GEOSPATIAL ANALYSIS OF ENCROACHMENTS ON OIL AND GAS PIPELINE RIGHT-OF- WAY AND ITS EFFECTS ON THE ENVIRONMENT ALONG SYSTEM 2D PIPELINE, KADUNA STATE, NIGERIA

BY

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DECLARATION

I declare that this Dissertation entitled "Geospatial Analysis of Encroachments on Oil and Gas Pipeline Right of Way and its Effects on the Environment Along System 2D Pipeline, Kaduna State, Nigeria" is a record of my own research work under the supervision of Prof. I. J. Musa, and Dr. B. Akpu. The information derived from the literatures have been duly acknowledged in the text and a list of references provided.

DANIEL Julius Kundi _____ _____

Signature Date

CERTIFICATION

This dissertation entitled "Geospatial Analysis of Encroachments on oil and gas Pipeline Right of Way and its effects on the Environment along System 2D Pipeline, Kaduna State, Nigeria" meets the regulations governing the award of the degree of Master of Science in Remote Sensing and Geographic Information System (GIS) of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to all those who lost their lives to pipeline accidents in Nigeria.

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ABSTRACT

There is rapid urban growth in Kaduna State and this came with conversion of farmland and bushes into built-up areas. The pipelines and their associated Rights of Way (ROW) were laid and established since 1976 when there was less quest for land for residential and other purposes. With the recent increase in population and the consequent urban growth, more residential buildings are being constructed where there were none. This research took a geospatial approach to analyze the encroachments on pipeline ROW and its effects on the environment along System 2D pipeline, Kaduna State, Nigeria between 2003 and 2015. Google Earth images of the study area for 2003, 2009 and 2015 were obtained. System 2D extends from Kaduna Refinery to Kano Depot via Zaria Pump Station. However, the length of the system 2D pipeline covered in this study is eighty seven (87) Kilometers. The coordinates of the pipeline markers were obtained using a GPS (Garmin 62) and plotted in ArcGIS 10.1 to show the route taken by the pipeline. A 25metres buffer was activated on the route taken by the pipeline to delineate the Right of Way. The satellite images for each of the years were georeferenced and the images were classified into built up, farmland, bare land and water bodies for each of the years using supervised classification. The ROW layer was then overlaid on the classified images for each of the years to delineate the encroachments on the ROW. The three images were overlaid on each other to show the encroachments on the ROW for each of the years and for each of the settlements. The results of the study showed that the pipeline traversed sixteen (16) settlements. Refinery Junction, Mahuta, Kamazou, Bagado, Keke, Saye, Kufena, Zaria Pump Station, Hanwa and Dogarawa had built up areas that encroached on the ROW, while Kakura, Kangimi, Kargo, Rigachukun, Jaji and Sabon Yelwa had encroachments on the pipeline ROW by farmlands. Hanwa had the highest encroachments on the ROW by buildings as at 2015, covering an area of 15.99 hectares, while Kakura had the highest encroachments on the pipeline ROW by farmlands, which was 27.26 hectares. The total encroachments on pipeline ROW by built up was 15.97%, 20.17% and 24.29%, while the total encroachments by farmlands was 84.03, 79.83% and 75.71% for 2003, 2009 and 2015 respectively. The study recommended more enlightenment on the dangers of encroachments on Pipeline ROW, improved surveillance and introduction of Aerial/Satellite monitoring of Pipeline, clearing of the ROW, replacing of ageing pipelines by the PPMC as well as discouraging farming activities on the ROW, as it exposes the pipelines to harsh environmental conditions and to vandals.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Around the world, the rate of failure in the transportation of petroleum products by rail and road was very high in the 1960s-70s with negative consequences to the environment and loss of lives (Ikelegbe, 2006). Distribution of petroleum products through Pipeline is preferred over road and rail transportation because of its relative safety, speed, efficiency and cost effectiveness. This has led to the rapid expansion and growth of pipeline networks in Nigeria and other parts of the world (Brume, 2007; Dey, 2004).

The oil and gas Pipeline network in Nigeria is a system of pipes designed for the haulage of petroleum-based products over long distances. These systems of pipes were designed to carry either mixed or monotype fluids from one part of the country to another (Agbazie, 2004). They are used to transport crude oil and its derivatives from the oilfields to the terminals where they are either exported or used as raw materials by refining plants to produce end products. These products include Premium Motor Spirit (PMS), dual purpose kerosene, aviation turbine kerosene for local consumption in Nigeria and for export to other countries within the West African sub Region (Ekwo, 2011).

