Wada
V3	355752	1224741	St Luke Wusasa
V4	356903	1224819	DanmagajiJuma'a Mosque
V5	361116	1229572	BATC (Tobacco)
V6	358385	1226286	Gaskiya Layout
V7	362713	1227333	AnguwarGwado
V8	352421	1233753	Quarter 3

The data in table 4.2.4 is the Geographical Location/Coordinates of 8 Visafone land masts which were spread across Zaria Urban area. The Coordinates was used to create the spatial distribution of MTN base station in figure 4.4

4.2.4. Spatial Distribution of Visafone Land Masts in Zaria Urban Area.

Figure 4.4 displays the spatial distribution of Visafone GSM Base Station in the study Area.

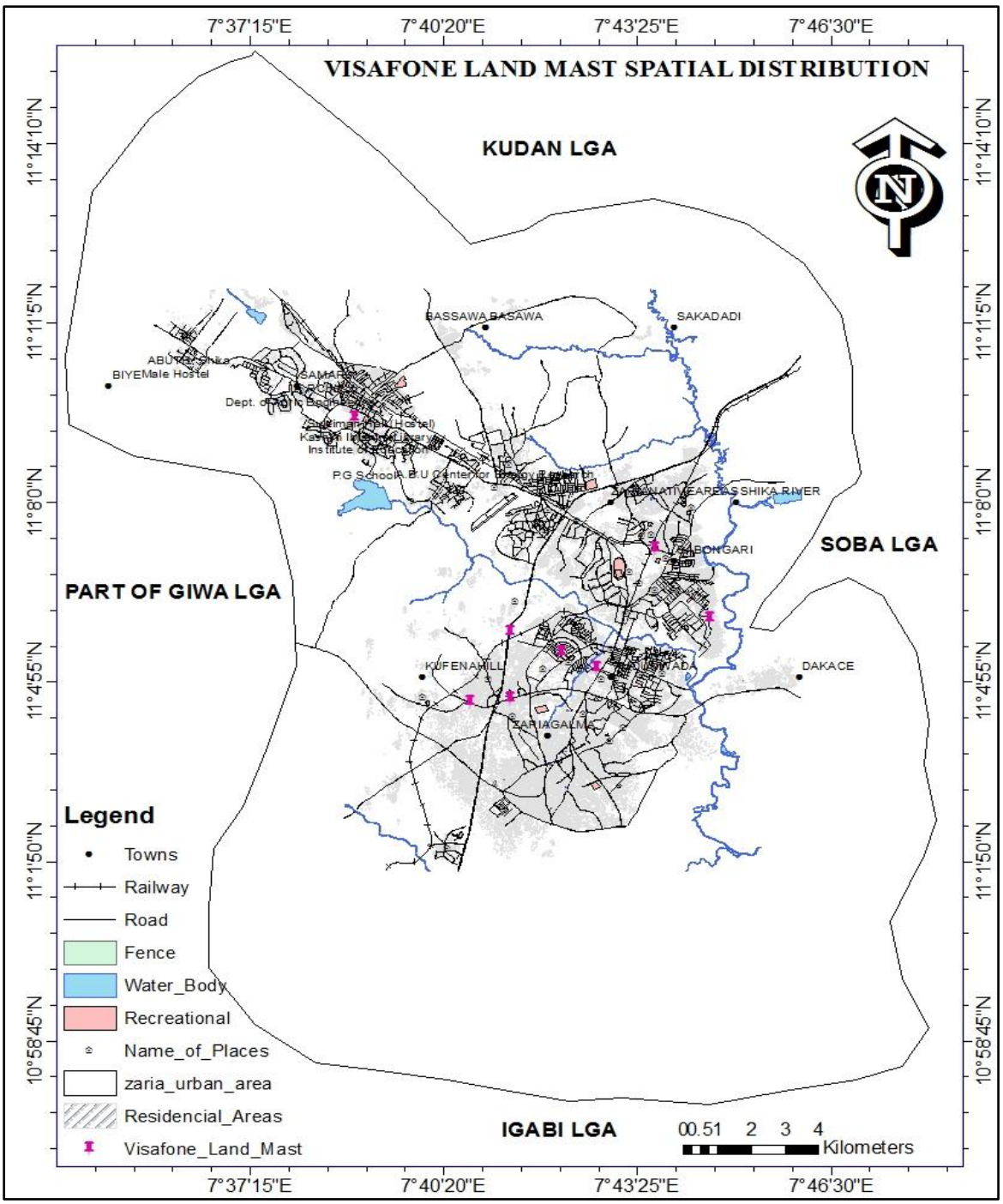


Fig 4.4: Spatial Distribution of Visafone Land Masts in Zaria Urban Area.

Source: Field Survey and Arc GIS, 2016.

The data in table 4.2.4 was used to display the spatial distribution of Visafone GSM Base Station in figure 4.4. The mast are located at the center of the study area with only 8 land mast, which provide network service in the study area.

Table 4.2.5: Geographical Location/Coordinates of Etisalat GSM Base Station in Zaria Urban Area.

SERVICE PROVIDER	COORDINATE		LOCATION
ETISALAT	EASTING	NORTHING	
E1	361484	1226206	Gyellesu
E2	361712	1230804	Sabon Gari
E3	360141	1231381	DogarawaAnguwanBarau
E4	362661	1226691	AnguwarGwadoKanTsauni
E5	360455	1227792	Near Unity Bank PZ area
E6	361198	1230309	Sabon Gari
E7	352882	1234047	samaru
E8	385406	124010	Zango

The data in table 4.2.5 is the Geographical Location/Coordinates of 11 Etisalat land masts which were spread across Zaria Urban area. The Coordinates was used to create the spatial distribution of Airtel base station in figure 4.5

4.2.5. Spatial Distribution of Etisalat Land Masts in Zaria Urban Area.

This has displayed the distribution of Etisalat land masts as seen in figure 4.5

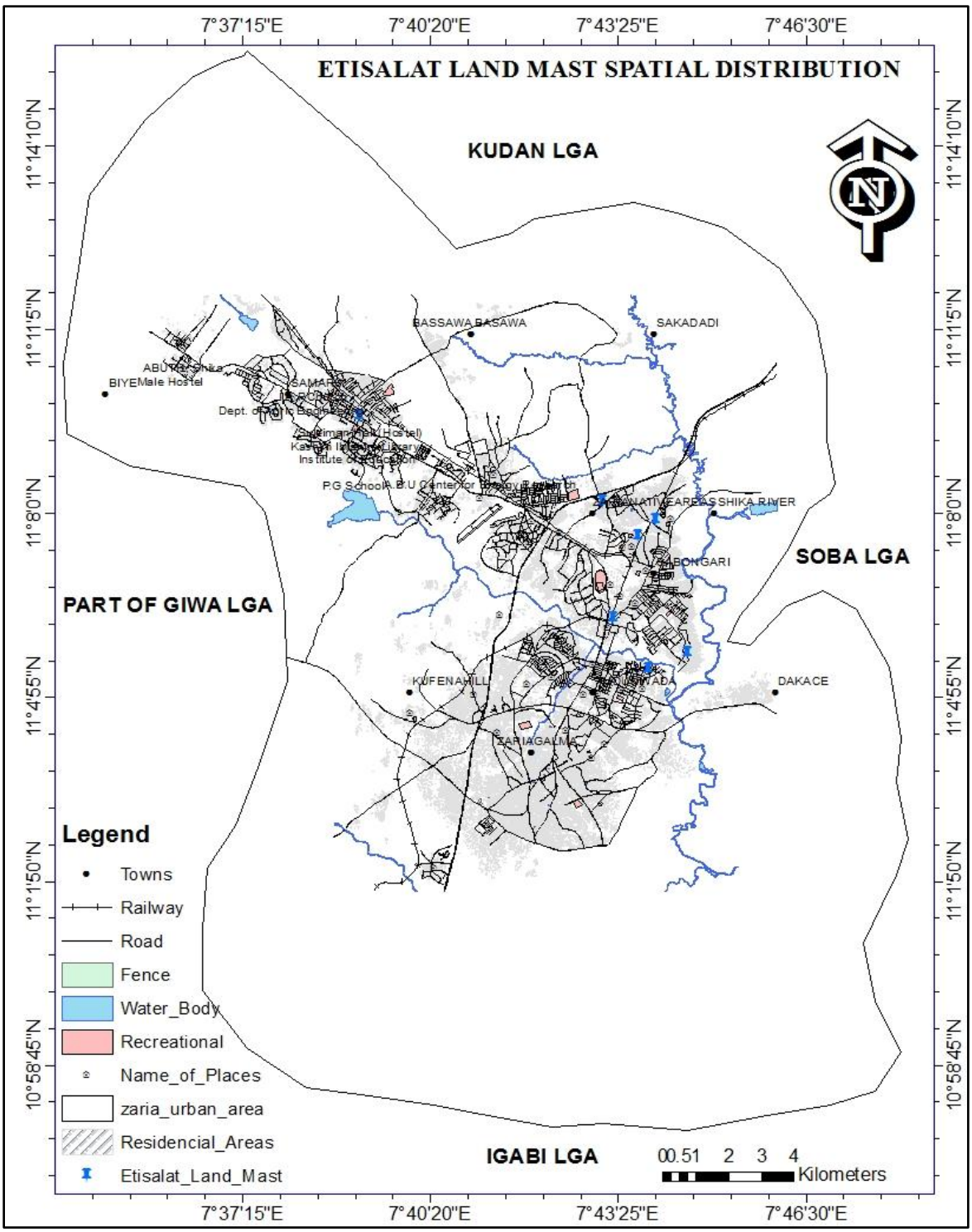


Fig 4.5: Spatial Distribution of Etisalat Land Masts in Zaria Urban Area.

Source: Field Survey and Arc GIS, 2016.

The data in table 4.2.5 was used to display the spatial distribution of Etisalat GSM Base Station in figure 4.5. Most of the mast are located at the center of the study area with only 8 land mast, which provide network service in the study area.

Table 4.2.6: Geographical Location/Coordinates of Globacom GSM Base Station in Zaria Urban Area.

SERVICE PROVIDER	COORDINATE		LOCATION
GLO	EASTING	NORTHING	
G1	360211	1225622	FanfonGwaiba
G2	358498	1226141	Gaskiya Layout Haruna Soba Street
G4	359059	1227077	TudunJukun
G5	357787	1226473	GonanGanye
G6	360217	1226009	Layin Wawa Tudun Wada
G7	359973	1226354	Agoro opposite filling Station
G8	355115	1223409	Madachi (wusasa)
G9	356307	1225364	AnguwarDankali
G11	361056	1227767	Dogon Bauchi Sabon Gari
G12	358585	1225977	NBPZ Annex Campus
G13	362688	1226105	JushinWaje
G14	360559	1227685	Sabon Gari Cresent Street
G15	362779	1226967	AnguwarGwadoTsauni
G16	360359	1230369	Chikaji Industrial Layout
G17	362282	1228342	Sabon Gari
G18	361325	1229313	Kings Road Sabon Gari
G19	361798	1228121	Nupe Street Sabon Gari
G20	361417	1227763	Cemetery Road Sabon Gari
G21	355171	1220131	NBPZ Main Campus

G22	356806	1221416	Low-cost Opposite Police Station
G23	358829	1230213	Yan Goro
G24	358595	1230149	New Extension Hanwa
G25	355030	1231828	Zango near Yan Shanu
G26	352931	1234713	Samaru
G27	351697	1234306	Behind all Saint Church
G28	84894	124367	Area G

The data in table 4.2.6 is the Geographical Location/Coordinates of 28 Globacom land masts which were spread across Zaria Urban area. The Coordinates was used to create the spatial distribution of Globacom base station in figure 4.6

4.2.6. Spatial Distribution of Visafone Land Masts in Zaria Urban Area.

Figure 4.6 displays the spatial distribution of Globacom GSM Base Station in the study Area.

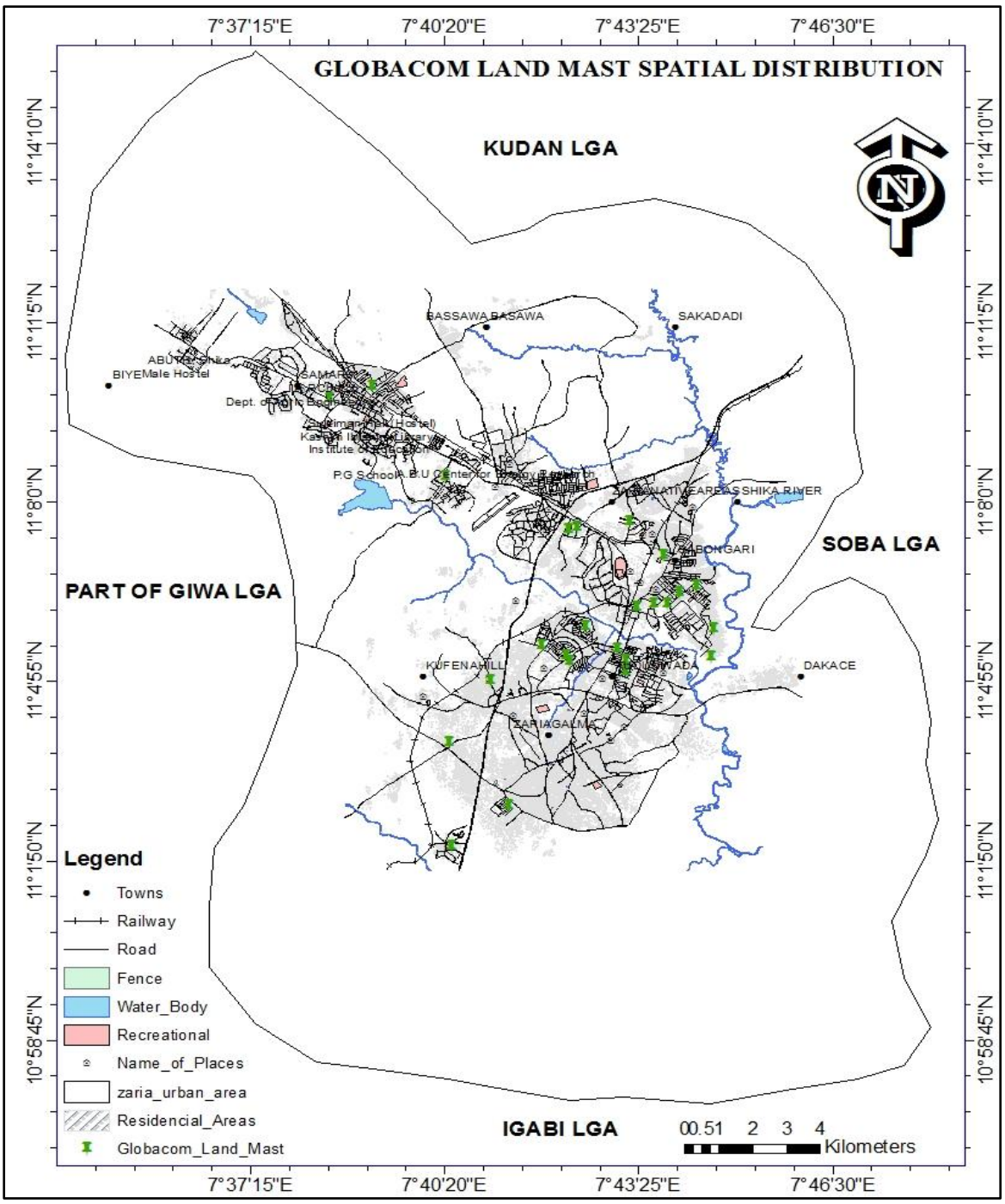


Fig 4.6: Spatial Distribution of Globacom Land Masts in Zaria Urban Area.