The Rights Of Way (ROW) for the petroleum pipeline in Nigeria refers to the 50m distance spanning the pipelines within which other land uses are not permitted (Brume, 2007). The oil and gas pipeline network in Nigeria presently measures over 7,000km in length (Agbazie, 2004). The pipelines were laid in 1976 and they occupy vast tracts of land across the country, ranging from the oil wells in the Niger-Delta to the

Kaduna refinery and other depots in the Northern parts of the country such as Gusau, Kano, and Maiduguri (Nnah & Owei, 2005).

Pipelines had provided an effective means of transportation to depots and receiving terminals for all petroleum products across the length and breadth of Nigeria before the advent of vandalism and sabotage in the 1990s. The pipeline network is also used to transport petroleum products to export terminals and platforms, with comparative advantages over road and rail transport in terms of cost and speed (Ekwo, 2011).

In Nigeria, the pipelines have suffered a series of acts of vandalism and sabotage over the past decades, to the extent that the Nigerian Government had contemplated the option of burying the pipelines 12m below the surface of the earth, where they will be less vulnerable (Chika-Amanze & Edomaruse, 2007). This option though unsustainably expensive, would also serve only as a temporary measure, because the ROW of the petroleum pipelines will still be encroached upon, thereby putting the lives and properties within it at risk.

Wherever the pipes were laid, a buffer zone called "the rights of way" was created. The pipes are buried about 1metre beneath the earth's surface to avoid accidental contact with other land-based activities (Ogundele, 2007). Although this precautionary embedding is applied along the pipelines, recent experiences have shown that its integrity and safety is incessantly compromised by acts of vandalism aiming at the theft of the petroleum products transported through it. Generally, property owners are prohibited from installing any structure, storing anything that could be an obstruction, or planting trees or shrubs along the right-of-way (ROW). Unauthorized buildings, planting or

excavation along this path is known as ‘encroachment on pipeline Right-Of-Way’ (Ekwo, 2011).

To enhance the distribution of crude oil products from the Niger Delta to other parts of the country, the network of oil pipelines was extended to link all the states at strategic locations. The network of pipelines consists of multi-product and crude oil pipelines across the country, linking the 22 petroleum storage depots, the four refineries at Port Harcourt (I and II), Kaduna and Warri, and the off-shore terminals at Bonny and Escravos. Other installations also connected by the network of pipeline include the jetties at Atlas Cove, Calabar, Okirika and Warri (Ekwo, 2011).

The North American Resource Development Subgroup (2011) observed that the leading causes of significant pipeline incidents in America are excavation damage, corrosion, and encroachments on pipeline ROW. These have been addressed through improved technologies, although industry emphasis in the past focused on detection as a higher priority than prevention. They submitted that solutions must include not only improved encroachment-detection technologies but also establishment and enforcement of regulations to prevent and document incidents of excavation-related damage.

The NNPC pipeline network is classified into systems 2A, 2AX, 2B, 2C, 2CX, 2D, 2DX, 2E and 2EX. System 2A connects Warri refinery to Auchi and Ore. System 2Bconnects Mosimi to Ilorin via Ibadan. System 2C connects Warri refinery to Kaduna refinery. System 2CX connects Auchi to Sarkin Pawa in Niger state via Abaji. System 2D connects the Kaduna refinery to Kano and Gusau Depots via Zaria pump station. It also connects Kaduna refinery to Jos. System 2E connects Jos to Maiduguri via Gombe and Biu. System 2E connects the Port Harcourt refinery to Yola via Enugu and Makurdi

depots (Agbazie, 2004). However, this research considers a part of the system 2D (Kaduna – Zaria – Kano Pipeline).

Kaduna state is witnessing urban growth especially in terms of structural development. More residential buildings are being constructed in places where there were none (Max Lock Centre, 2008). Cursory observation revealed that the bushes through which these pipelines traverse in the past are now being used for residential and other purposes. People acquire and develop plots of land without caution or minding the risks associated with such developments thereby encroaching on the pipeline ROW.

In order to manage and monitor the ROW, geospatial techniques such as Geographic Information System (GIS) and Remote Sensing have proved to be effective in monitoring this national infrastructure. GIS has the ability to integrate data from different sources and to provide up-to-date information through satellite imagery and an efficient decision support system. GIS is a system of computer hardware, software and people that stores, retrieves, inputs, outputs and analyzes spatial data in order to make better decisions. Geospatial techniques have an established record in the pipeline industry for assuring regulatory compliance and integrity management. Pipeline operators rely on geospatial techniques for data maintenance and operational management. Key uses include field data collection, environmental and land management; as well as Rights-Of-Way monitoring (Agbakwuru, 2011). This work will therefore analyze the encroachments on the ROW and the risks associated with such encroachments.

1.2 Statement of the Research Problem

In ensuring the safety of the grid of oil and gas pipelines, the government acquired a 25 metres right-of-way on each side of the pipelines before they were laid and the pipes were buried a meter deep to prevent accidental contact with land-based activities (Ogundele, 2007). However, recent events have shown that the integrity and safety of the pipelines have been compromised by vandals who tap into them resulting in damages and ruptures that affects lives and property within the ROW.

The oil and gas pipelines were laid in 1976, when there was less pressure on land for residential and other purposes (Nnah & Owei, 2005). They were laid far away from residential or built up areas. With the recent population explosion in urban centres, (Kaduna in particular), these bushy areas (where the pipes were laid) are rapidly being converted to other land uses, thereby encroaching on the pipelines ROW. No developmental activity of any kind is permitted on the ROW. This is because in the event of an explosion or pipeline failure, lives and properties would be safe from the disaster. Another reason is that in case of any pipeline maintenance that would involve excavating the surface of the earth, people and their property will not be displaced (Brume, 2007).

Observation revealed that physical development was going on within the ROW of oil and gas pipelines. Some of these structures may have been built right on the pipeline. A broken pipeline marker lying at the entrance to a shop kindled the researcher's interest. In some areas, farming activities have dominated the ROW. Despite the pipeline markers and caution signs by the NNPC on the dangers and risks of encroachments on the ROW, people throw caution to the wind, went ahead to build and raise structures on the ROW.

The consequences of poor management of the ROW of the petroleum pipeline range from the loss of thousands of lives; fire outbreaks on vandalised pipelines; and pollution of the environment; to loss of income by the government and the scarcity of refined petroleum products in the country. There has been several oil spills, some of which resulted in fire outbreaks, land and water pollution, respiratory stress and acid rain, which depress agricultural yields, and the most affected areas are those within the pipeline ROW (Odoh and Iyi, 2005). For instance, Francis (2011) found out that between 1976 and 2001, a total of 6744 spill incidents took place in Nigeria, resulting in approximately 2,369,470 barrels of oil being spilled on the environment. As earlier stated, a considerable proportion of the pipelines ROW in the study area have been covered by human settlements and vegetation. Hence, the need to assess the encroachments on the ROW along System 2D through the application of Geospatial techniques.

Chastian (2009) carried out a study on pipeline related accidents in the US. The author found that in recent years, there are major pipeline incidents resulting in loss of life, serious injury and/or major property damage in the United States and the most vulnerable areas are those that have encroached on the ROW. It was therefore, suggested remotely piloted aerial patrol drones, fiber optics, seismic sensors and acoustic impact detection systems can be used.

Gauthler, Maloley and Fung (1997) carried out a research on land cover anomaly detection on pipeline ROW, and reported that High spatial resolution black and white photographs have been used for pipeline monitoring for several decades. They demonstrated how new digital remotely sensed image data can be applied to enhance

some of the routine environmental operations and provide cost benefits to these operations for pipeline right-of-way monitoring.

Gauthler, Maloley and Fung (2001) examined the use of Remote Sensing data in monitoring pipeline ROW and submitted that the visual surveys do not produce adequate spatial documentation that can be used in modern GIS corridor management systems. Traditionally, such small-scale detection exercises have been done visually from an airborne platform with an experienced human observer (often referred to as a line patrol). While this is an effective means of monitoring a corridor passing through populated areas, it is often not performed on a regular basis in inaccessible areas where the costs of such airborne visual surveys can become very high.

Agbakwuru (2011) examined the advances in pipeline third party encroachment alert systems and leak control methods in the oil/gas industry. The research highlighted the extent of spill/pollution issues in the Niger Delta region due to intended/unintended damages and suggests a possible method of control. Acoustic monitoring of change in the operational sound generated from a given pipeline section is suggested to be practicable to identifying sound abnormalities of third party encroachments. The suggestions from the research is that a combination of impressed alternating cycle current (IACC) which traces encroachment on the pipeline coating and an acoustic system be used to manage intended and unintended pipeline potential damages.

Ekwo (2011) carried out a research on collaboration-based management of petroleum pipelines ROW in Nigeria. The research examined the management practices of ROW on systems 2A, 2C and 2E pipelines. The findings of the research showed that the most affected communities in cases of fire outbreaks and pipeline ruptures were those

that have encroached on the ROW. The findings also revealed that most of the pipeline ROW had been covered by both residential and commercial buildings, as well as activities like welding, auto-mechanic workshops, and trading were carried out on the ROW.

To the best of the researcher's knowledge, no research had been carried out on encroachments on pipeline ROW along the system 2D pipeline. This gap identified addresses the research problem, which is assessing the encroachments on pipeline ROW and its effects on the environment.