Source: Field Survey and Arc GIS, 2016.

The data in table 4.2.6 was used todisplay the spatial distribution of Globacom GSM Base Stations in figure 4.6. They arerandomly distributed in the study area, because

they are found almost everywhere in the area which helps to provide network services in the area

In totality there are 23 AIRTEL base stations representing 19.8% of the total facilities in urban Zaria as shown in Table 4.1. Additionally, 38 base stations covering 32.8% are owned by MTN service providers as shown in table 4.2. However Table 4.3 further revealed 11 erected base stations owned by Startcomms in urban Zaria, these facilities represents 9.5%. Also Table 4.4 further revealed 8 erected base station owned by Visafone in urban Zaria, these facilities represents 6.9%. More so 8 base stations covering 6.9% are owned by Etisalat service provider as shown in Table 4.5. Finally table 4.6 further revealed 28 erected base stations owned by Globacom in urban Zaria, these facilities represents 24.1%.

This implies that the dominant erected facilities in the area of study belong to MTN masts with 38 land masts, follow by Globacom with 28 land masts, this is followed by Airtel with 23 land masts, follow by Startcomms with 11 land masts, While Visafone and Etisalat have 8 land masts each.

4.2.7. Spatial Distribution of All GSM Base Stations in Zaria Urban Area.

Figure 4.7below is the generic map for the study area at a glance. This showing the spatial distribution of all GSM Base stations in Zaria urban.

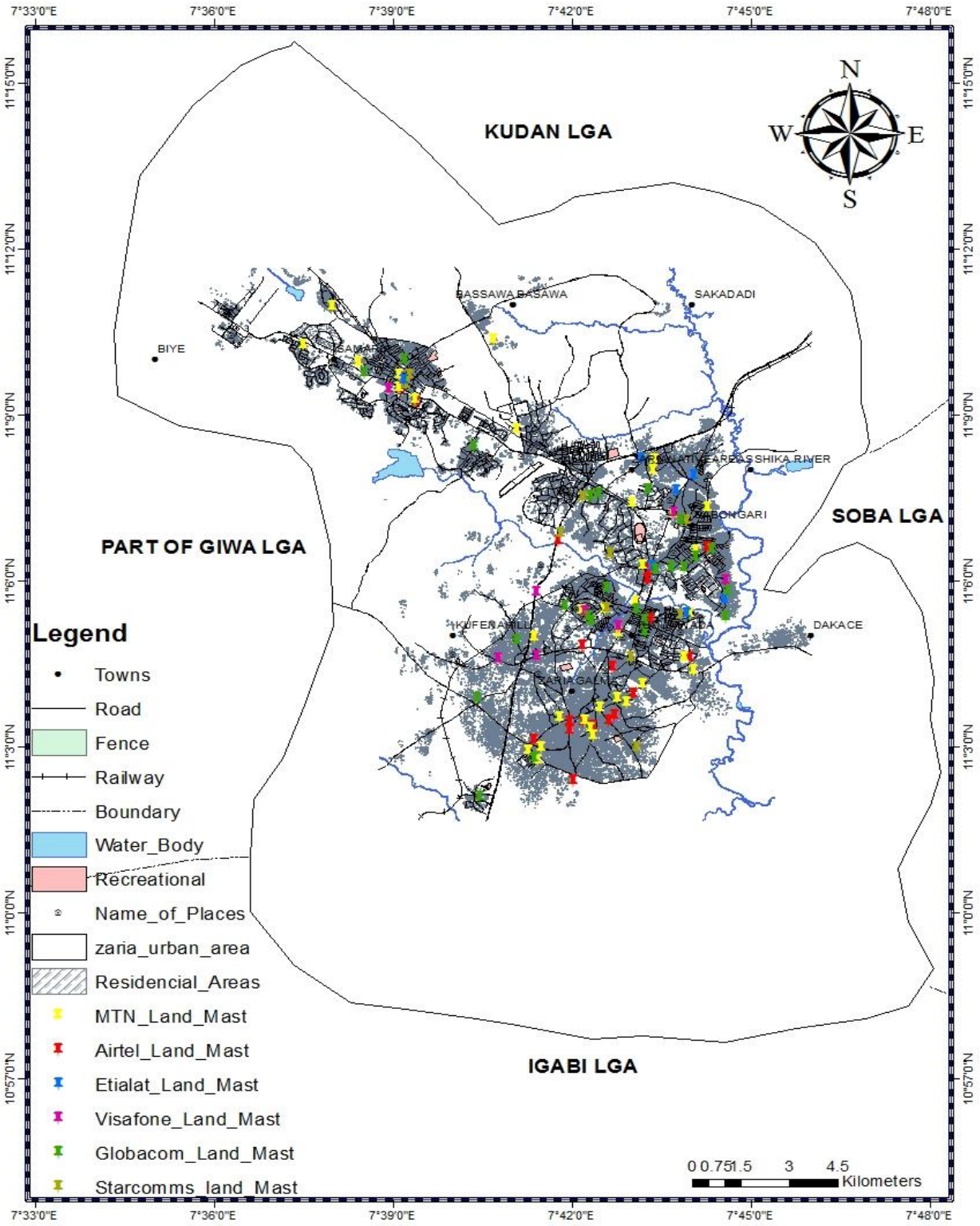


Fig 4.7: Spatial Distribution of All GSM Base Stations in Zaria Urban Area.

Source: Field Survey and Arc GIS, 2016.

Figure 4.7 displayed the spatial distribution of GSM Base Stations in the study Area. Also from the map there are more mast situated in the southern and north east part of the study area.

4.3 Locational Distribution of Base Stations from Residential Areas.

As such, the WHO (2007) recommended standards for locating GSM Base Stations in Nigeria, that mast should be erected 10meters away from residential areas was adopted. The buffering of 5m, 10m, 12m and 20m was created around the Base Stations within the software environment, so that proximity analysis to the Residential areas was done.

4.3.1. Area G gate of ABU Samaru Campus and Bomo Area.

This has displayed the distribution of three land masts as seen in figure 4.8, two of the facilities are located at area G gate of ABU Samaru Campus and the other is situated at Bomo ward.

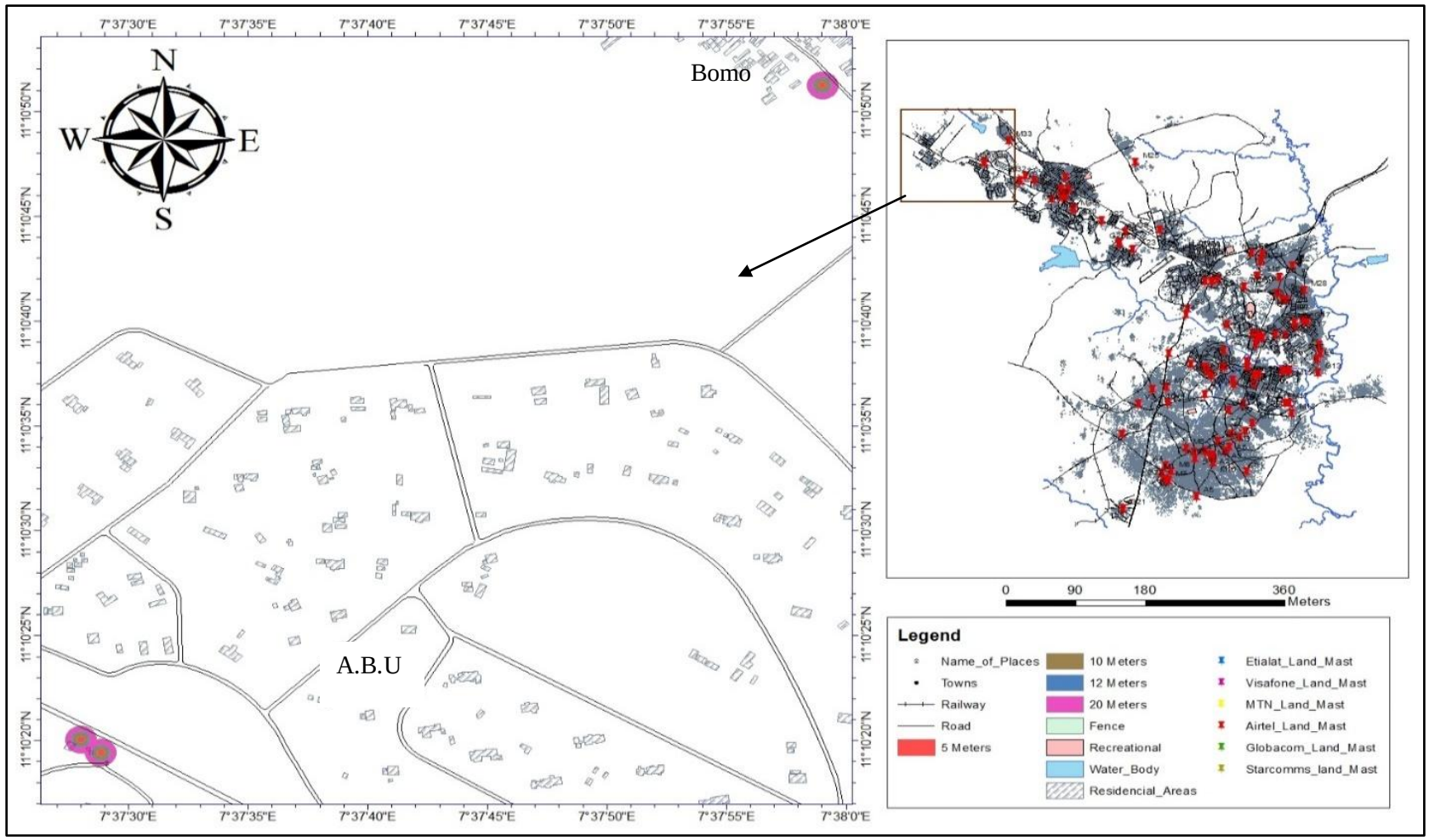


Fig 4.8: Buffered Zones around GSM Base Stations in area G gate of ABU Samaru Campus and Bomo Area.

Source: Field Survey and Arc GIS, 2016.

The buffer at 10meters zones around each land masts suggests that, no residential buildings are found within the buffer zones. This shows that the location of the three facilities is in line with the WHO standard.

4.3.2. Police station, Samaru out post division; Department of Agriculture College (DAC); and Ganga UkuArea.

The buffer zones displayed in Fig 4.9 show the locations of one base station erected each at Police Station, Samaru out post division; Department of Agriculture College (DAC); and Ganga Uku respectively.