This research attempted to answer the following research questions;

1. Is there a defined ROW?
2. What is the extent of encroachment on the ROW between 2003 and 2015?
3. Which land uses have encroached on the ROW?
4. What are the factors responsible for these encroachments?
5. What are the environmental effects of these encroachments?

1.3 Aim and Objectives

The aim of this research was to assess the encroachment on oil and gas pipeline ROW along the System 2D pipeline network and its effect on the environment using Geospatial techniques.

This was achieved through the following specific objectives which are to:

i. identify and map the ROW;

ii. determine the extent of encroachment on the ROW between 2003 and 2015;

iii. identify the land uses that have encroached on the ROW;

iv. examine the factors responsible for the encroachments;

v. examine the effects of these encroachments on the environment.

1.4 Scope of the Study

This research examined the encroachments on the ROW between Kaduna and Zaria (2003-2015). The choice of temporal scope for this research was based on the data available. The System 2D pipeline network connects Kaduna Refinery to Kano and Gusau Depots via Zaria Pump Station. However, this research is limited to a segment of this pipeline, that is, from Kaduna Refinery to the boundary of Sabon Gari Local Government Area in Zaria. The study considers part of the pipeline that traverses Chikun, Igabi, Zaria, and Sabon Gari Local Government Areas. This research analyzed the land uses that have encroached on the ROW within the period. The extent of encroachment was also determined. The causes and environmental effects of encroachments were also examine by the study. The portion of the environment considered in this study was only the fifty (50) metres buffer representing the ROW.

1.5 Justification for the Study

The scope and complexity of right-of-way activities require the use of modern technologies to streamline some of the implementation processes, particularly those involving mapping, inventory, and information storage and retrieval. Over the years, utility companies have effectively used surveillance, hybrid mapping and database management system popularly known as automated mapping/facility management (AM/FM) to manage and maintain their utility network systems.

The main advantage of geospatial techniques over other methods of pipeline ROW management such as aerial surveys is faster information retrieval. The task of converting and maintaining documents in digital form remains a prerequisite to some potentially great advantages. The greatest advantage of GIS can be attributed to the superior graphic image obtained, which is much easier to interpret than tabular data, and greatly enhances the speed of decision-making.

This study demonstrated a Geospatial based method for demarcating the ROW of petroleum pipelines. The results of the analysis from this research will also serve as a warning to people or property owners whose property have encroached on the pipeline ROW on the risks associated with this act. The result from this study will aid the Pipeline and Product Marketing Company (PPMC) to be proactive in decision making regarding ROW management. The Kaduna State Urban Planning and Development Authority (KASUPDA) will find this document useful in development control along the pipeline ROW corridor in the study area.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter is designed to provide a detailed review of concepts that relate to the topic of discussion as well as the accessible literatures on the challenges associated with the management of pipelines and their ROW.

2.2 Conceptual Issues

2.2.1 Right of Way (ROW)

Right of way is a term used to describe "the legal right, established by usage or grant, to pass along a specific route through grounds or property belonging to another", or "a path or thoroughfare subject to such a right". A further definition is that it is a type of easement granted or reserved over the land for transportation purposes, this can be for a highway, public footpath, railway, canal, as well as electrical transmission lines, oil and gas pipelines (Paul, 2001). The ROW allows pipeline operators access for inspection, maintenance, testing or in an emergency; it also helps to identify areas where certain activities are prohibited to protect public safety and the integrity of the pipeline.

Pipeline ROW can be identified by the pipeline markers – located at roads, railways, and other intervals along the ROW – which include the name of the operator, emergency contact information, and a general description of the product in the pipeline. ROW must be kept free of buildings, trees, storage materials and other obstructions. ROW clearing, tree trimming and removal are part of the routine maintenance carried out by the pipeline operators, and are necessary to maintain the integrity of the pipeline and to facilitate ground and aerial inspection (Paul, 2001).

Generally, property owners are prohibited from installing any structures, digging, storing anything that could be an obstruction, or planting trees or shrubs along the right-of-way. Unauthorized building or planting in the pipeline right-of-way is known as right-of-way encroachment. Pipeline operators will regularly conduct aerial and ground inspections to check right-of-way conditions, test for leaks, install and maintain pipeline makers and to clear bushes that restricts access to the right-of-way or visibility during inspections. Rights-of-way are kept clear so the pipeline operator can safely operate, inspect, maintain and repair its pipelines.

2.2.1.1 Types of Right Of Way

1. Private Right of Way

A Private Right of Way is a type of ROW that allows an individual access to a property owned by another person to reach a public road. This type of ROW is common for properties that are landlocked and impossible to access by foot or by vehicle without going through another person's property.

2. Property Right of Way

Property Right of Way is a type of ROW that allows individual access to a property owned by another person to reach a different location. This type of ROW is common for properties that are adjacent to another property owned by a different person, which has the only access to a public area such as a swamp, lake, or river .

3. Public Right of Way

Public Right of Way is a type of ROW that allows the public to travel over a private piece of land unhindered. This type of ROW is in reference to sidewalks and roads that are adjacent to private land.

4. Pipeline Right of Way

The pipeline ROW in most cases is used to construct, operate, protect, inspect, maintain and/or replace one or more pipelines. Rights-of-way vary in width; depending on whether there is one pipeline or multiple pipelines within the ROW. The pipeline ROW are often recognizable corridors that are clear of trees, buildings or other structures except for pipeline markers. Another thing that might be seen is a fence and secured area with some above ground piping; these secured areas provide access to valves along the pipeline system (Paul, 2001).



Figure 2.1 An ideal Pipeline ROW
Source: (Paul, 2001)

2.2.1.2 Pipeline as a means of Transportation

Safe pipeline transportation of energy resources is a major concern for the public and the pipeline industry. Today, the pipeline owners and operators are under increasing pressure to produce accurate maps of pipeline routes to assure safety in design, construction, operation, maintenance, and emergency response of pipeline facilities. Pipeline safety problem starts before the actual construction begins and exists in the all life cycle of a pipeline since it has been built and been placed into services. Since a pipeline has been built and buried, geologic hazards, corrosions and third-party damages all pose cumulative internal and environmental risks to the pipeline's integrity. Excavation damage is the single greatest cause of pipeline failures with all other underground utilities being equally vulnerable.

The most widely used methods for pipelines monitoring include foot patrols along the pipeline routes and aerial surveillance using drones, small planes or helicopters. These patrols perform facility inspections, check for construction activity in the vicinity of the pipeline, and maintain the pipelines' ROW. Heavily congested areas are inspected and patrolled more frequently. In addition, the pipelines undergo periodic maintenance inspections, including leak surveys, and safety device inspections so the developments and events that could place high-pressure on pipelines, the surroundings of pipelines or security of supplies at risk could be prevented. In a continuing effort to remove the guesswork from pipeline operations and reduce costs, many new techniques have been employed to develop software and hardware systems that analyze pipeline risks and maintenance needs in a scientific fashion.

2.2.2. Pipeline Accidents

Natural gas, crude oil and petroleum products represent the main products transported by pipeline networks. Generally, pipeline transport risk is defined as the product of the probability of leakage or bursting and the related magnitude (Muhlbauer, 1996). Moreover, an accident is classified according to the probability that a loss (or release), a hole or a rupture can occur in a pipe. So, in a quantitative risk analysis, safety and security must be evaluated by decision makers and planners both analytically and statistically. The main types of pipeline accidents as well as the main factors that directly or indirectly may lead to them are described below.

2.2.2.1 Types of Pipeline Accidents

Several types of accidents have been identified by the gas and oil pipeline industry

a. *Third parties* that represent a damage caused by operations carried out by others in the pipeline vicinity and not related to its management;

b. *Corrosion*, when pipeline is subject to two types of corrosion, the first one is an inside corrosion, derived from water or other substances transported with hydrocarbons (viscosity and temperature are crucial information for the accident analysis), the second one is an outside corrosion related to the pipe coating and cathodic protection*;*

c. *Mechanical failure i.e.* fractures or cracks that occur when efforts go beyond the efforts of the system permits*;*

d. *Operational error*, which are caused by excessive pressure or system malfunction;

e. *Natural events* such as landslides, floods, erosion in general, subsidence, earthquakes, frost or lightning.

2.2.3 The Nigerian Petroleum Pipeline in History

The development of oil and gas pipelines in Nigeria started with the discovery of oil in commercial quantities oil in 1956 at Oloibiri in the Eastern Niger Delta region after half a century of exploration activities. The discovery was made by Shell-D'Arcy (later changed its name to Shell BP), which was a joint venture between the Shell Royal Oil Company and British Petroleum. At the time, this company was the sole concessionary of oil and gas exploration over the whole of the territory of Nigeria (NNPC, 2002). Pioneer production began in 1958, with foreign multinational oil companies spearheading the building of Nigeria's national oil and gas infrastructure, including the pipelines which they solely owned as well. The average daily production from the Oloibiri Oil field was estimated at 5,100 barrels (NNPC, 2002). Further expansion in the pipeline occurred in 1960 when exploration rights in onshore and offshore areas adjoining the Niger Delta were extended to other foreign companies. In 1965, another oil field was discovered by Shell in the shallow water southeast of Warri, and soon afterwards, pipeline was extended to this oil field.