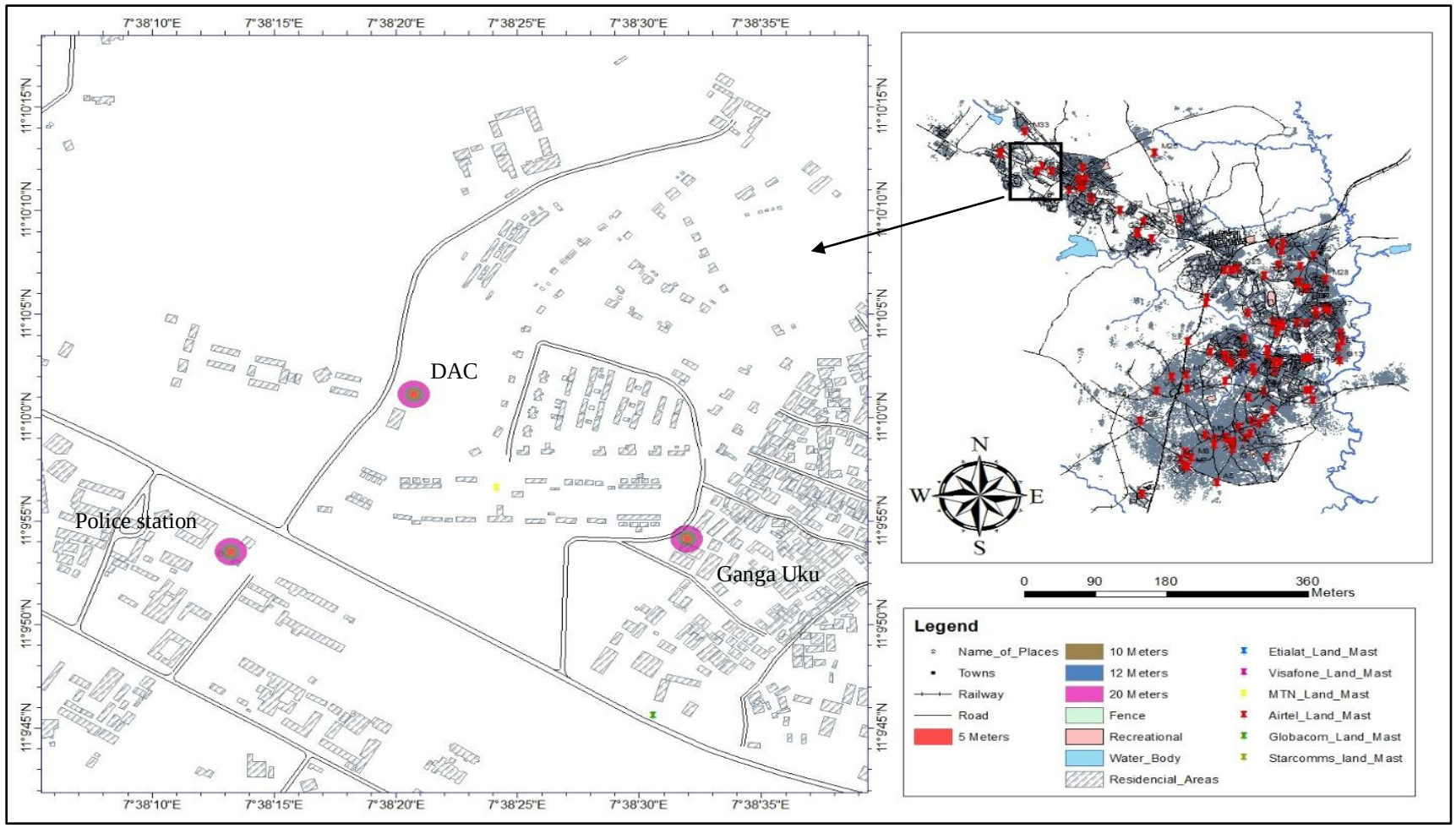


Fig 4.9: Buffered Zones around GSM Base Stations in Police Station, Samaru out post division; Department of Agriculture College (DAC); and Ganga UkuArea.

Source: Field Survey and Arc GIS, 2016.

According to the proximity analysis in figure 4.9, the facilities at both the police station and Ganga Uku are located within the buffer zones of 10m, these locations are therefore found to disagree with the WHO established standards. On the contrary, the base station sited at DAC is located far away from residential buildings, thereby agrees with the standards set by WHO.

4.3.3. Danraka area Samaru ward, ABU Main Campus and HanyinDogo Area.

The buffer zones displayed in Fig 4.10, shows the locations of six base stations all erected at Danraka area Samaru ward, one at HanyinDogo and a single base station at Quarter Three ABU Zaria staff Quarters, Samaru Campus**.**

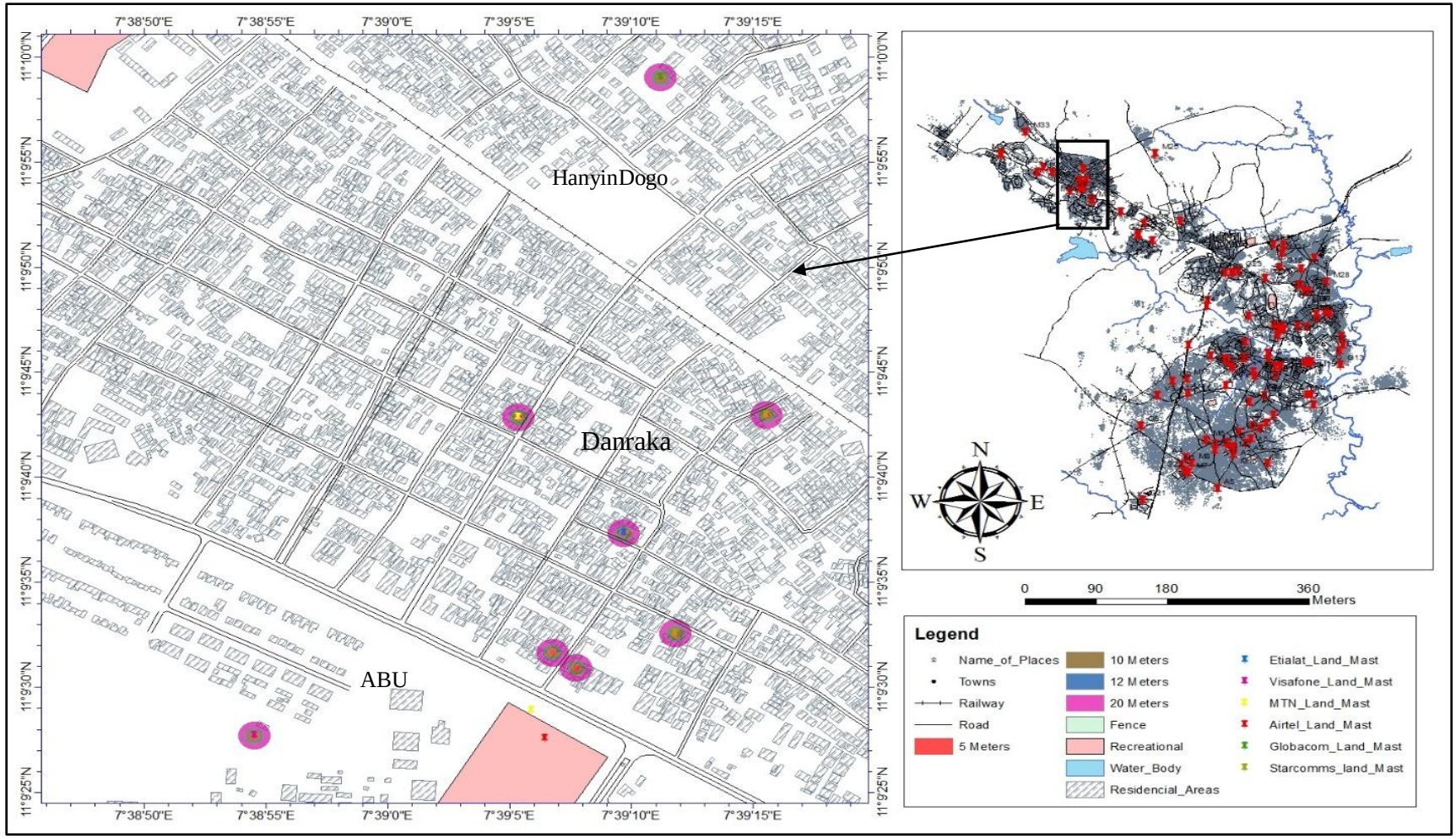


Fig 4.10: Buffered Zones around GSM Base Stations in Danraka area Samaru ward, ABU Main Campus and HanyinDogo Area.

Source: Field Survey and Arc GIS, 2016.

These locations according to the proximity analysis in figure 4.10, have fallen within the buffer zones of 10m, therefore extremely disobeyed the WHO standards. On the contrary, the figure further shows a single base station at Quarter Three ABU Zaria staff Quarters, Samaru Campus located 10m away from residential buildings, thereby agrees with the standards set by WHO.

4.3.4. ABU Samaru Campus and Center for Energy Research Gate.

Figure 4.11 displays the distribution of three land masts as seen, two of the facilities are located at ABU Samaru Campus and the other is situated at Center for Energy Research Gate.

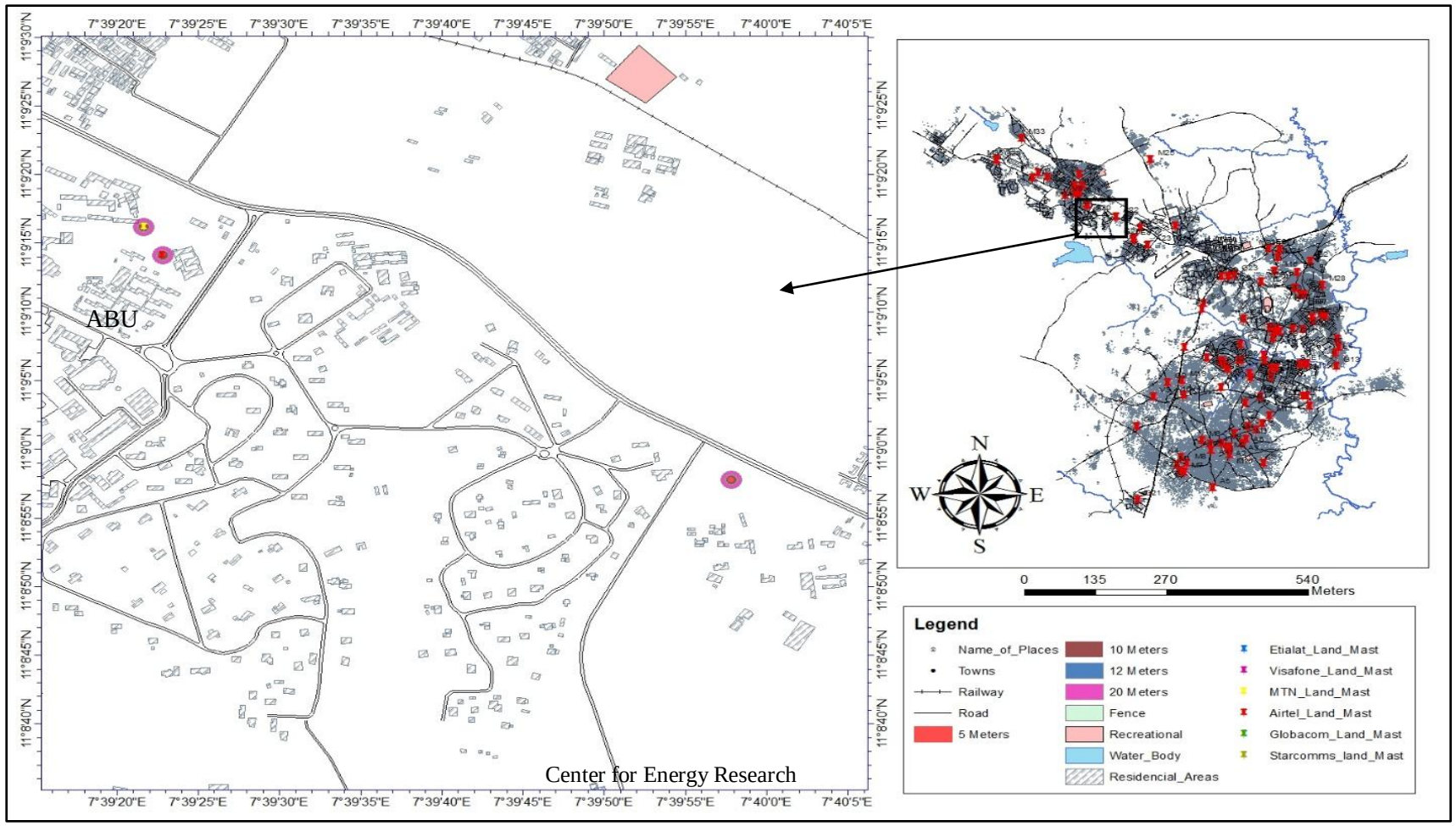


Fig 4.11: Buffered Zones around GSM Base Stations in ABU Samaru Campus and Center for Energy Research Gate.

Source: Field Survey and Arc GIS, 2016.

The buffer of 10meters around each land masts in figure 4.11,suggests that no residential buildings are found within the buffer zones. This shows that the location of all the facilities is in line with the WHO standard.

4.3.5. Zango and Palladan Area.

The buffer zones displayed in Fig 4.12 shows the locations of four base stations erected at Zango and only one base station erected at Palladan respectively.