By the late 1960s and early 1970s, Nigeria had attained a production level of over 2 million barrels of crude oil a day from its oil fields, which had increased to a total of ten. It was necessary to extend the pipeline network to all of them in order to evacuate crude oil to the export terminals for onward transport to Europe and America. Although production figures dropped in the 1980s due to the economic slump of the mid 1990s, this did not affect the pipelines already built; further expansion was, however, halted until the beginning of 2004, which saw the total rejuvenation of oil production to a record level of 2.5 million barrels per day, with a projected estimate aimed at increasing production to 4

million barrels per day by the year 2010. This has enormous implications for expansion in the network of petroleum pipeline to connect the new oil fields being developed across the coastal areas of the country. Petroleum production and export, which mainly depends on transportation through the pipelines, play a dominant role in Nigeria's economy and has over the past three decades accounted for about 90% of its gross earnings (Duruigbo, 2004).

2.2.4 Systems of Pipeline in the Pipeline Network in Nigeria

Oil pipeline operates in the form of discrete systems, conveying both crude and refined petroleum products to all parts of the country. The pipelines, most of which are owned by the NNPC traverse many communities, transporting petroleum products to different parts of the country. The multi-product pipelines transport oil from the refineries and import jetties located along the coast to the 22 storage depots located in disparate locations nationally. The four refineries are located in Kaduna (1), Port Harcourt (2) and Warri (1). While the refineries in Port Harcourt and Warri are strategically located within the oil rich Niger Delta region, in fulfillment of the industry localisation factor of nearness to raw materials (Jones and Holt, 2002), the location of the refinery in Kaduna is based on both political exigency and the location of the market for the refinery’s products. Apart from the refineries, there are two offshore terminals at Escravos and Bonny, and four jetties located at Okrika, Atlas Cove, Warri and Calabar, all of which are connected to the pipeline network.

The pipeline in Nigeria are systematically named. The Systems Nomenclature of the pipeline network in Nigeria is given below:

1. System 2A Warri–Benin–Ore–Mosimi
2. System 2AX Auchi–Benin
3. System 2B (a) Atlas Cove–Mosimi–Ibadan–Ilorin

   (b) Mosimi–Satellite (Ejigbo in Lagos)

   (c) Mosimi–Ikeja
4. System 2C Escravos–Warri–Kaduna (crude lines)
5. System 2D (a) Kaduna–Zaria–Kano–Zaria–Gusau

   (b) Kaduna–Jos–Gombe–Maidugiri
6. System 2E PH–Aba–Enugu–Makurdi
7. System 2EX PH–Aba–Enugu–Makurdi–Yola
8. System 2CX (a) Enugu–Auchi (interconnection)

   (b) Auchi–Suleja–Kaduna

   (c) Suleja–Minna
9. System 2DX Jos-Gombe

System 2A runs from Warri refinery to Mosimi via Benin and Ore. System 2B connects Mosimi and Ikeja. The system 2C pipeline has its origin at Escravos in Lagos state. It is a crude oil supply system that runs through Warri to Kaduna. This system is the crude oil supply channel to the refinery in Kaduna. The 2C system is a long distance pipeline that traverses seven states and four geopolitical zones of the country. Another system of pipeline that is also composed of sub-systems is the 2D. This system has its origin in Kaduna and runs through to Gusau in the North West and Maiduguri in

northeastern zones. The two sub-systems are the Kaduna–Zaria–Kano–Zaria–Gusau and Kaduna–Jos–Gombe–Maiduguri sub-systems. The 2D system operates only in the northern region of the country (Ekwo, 2011).

System 2E originates at Port Harcourt, and runs through Aba and Enugu, terminating in the Makurdi products distribution depot. This system is a major supply source that cuts across Rivers, Abia, Enugu and Benue States. System 2DX originates in Jos and operates only to Gombe, supplying products between the two states; while the 2CX System consists of three sub-systems, namely: the Enugu–Auchi interconnection sub-system, the Auchi–Suleja–Kaduna sub-system and the Suleja–Minna. This system is the longest in the network of pipelines in Nigeria (Ekwo, 2011).

Oil and gas pipelines were buried one metre below the surface of the earth. However, because of the undulating nature of land surface in Nigeria, a considerable length of the pipeline can be seen either on or above the ground. The ROW measuring 25 metres wide are specifically acquired by the government throughout the communities traversed by the pipelines in Nigeria (Abolurin, 2008; Brume, 2007). The initial oil project of 1956 needed no protection because the people in the communities traversed by the pipeline saw it as a form of government presence which they were obliged to protect; however, the pipeline became the object of vandalism in the 1980s in the Niger Delta region. Acts of vandalism continued throughout the 1990s to the northern region, and had implications for land contamination, oil spillage and loss of products valued in billions of dollars (Onuoha, 2008).

2.2.5 Pipelines and Oil Transportation in Nigeria

The relative economic advantage, administrative convenience and speed of oil product transportation by means of pipelines, already established in other countries like India, Britain and Canada, was relied upon in the rapid post-oil discovery activities in Nigeria (Nwilo & Badejo, 2006). In the last two decades, petroleum industry has become of strategic importance in the Nigerian economy, accounting for as high as 78 percent of Gross Domestic Product and up to 90 percent of the country's total annual revenue and foreign exchange earnings (National Bureau of Statistics, 2008). Movement of products from depots to service stations numbering several thousands of kilometers - where they are retailed to the final consumers all over the country involves the use of road as the mode of transportation and the products are moved by large trucks. Rail transport was the first mode that was used for the distribution of petroleum products in the early 1960s, subsequently; road transport was then engaged in the distribution while pipeline was used lately. The state of the railway system gave rise to the usage of road transport as a major mode of distributing petroleum products while pipeline transport is limited due to underutilization and vandalization. Movement of products in large quantities sometimes necessitates the use of sea as the mode of transportation. Marine tankers and coastal vessels are used for coastal transportation of petroleum products and to ferry from the coastal refineries of Warri and Port Harcourt, to Lagos.

The most suitable means of transportation of liquid substance is the pipeline. Hence PPMC uses pipelines frequently to convey products from refineries to depots which are located in strategic places across the country. However, according to Kupolokun (2006), over 75% of the pipelines have been vandalized, and are not currently

in use. The petroleum products available for distribution through an elaborate 3,949 kilometres of pipelines used to be intercontinental to 21 widely dispersed depots. The products were obtained either from the four local refineries or in the event of a supply short-fall from offshore refineries by way of import of processed Nigerian crude oil. In some cases, and mostly through vandalization, these pipelines burst into flames, causing serious damages to life and property. By multiplier effect, the environmental, economic and social negative impact of such damages is usually enormous. In most cases, the four refineries produce about 61% of the total petroleum needs of the country. The distribution of petroleum products is facing a lot of challenges in the Nigerian environment (Ehinomen and Adeleke, 2012).

2.3 LITERATURE REVIEW

2.3.1 Distribution of Petroleum products in Nigeria

Ehimomen and Adeleke (2012) assessed the distribution of petroleum products in Nigeria. The findings of the study revealed that low capacity utilization of refineries poses a lot of challenge to NNPC on the distribution of petroleum products, which result to petroleum products shortage and eventual importation of the products. This study only examines the capacity utilization and did not consider the cost, time, distance and constraints of petroleum products distribution as it relates to the environment.

Onwioduokit and Adenuga (2000) determined the factors of urbanization on the distribution of petroleum products in Nigeria's urban centers. Such factors include gross domestic product (GDP), proportion of urban population, contribution of agriculture to GDP, contribution of manufacturing to GDP and contribution of services to GDP. The findings of the study revealed as follows: first, urbanization has a positive impact on the

consumption of liquid petroleum gas (cooking gas); second, the elasticity for petrol shows a positive trend; third, the consumption of household kerosene is negatively correlated, showing that demand for kerosene decreases with urbanization. However, three major weaknesses have been observed in this study, which call into question the accuracy of its results. First, the variables used in this study, especially as they concern the premium motor spirit (highway transportation fuel) were insignificant parameters and are therefore incapable of estimating the elasticity of demand for the product. Second, the study did not cover the rural areas where 70 percent of the Nigerian populations reside. Third, this study excluded automotive gas oil (diesel) from the analysis in spite of the fact that the product is among the three most important products being consumed in Nigeria.

Alatarighabofa (2010) studied on the impact of production scheduling on the distribution performance of petroleum products by KRPC and discovered that the production scheduling is not computerized which led to distribution of petroleum products to specific marketers. Also, distribution was based on first come first serve. However, it was recommended that KRPC needs to be computerized to aid effective distribution and production planning.

Eke and Enibe (2007) examined optimal scheduling of petroleum products distribution in Nigeria. The objective was to determine an efficient and equitable distribution of three blends of petroleum products. Post-optimality analysis was performed investigating the effect of varying supply, demand and distribution from refineries to storage depots or selling points. The study reveals that any variation in supply, demand and transportation cost changes the optimal solution.