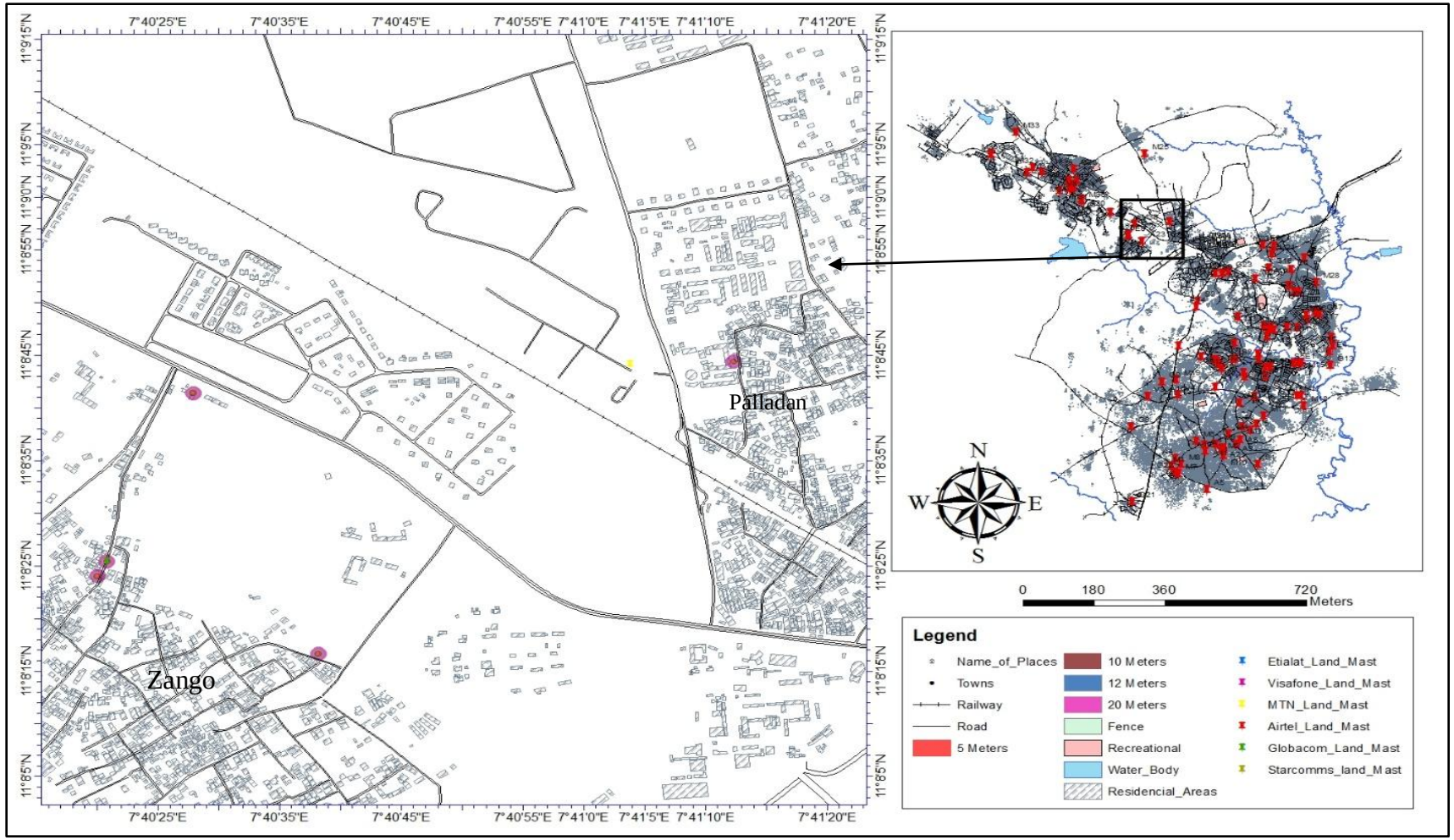


Fig 4.12: Buffered Zones around GSM Base Stations Zango and Palladan Area.

Source: Field Survey and Arc GIS, 2016.

According to the proximity analysis in Fig 4.12, the facility identified at Palladan is located within the buffer zones of 10m, this location is therefore found to disagree with the WHO established standards. While on the other hand three of the facilities identified at Zango are located within the buffer zones of 10m this location is therefore found to disagree with the WHO established standards, On the contrary, only one base station in Zango is located far away from residential buildings, thereby agrees with the standards set by WHO.

4.3.6. Kwangila, Hanwa and DogarawaArea.

The respective buffer zones displayed in Fig 4.13, show the locations of five base stations, four erected at Kwangila, Hanwa area and one at Dogarawa Area.

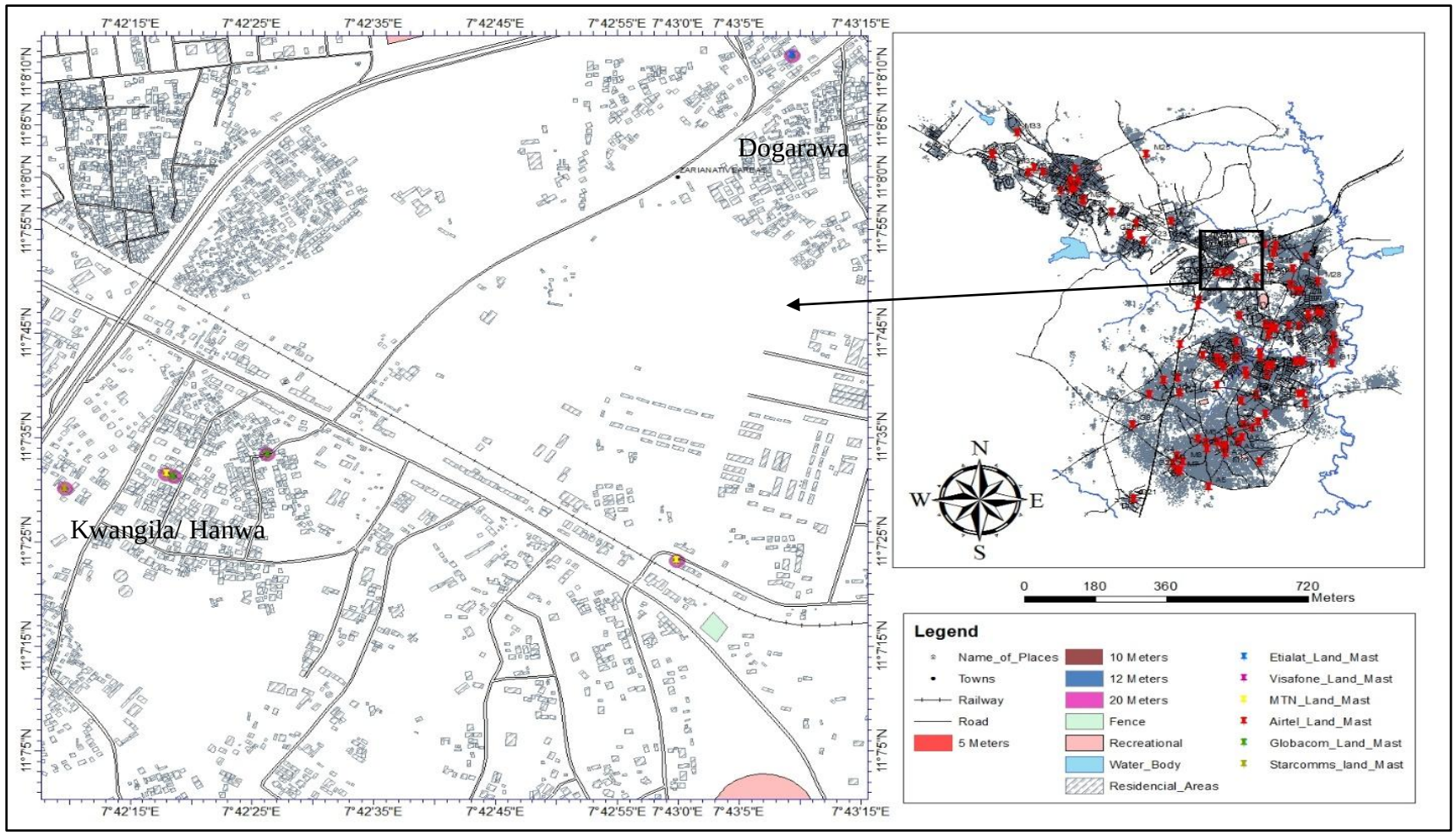


Fig 4.13: Buffered Zones around GSM Base Stations in Kwangila, Hanwa and DogarawaArea.

Source: Field Survey and Arc GIS, 2015.

The locations of the base stations in figure 4.13 according to the proximity analysis, all have fallen within the buffer zones of 10m, and therefore disobeyed the WHO recognized standards.

4.3.7. Chikaji Area of Sabon Gari L.G.A.

Figure 4.14 displays the distribution of seven land masts as seen.

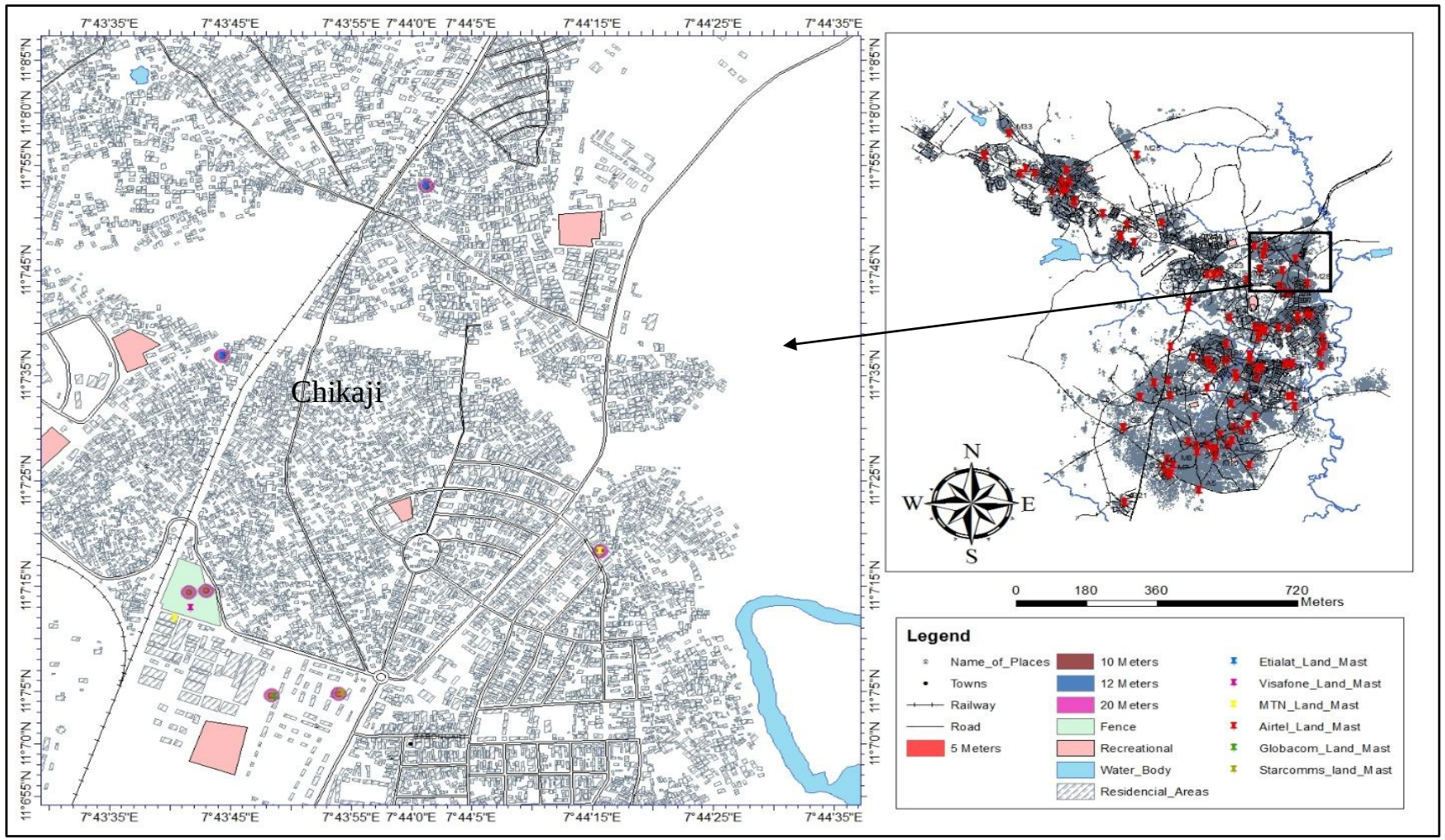


Fig 4.14: Buffered Zones around GSM Base Stations in Chikaji Area of Sabon Gari L.G.A.

Source: Field Survey and Arc GIS, 2016.

From figure 4.14 two of the facilities are located at Tobacco Company in Chikaji. The buffer at both 10meters around the two land masts suggests that, no residential buildings are found within the buffer zones. This shows that the location of all the facilities is in line with the WHO standard. While the other five facilities that are situated within Chikaji area, are located within the buffer zones of 10m this location is therefore found to disagree with the WHO established standards.

4.3.8. Sabon Gari Area.

The distribution of nine land masts is presented in figure 4.15.

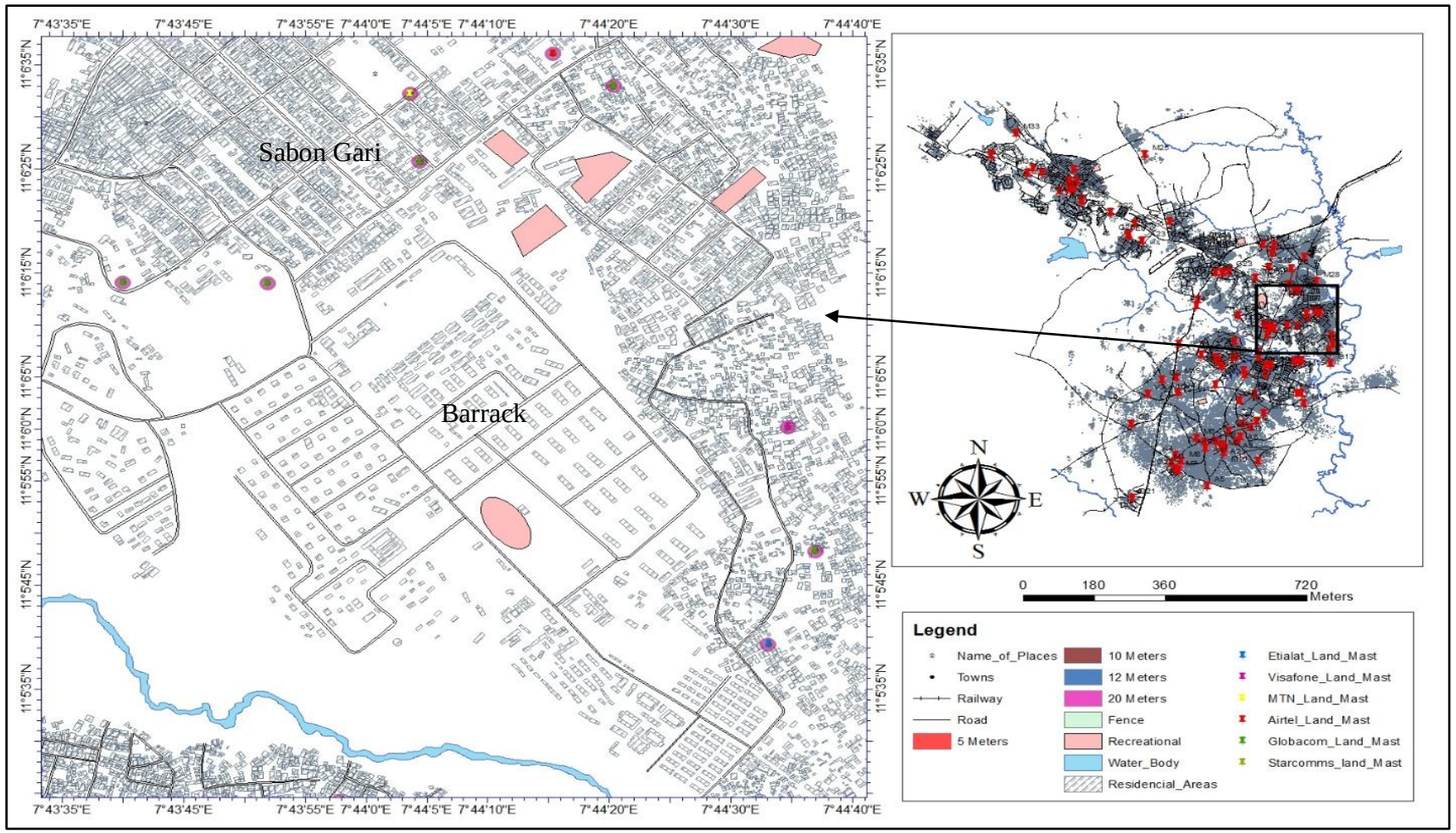


Fig 4.15: Buffered Zones around GSM Base Station in Sabon Gari Area.

Source: Field Survey and Arc GIS, 2016.

Two of the facilities are located in the Sabon Gari area as seen in figure 4.15. The buffer at both 10meters around the two land masts suggests that, no residential buildings are found within the buffer zones. This shows that the location of thesetwo facilities is in line with the WHO standard. The other seven facilities that are situated in the area, are located within the buffer zones of 10m this location is therefore found to disagree with the WHO established standards.

4.3.9. PZ, Tudun Wada and TudunJukun Area.

The buffer zones displayed in Fig 4.16, show the locations of fourteen base stations, five at PZ area, four at TudunJukun and five at Tudun Wada Area.

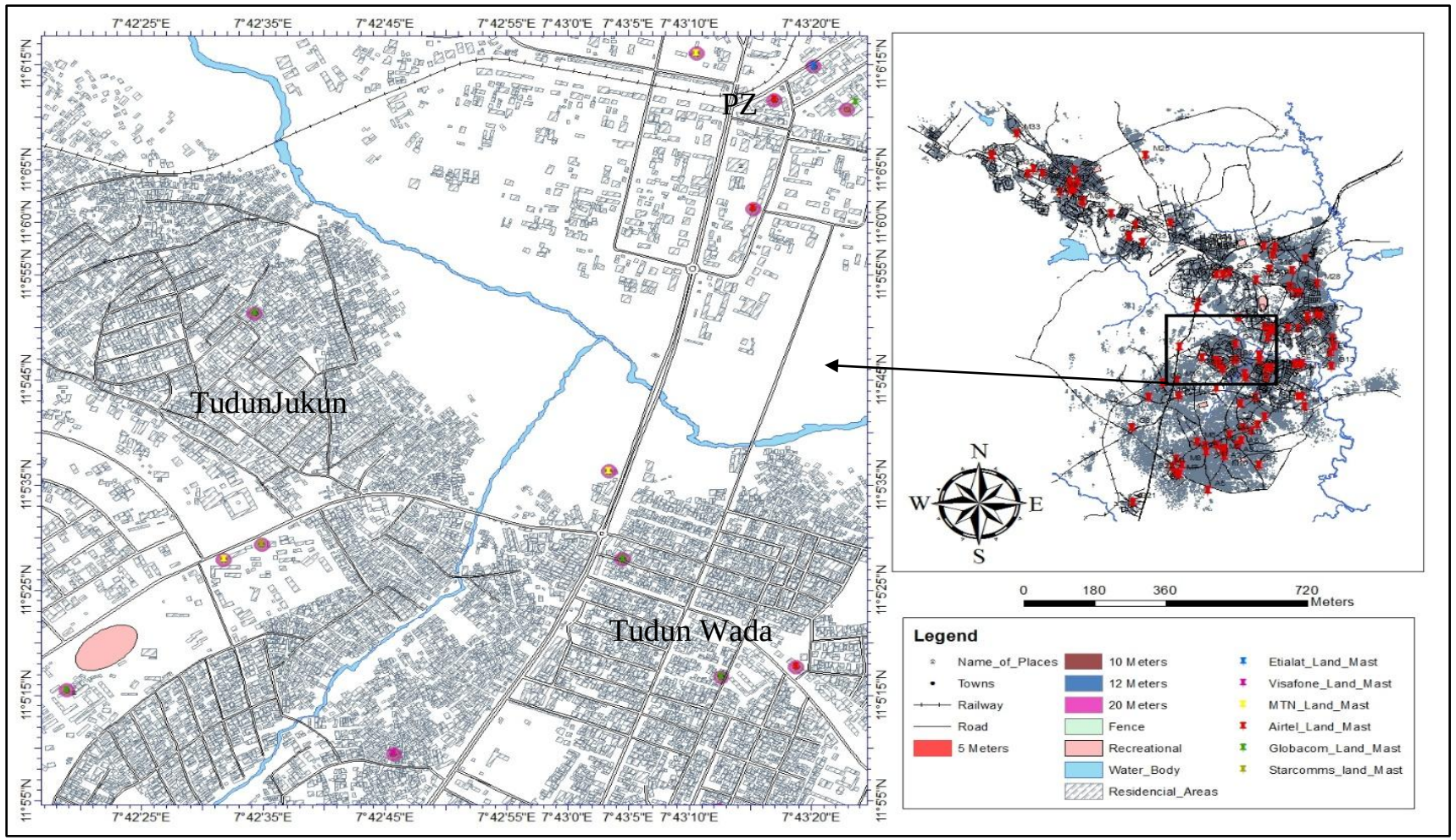


Fig 4.16: Buffered Zones around GSM Base Stations in PZ, Tudun Wada and TudunJukun Area.

Source: Field Survey and Arc GIS, 2016.

The locations of the base stations in figure 4.16 according to the proximity analysis, allhave fallen within the buffer zones of 10m, and therefore disobeyed the WHO recognized standards.

4.3.10.Dan Magaji and WusasaArea.

This displays the distribution of five land masts as seen in figure 4.17, two of the facilities are both located in Dan Magaji and Wusasa area.

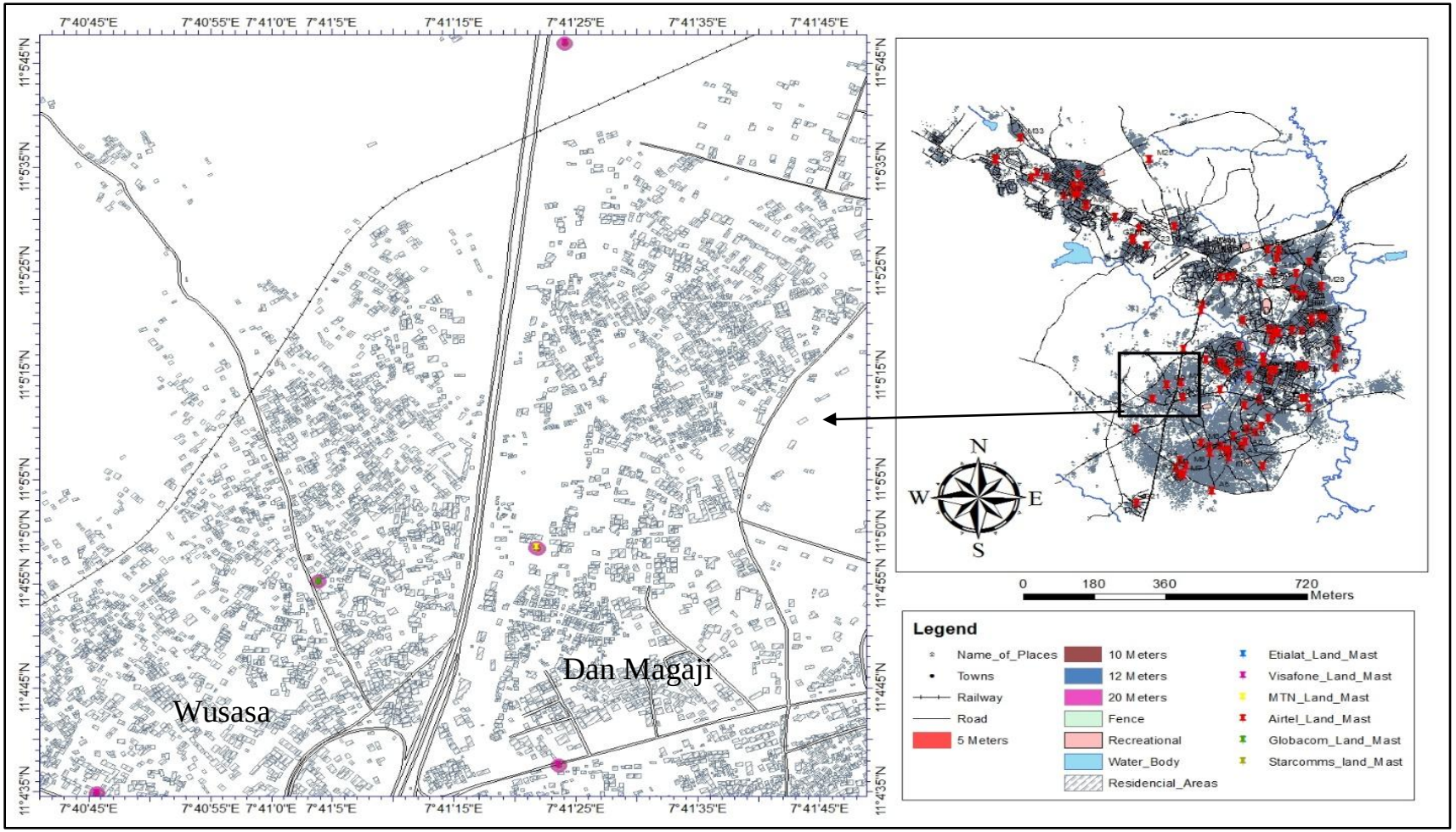


Fig 4.17: Buffered Zones around GSM Base Stations in Dan Magajiand WusasaArea.

Source: Field Survey and Arc GIS, 2016.

The buffer of 10meters around the two land mass in figure 4.17, suggests that no residential buildings are found within the buffer zone. This shows that the location of this facilities is in line with the WHO standard. The other two of the base station also located in the Dan Magaji area are located within the buffer zones of 10m, this location is therefore found to disagree with the WHO established standards. The facility that is situated in Wusasa area has also fall within the buffer zones of 10m this location is therefore found to disagree with the WHO established standards.

4.3.11. Tudun Wada, Gyallesu and A.B.U Congo Campus Area.

The buffer zones displayed in Fig 4.18 shows the locations of three base stations erected each at Tudun Wada, Gyallesu and A.B.U Congo Campus Area.

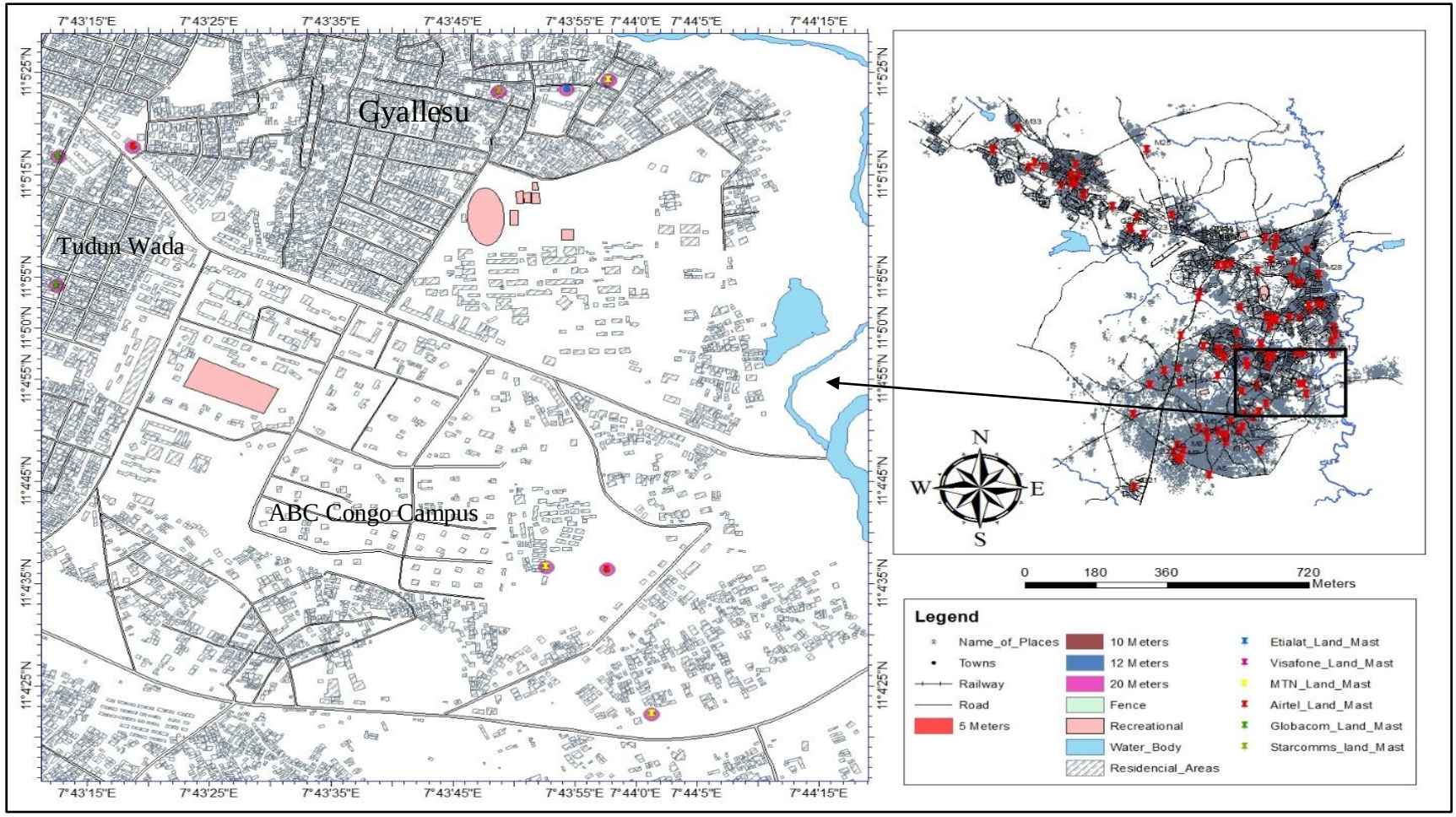


Fig 4.18: Buffered Zones around GSM Base Stations in Tudun Wada; Gyallesu; and A.B.U Congo Campus Area Area.

Source: Field Survey and Arc GIS, 2016.

According to the proximity analysisin Fig 4.18, the facilities identified at both the Tudun Wada and Gyallesu; are located within the buffer zones of 10m, these locations are therefore found to disagree with the WHO established standards. On the contrary, two of the base stations sited at A.B.U Congo Campus is located far away from residential buildings, thereby agrees with the standards set by WHO. The remaining one facility that is situated in A.B.U Congo Campus also falls within the buffer zones of 10m this location is therefore found to disagree with the WHO established standards.

4.3.12. Zaria City

The respective buffer zones displayed in Fig 4.20, shows the locations of twelve base stations all erected at Zaria City.

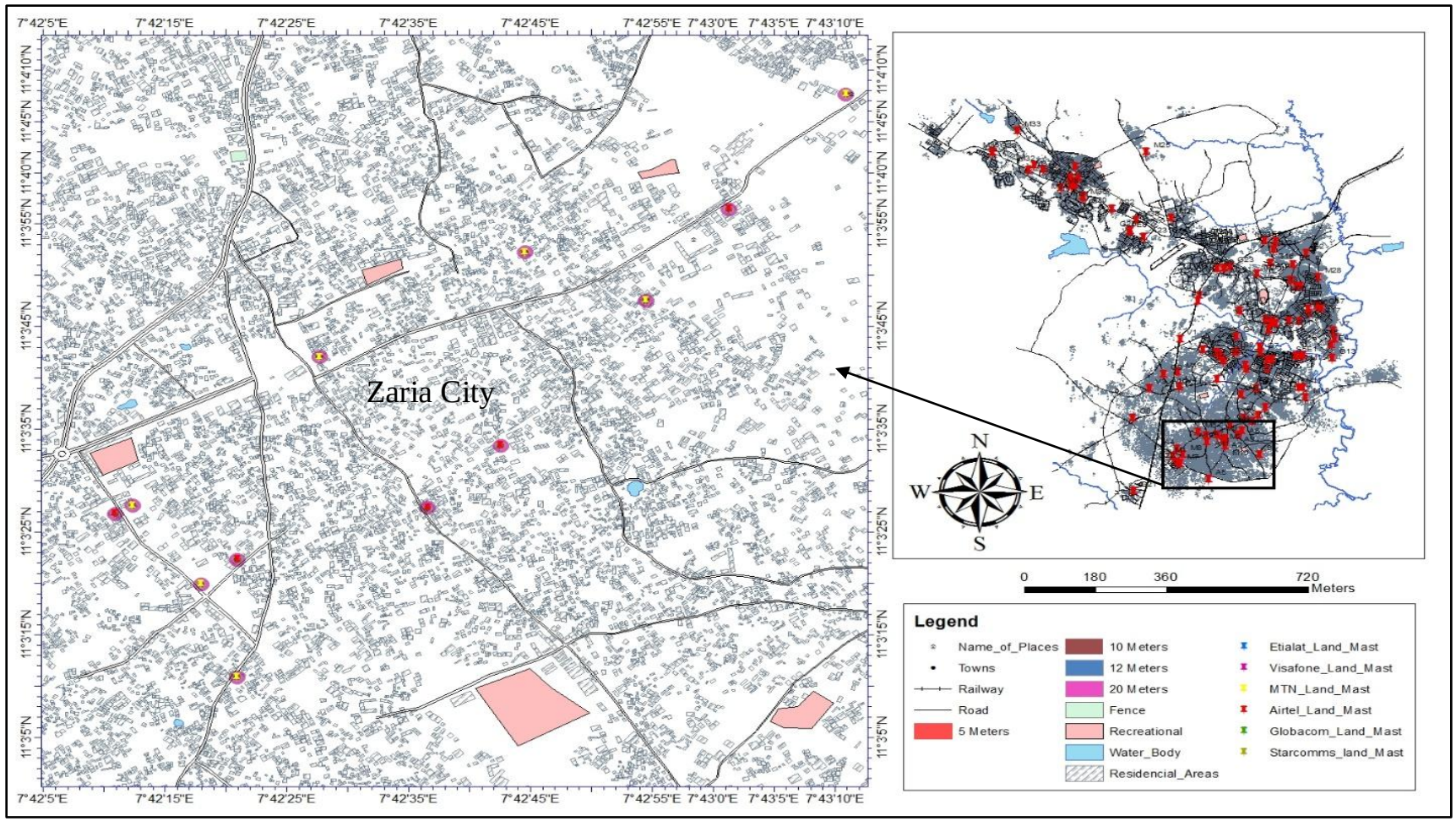


Fig 4.19: Buffered Zones around GSM Base Stations in Zaria City.

Source: Field Survey and Arc GIS, 2016.

The locations in figure 4.19 according to the proximity analysis, have fallen within the buffer zones of 10m, therefore extremely disobeyed the WHO recognized standards. On the contrary, figure 4.19 further shows a single base station within the Zaria City located 20m away from residential buildings, thereby agrees with the standards set by WHO.

4.3.13. NuhuBamalliPolytechnic Zaria.

Figure 4.20, shows a single base station in NuhuBamalli Polytechnic Zaria.

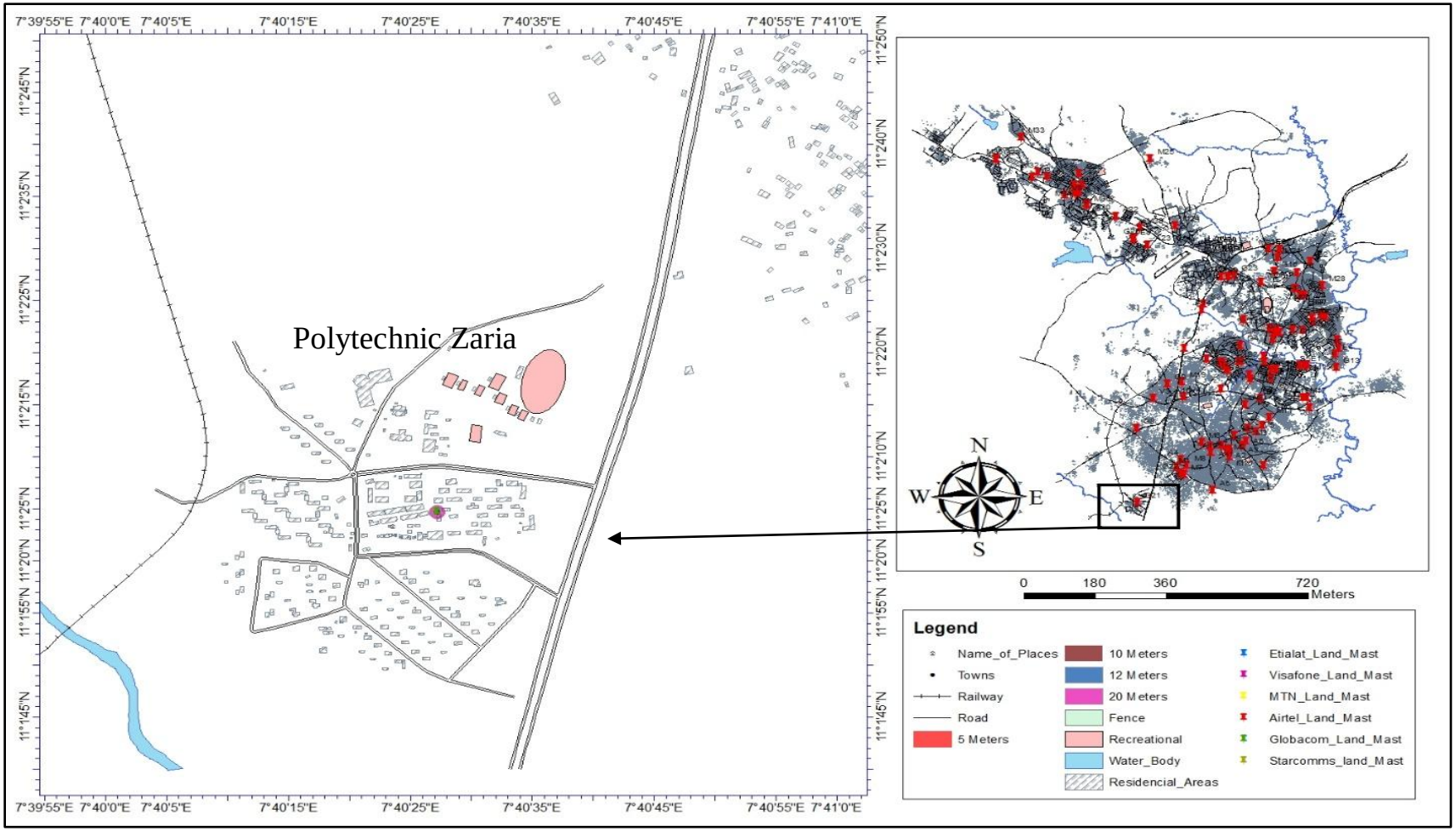


Fig 4.20: Buffered Zones around GSM Base Stations in NuhuBamalliPolytechnicZaria.

Source: Field Survey and Arc GIS, 2016.

This location according to the proximity analysis, has fallen within the buffer zone of 10m, therefore extremely disobeyed the WHO recognized standards.

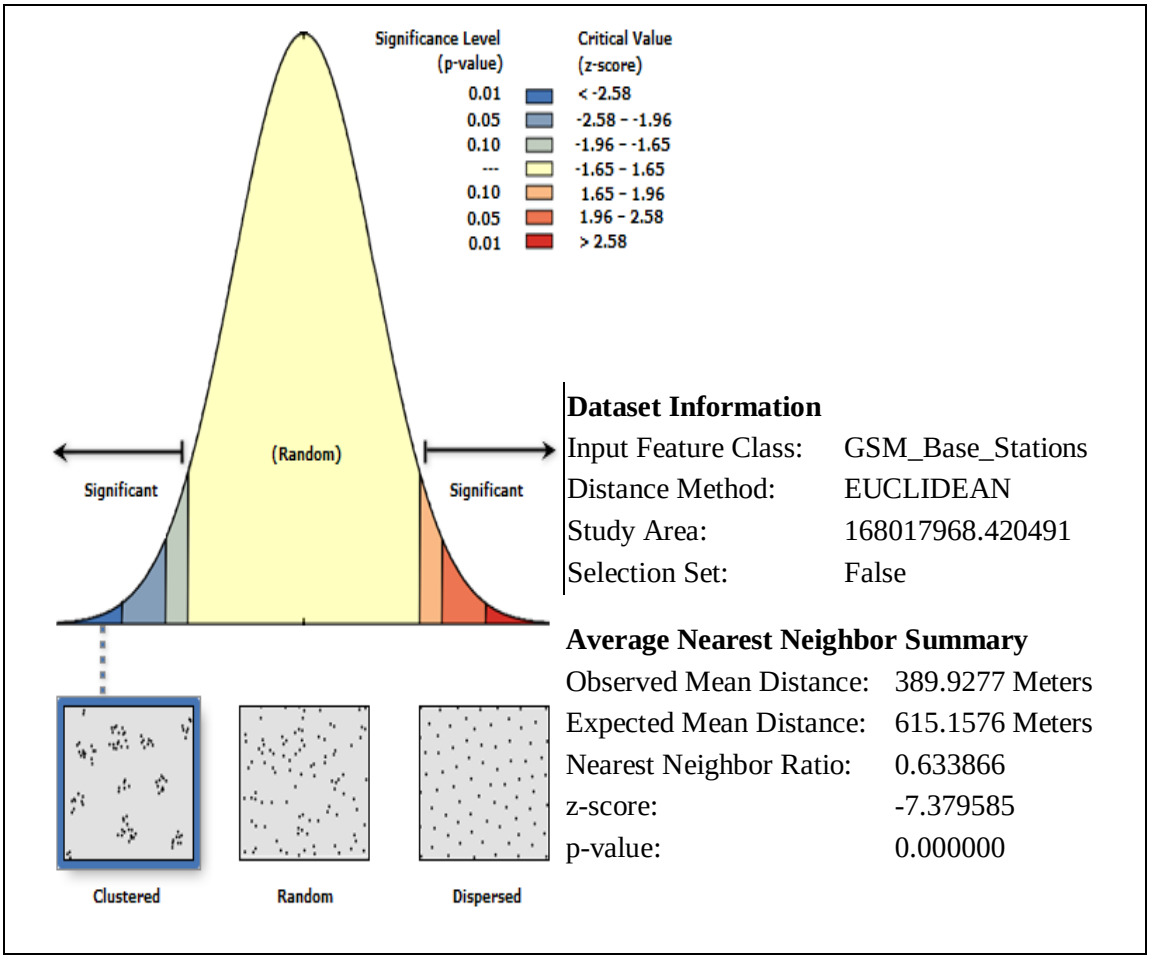
A general look at the scenario implies that, only 16 masts have agreed with the standard set by WHO, these areas are Bomo, Area G gate in ABU Main Campus, Department of Agriculture College (DAC), ABU Main Campus itself, Center for Energy Research Gate, ITN Zango, Tobacco company Chikaji, around barrack area Sabon Gari, Dan Magaji and ABU Congo Campus. Apart from these mentioned locations, all other areas in urban Zaria have suffered from indiscriminate installation of land masts which totally disobeyed the WHO recognized standards.Most masts are closer to homes signifying non-adherence to the minimum standard of locating masts. It has been deduced from the geospatial analysis that most service providers violate the established standards and located the facilities very close to where people live. Many factors are responsible for such indiscriminate installations;greediness of land owners, bribery and ineffectiveness of planning authorities and political influences might probably have been among others.

Therefore, residents living around GSM Base Stations are at high health risk of being affected by many diseases. These areas that are vulnerable include Danraka, Zango, Palladan, Kwangila, Dogarawa, Chikaji, Sabon Gari, PZ, Tudun Wada, TudunJukun, Danmagaji, Wusasa, Gyallesu, Zaria City and NuhuBamalli polytechnic Zaria. As seen mostof the study area is affected with electromagnetic radiation due to indiscriminate installation of land masts. This is true, because Emma (2012) disclosed that, increase in population growth and the easier access of communication between individuals has necessitates the increase in number of the facilities across the city, to the extent that residential areas has become signal transmitting stations. It is very common to find

erected mast located within residential areas in the study location. This further agrees with Aderoju, M., Godstime, J., Olojo, O., Oyewumi, A., Eta, J., Onuoha, U., Salman, K., Nwadike, K (2014), whose result within three Abuja districts (Utako, Garki and Wuse) shows that, all the 119 Base Transceiver Stations (BTS) sampled in his study area failed the 10m and 12m buffer zone tests, which makes the inhabitants around GSM Base Station at high health risk.

4.4 SPATIAL PATTERN OF THE LOCATION OF THE BASE STATIONS

To explain the degree of regularity, randomness or clustering, the nearest



neighbor analysis was done and the result of the analysis is shown in fig. 4.21

Fig 4.21:Spatial Pattern of the Location of the Base Stations.

Source: Field Survey and Arc GIS, 2016.

The Rn value calculated was 0.633866 which shows that the distribution of GSM Base station in urban Zaria are in Random form and the negative z scores with the value of -7.379585 shows that they are in clustered form. This implies thatmasts are sited randomly close to each other when viewed against the background of the area perimeter. The implication of this can be much. Some buildings would fall within intersections of danger zones and may be prone to multiple effects that may accrue from mast. The window period may be hastened and the effects of the rays from the masts be felt sooner than expected especially on residents in the houses within intersection of danger zones.

4.5 AREAS VULNERABLE TO THE HEALTH HAZARDS RELATED TO ELECTROMAGNETIC RADIATION AND HEALTH IMPLICATIONS FROM GSM BASE STATIONS

From the figure 4.22, 4.23 and 4.24 below a buffer of 10 meters was conducted as stated by the World Health Organization (WHO 2007). It is clearly shown that the residence that fall within the distances of 10m are vulnerable to electromagnetic radiation emitting from the GSM Base Stations in the entire district going by the WHO regulations. The figure 4.22, 4.23 and 4.24 below is simply a map showing settlement at risk with respect to radiation and early grave diseases from GSM Base Stations using the WHO standards of 10m. It has been deduced from the geospatial analysis that most service providers violate the standards issues by WHO which makes the inhabitants around GSM Base Stations at high health risk.

The analysis shows that most masts are closer to homes signifying non-adherence to the minimum standard of mast which is 10m as stated by the WHO. Due to large nature of the study area, the map is divided into three part in order to be display fully as shown in figure 4.22, 4.23 and 4.24.

4.5.1 Risk map of A.B.U main Campus to Hanwa G.R.A.

Figure 4.22, shows several locations of GSM base station from A.B.U main Campus to Hanwa G.R.A.

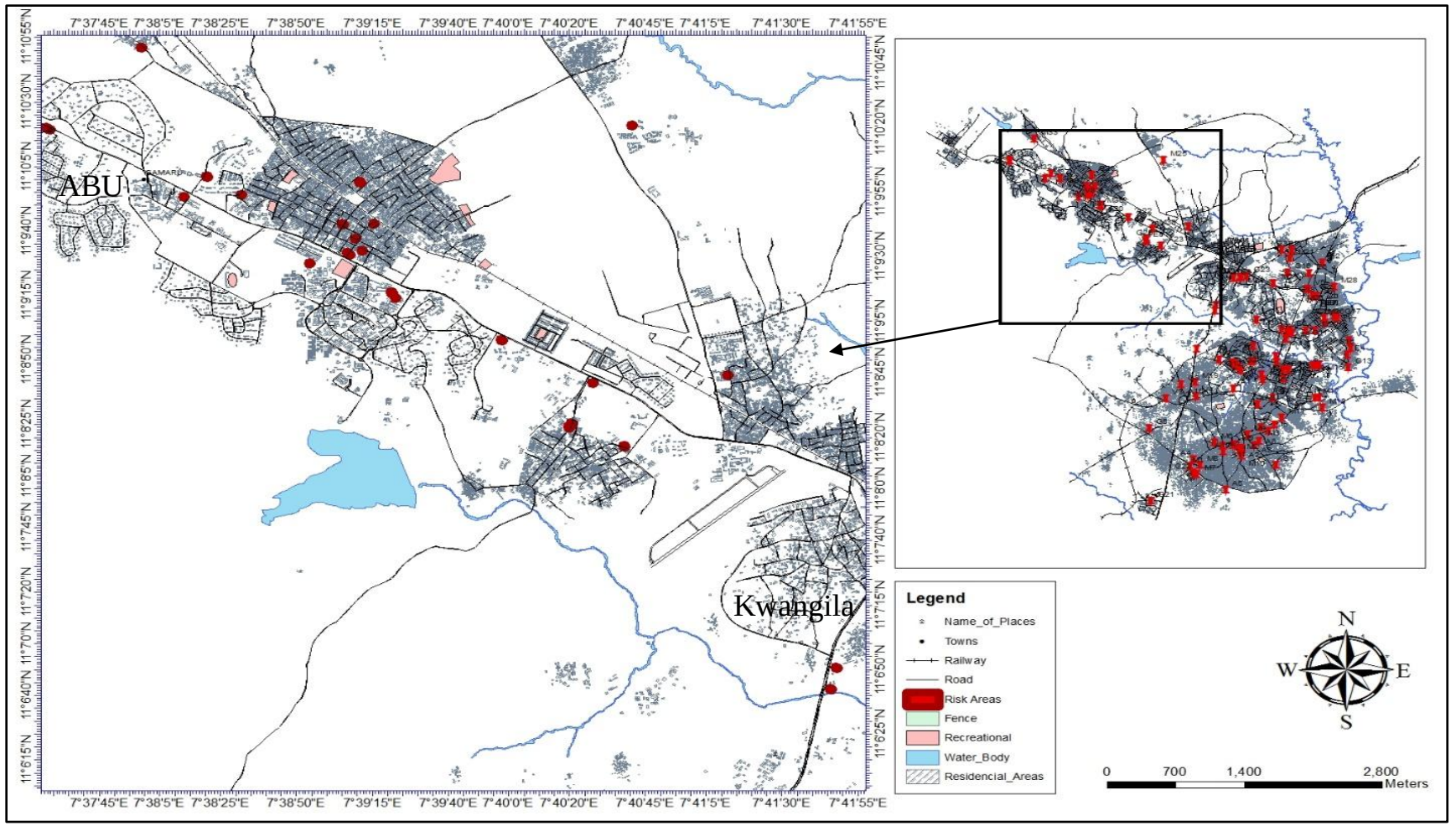


Fig 4.22: GSM Base Station Settlement Risk Map (A.B.U main Campus toHanwaG.R.A)

Source: Field Survey and Arc GIS, 2016.

Fig. 4.23, shows several locations of GSM base station within a buffer zone of 10m, these locations as shown by the figure are situated within so many residential places ranges from ABU Samaru to Hanwa GRA. Having fallen within such distance from residential buildings, the areas are considered risk locations in terms of the effect of electromagnetic radiation.

4.5.2 Risk map of Kwangila to Zaria City.

Figure 4.23, shows several locations of GSM base station from Kwangila to Zaria City.

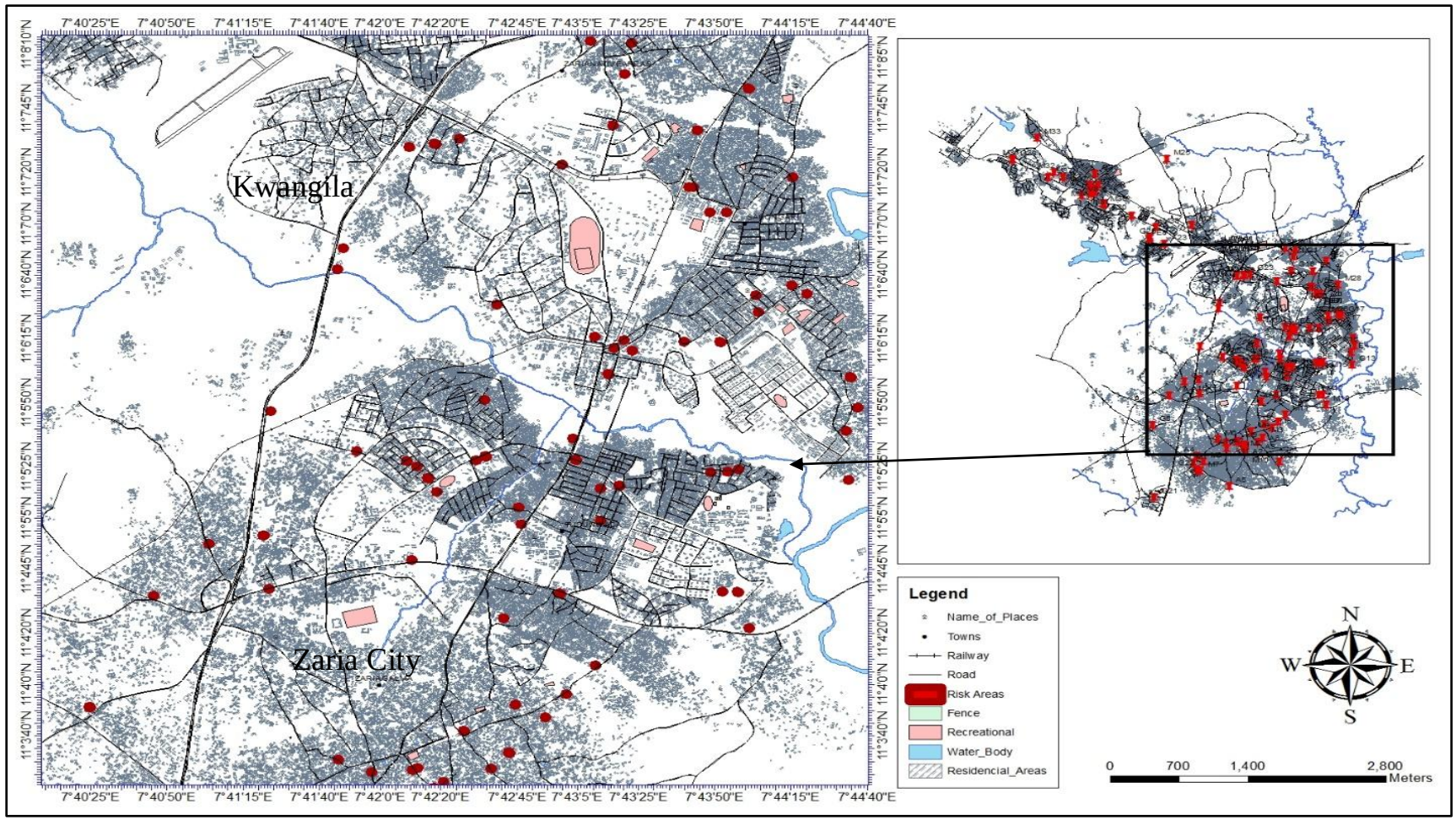


Fig 4.23: GSM Base Station Settlement Risk Map (Kwangila to Zaria City).

Source: Field Survey and Arc GIS, 2016.

Fig. 4.23, shows several locations of GSM base stations within a buffer zone of 10m. These locations are situated within so many residential places, ranging from Kwangila to Zaria City. Having fallen within such distance from residential buildings, the areas are considered risk locations in terms of the effect of electromagnetic radiation.

4.5.3 Risk map of Zaria City to NuhuBamalliPolytechnic Zaria.

Figure 4.24, shows several locations of GSM base station from NuhuBamalli Polytechnic Zaria.

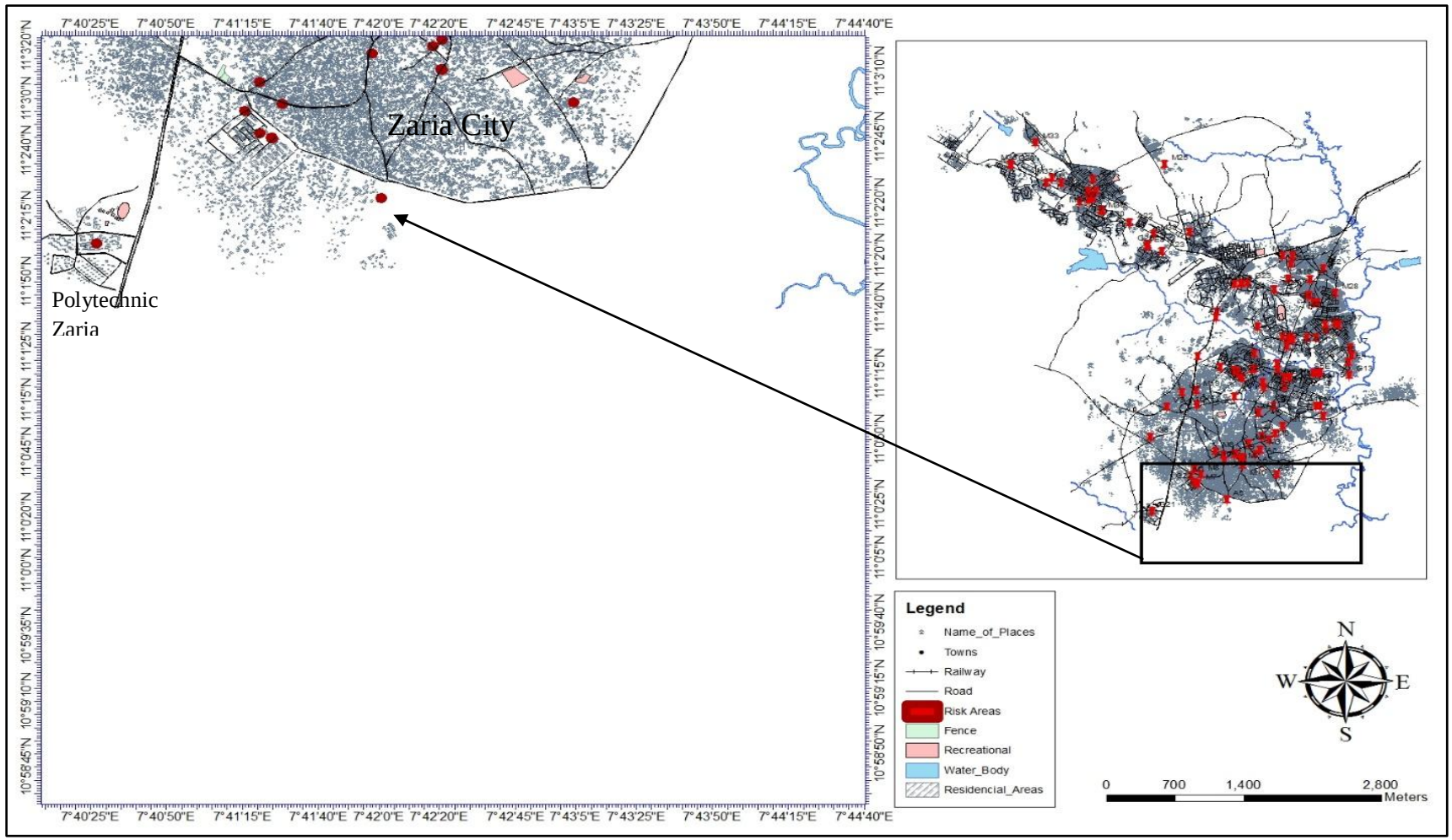


Fig 4.24: **GSM Base Station Settlement Risk Map (Zaria City to NuhuBamalliPolytechnic Zaria).**

Source: Field Survey and Arc GIS, 2016.

Fig. 4.24, shows several locations of GSM base stations within a buffer zone of 10m, these locations as shown by the figure are situated within so many residential places rangingfrom Zaria City to NuhuBamalliPolytechnic Zaria. Having fallen within such distance from residential buildings, the areas are considered risk locations in terms of the effect of electromagnetic radiation. it could be seen that, the spatial distribution of these facilities within the residential areas are not only incompatible with the established standards as shown by the proximity analysis, but also exposed such areas to the effect of electromagnetic radiation emitting from the Base Stations and subsequently leading to early grave diseases, such fatigue, headache, decreased concentration, dizziness, local irritation, tumour induction, sperm motility, morphology and viability, cancer, especially brain tumour and leukaemia, viral and infectious diseases.

This agrees with the observation made by Emma (2012), who discovered that, fumes from the generator emit carbon monoxide which could be harmful to respiratory organs when inhaled in large quantity and this may result to health implications or death. The noise causes pollution to the environment and this causes partial deafening of ear if it persists. The vibration from the mast may curse headache, sleeplessness and risk of brain tumor for people living around the area.

CHAPTER FIVE: SUMMARY CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the summary, conclusions drawn from the result of the data analysis as well as the recommendations made in order to draw attention of both the general public and policy makers towards the danger involved in the indiscriminate location of GSM base stations in the study area.

5.2 SUMMARY

This study employed the use of GIS techniques (Buffering, Proximity, Querying and Neighborhood) analysis in mapping and analyzing the spatial distribution of GSM Base Stations in Zaria Urban area, Kaduna State, Nigeria. It also examined the locational distance of each base station from Residential areas (educational, hospital, and child care centers) using (WHO 2007) standards.

Findings revealed that out of the 116 GSM Base stations in the study area most of the land masts were 5m, 10m, 12m and 20m buffer zone tests and it appear to be majority of the GSM Base stations did not met the World health Organization (WHO 2007) standards of 10m and 12m distance to Residential areas. The areas include Danraka, Zango, Palladan, Kwangila, Dogarawa, Chikaji, Sabon Gari, PZ, Tudun Wada, TudunJukun, Danmagaji, Wusasa, Gyallesu, Zaria City and NuhuBamalli polytechnic Zaria. only 16 land masts has agrees with the standards set by WHO, these areas are Bomo, Area G gate in ABU Main Campus, Department of Agriculture College (DAC), ABU Main Campus itself, Center for Energy Research Gate, ITN Zango, Tobacco company Chikaji, around barrack area Sabon Gari, Dan Magaji and ABU Congo

Campus. Also there is a relatively high degree of randomness of the masts within the study area because the Rn value calculated was 0.633866 and this is far from 2.15, or 1 but tends towards zeroand the negative z scores with the value of -7.379585 shows that they are in clustered form. All these GSM Base stations belong to MTN, Visafone, Etisalat, Startcomms, Globacom, and Airtel.

5.3 CONCLUSION

One may conclude that most of telecommunication masts location do not adhere to the minimum standards set for the sitting of masts by WHO. This implies that both in the short and long term, the livability of residents in Urban Zaria is impaired by the location of these masts. Very many residents are sitting on a time bomb and after some time, repercussions of exposure to these dangerous waves may come.

Masts are erected very close to sensitive areas like Residential areas (educational, hospital, and child care centers inclusive) without obeying the WHO planning standards, the health of the people is at risk if the mast does not obey minimum standard and this is due to noise from mast generator and vibration from mast, clustering of mast reduces the environment aesthetics. Sometimes the distance from one mast to another is not more than 10 meters talk less of 10 meters away from residential areas, in fact some of the masts share the same boundary with residential houses. More so Most masts are erected anywhere in the area to improve the operator's economy without considering planning sites. The major factor responsible for the substandard location in the study area is greediness of land owners, bribery and ineffectiveness of planning authorities and political influences.

5.4 RECOMMENDATIONS

The following preventive measures should be followed in order to make the environment and community safe from the effect of the masts. The study has therefore recommended that:

a. The regulatory agencies should keep checks on service providers that violate the 10m and 12 m of siting GSM Base stations away from residential areas as stated in the WHO regulations for telecommunication and broadcasting standards, It has been deduced from the geospatial analysis that most service providers violate the established standards and located the facilities very close to where people lives.
b. Telecom operators can come together to have one base station (mast) and each operator can connect with this base station. This reduces clustering of masts within an area
c. There should be proper awareness to the public on the possible health risk on people living close to a GSM Base stations. Because from the study the spatial distribution of these facilities are mostly within the residential areas.
d. World health Organization (WHO), Nigerian Communications Commission (NCC) in collaboration with the National Environmental Standard and Regulations Enforcement agency (NESTRA) should shut down the facilities of the operator that do not comply with the set standard.
e. A law should be enacted to punish land owners who release their lands for the telecom operators for installing mast without obeying the minimum standards set

by WHO, because many landlords are very inconsiderate; they just allow these telecom operators to fix their mast anywhere, not minding the side effect this can have on their tenant.

5.4.1 Areas for Further Studies

The following areas are recommended for further studies:

i. Further research should be conducted to assess the health status of residents before and after GSM revolution.

5.4.1 Contribution to Knowledge

The following are some of the contribution of this study:

i. Map were created that showed distribution or spatial location of existing land mass.

ii. The spatial pattern of the facilities was also recognised and this reveals the communities were the facilities are skewed were also identified within the study area.

iii. The study shows that most of the GSM base stations violates the WHO standard and thereby placing communities vulnerable to its related consequences.

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APENDIX

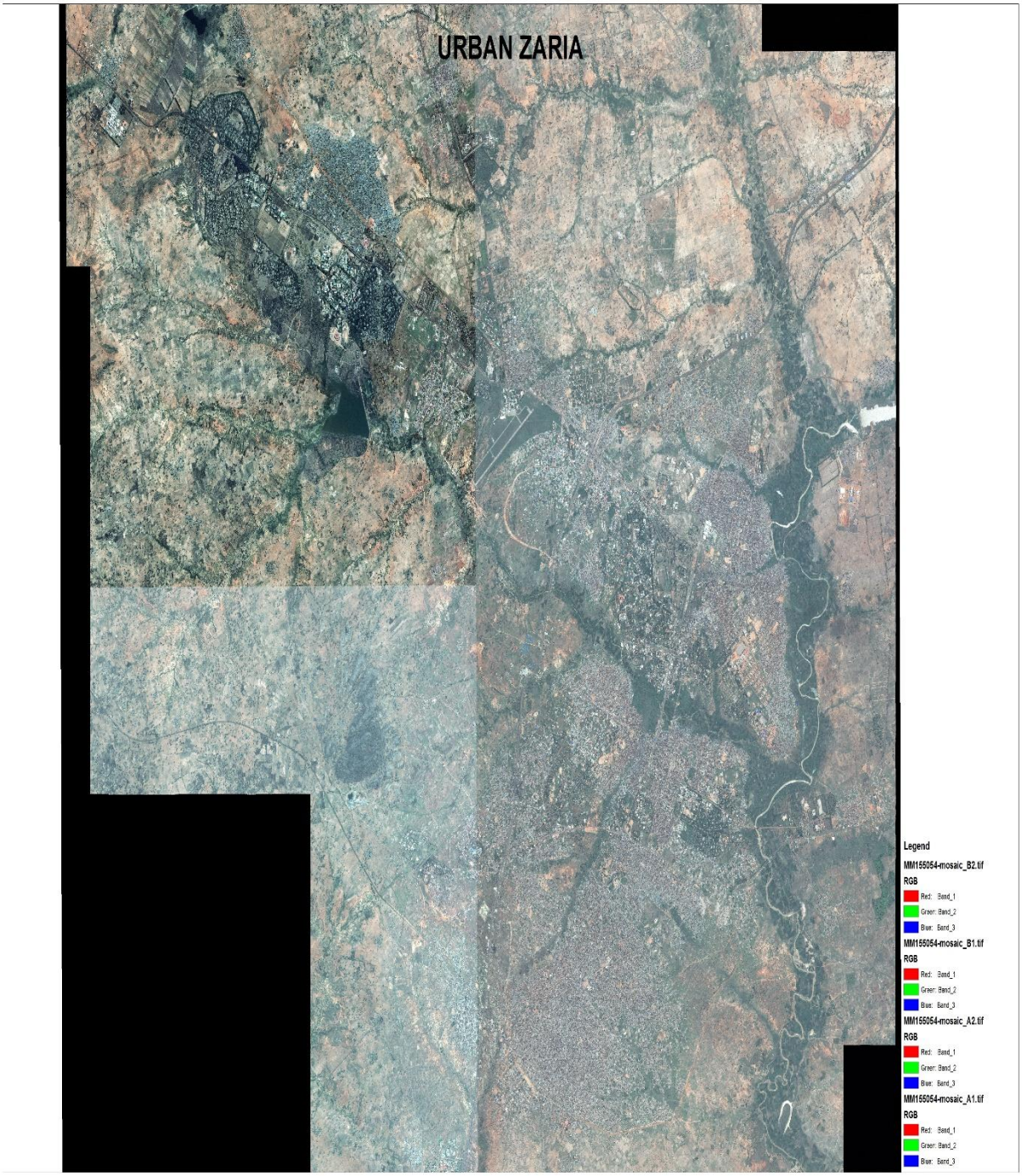


Fig 1: Quick bird Satellite image of Urban Zaria Area.

Source: Ministry of Land and Physical Planning, Bamayi House, No. 30. Sokototo Road, Kwangila, Zaria - Kaduna Nigeria.

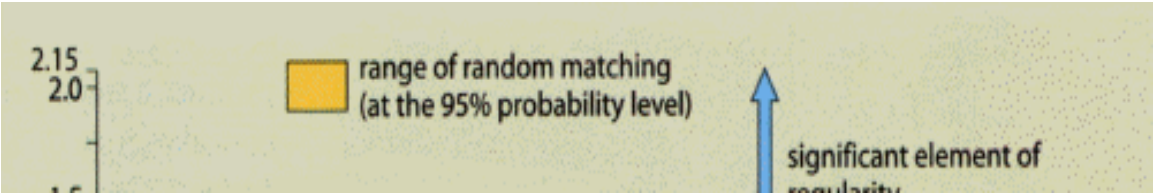


Fig. 1: Interpretation of Rn Value with range of random matching

Source: (David Waugh, 1996)