Furthermore, Zhen (2011) assessed pipeline and vehicle transportation problems in the petroleum industry. Based on this study, petroleum product logistics was divided into transportation of petroleum products by pipeline or railway transport from the refineries to oil depots and tanker (road transport) was used for distribution from oil depots to oil stations. The study revealed that transportation of petroleum products was faced with three problems that can be solved by mixed integer programming model and that oil product transportation costs account for a proportion of sales fees in the Chinese petroleum industry that is considerably higher than the average international level. Hence, reducing costs incurred from the transportation of oil products has become a highly important problem for Chinese oil companies.

Similarly, Samari (2010) studied minimizing transportation cost of petroleum products through distribution networks linking depots operated by bulk oil storage and transportation company limited (BOST) in Ghana using transportation model. The transportation model deals with the distribution of petroleum products from several points of supply (sources) to a number of points of demand (destination) such that the total transportation cost is minimized. The study revealed that the bulk of transportation cost for petroleum products distribution network linking all the five petroleum products storage depots in Ghana can be reduced by 14.16 percent.

Most of the review work were based on issues such as the distribution of the petroleum products, performance rating of various modes, factors of urbanization on the distribution of petroleum products, optimal scheduling of petroleum products distribution, pipeline and vehicle transportation problems in the distribution of petroleum products. An examination of all these studies reveal that most of them did not consider an

in-depth comparative analysis of the various modes used in hauling petroleum products from the depots to the final destinations and the relationship between these modes of transportation and the environment. It is against this background that this study was embarked upon to determine the encroachments on System 2D pipeline ROW and its effects on the environment. It is this knowledge gap therefore, that this study was carried out to fill.

2.3.2 Causes of Pipeline Accidents

Major pipelines across the world transport large quantities of crude oil, natural gas, and petroleum products. These pipelines play an important role in modern societies and are crucial in providing needed fuels for sustaining vital functions such as power generation, heating supply, and transportation. In light of the hazardous properties of the products being transmitted through these pipelines, a ruptured pipeline has the potential to do serious environmental damage. This problem is further compounded by the fact that many developing countries have not established proper guidelines and standards for the design, construction, operation and maintenance of major oil pipelines. The risk associated with pipeline in terms of safety of people, damage to the environment and loss of income has been a major concern to pipeline integrity managers.

Sources of failure include Structural problem, Operator error, Others, Outside force damage and lastly Control problems. Agbaeze (2000) shared his view on how to improve pipeline Integrity Management, opining that Pipeline operators can realize many benefits by implementing a data integration approach that; enables integrity managers, risk assessment specialists and pigging Engineers to view and analyze combined

information from disparate surveys. There have been a number of studies conducted by researchers on causes of oil pipeline failures in the oil and gas industry.

Ikporukpo (1998) examined the causes of pipeline leaks versus pipeline ruptures and the proportion for each. In failures resulting in product loss, leaks constituted 86.8% of failures and ruptures 13.2%. Corrosion is the predominant cause of leaks. According to the findings, third party damage is the leading cause of line ruptures. Since 1994, 191 hits were recorded, and these are not included on the graph as they did not result in either leaks or ruptures. The hits equalled 47% of all recorded third-party incidents for the years 1994-1997, demonstrating that approximately half of all third party incidents resulted in a pipeline failure. Onosode (1997) showed that about 50% of third-party incidents resulted in loss of pipeline products. Ndifon (1998) reviewed the number of internal corrosion failures for multiphase pipelines and discovered that internal corrosion failures increased steadily while the number of external corrosion failures held steady. However, the failure frequency has been quite consistent (Eromosele, 1998).

Moffat and Linden (1995) compiled background research and information that is associated with oil pipeline failures, it shows that for crude oil pipelines, the causes of failures appeared to be fairly random in nature, and that no trends were apparent. They stated for sour gas pipelines, internal corrosion is the major cause of failure. External corrosion failures have declined in recent years, possibly as the result of improved coatings and increased inspection. Of the sour line failures, about 86% were leaks and 14% were ruptures. They used the latest technology in the fields of internal electronic inspection, metallurgy, coatings, cathodic protection, and chemical inhibition.

Odusola (1996) studied the effects of internal corrosion failures for natural gas pipelines which have generally been increasing. Some other category which include high vapour pressure liquids, low vapour pressure liquids, fuel gas, and all others showed failure rates to be relatively few and the causes to be relatively random.

Rivers state has a high pipeline failure rate as at 2005. This high rate could be due to good reporting of oil spills. One oil spill in Rivers state was definitely identified as sabotage. The ages of Rivers state's pipelines are unknown, but as Rivers state is a mature oil-producing state, a reasonable assumption is that the pipelines are older than average. The pipeline failure rate in Akwa-lbom is low. This could be due to poor reporting of oil spills, newer pipelines, better quality of materials used, better maintenance, or less corrosive soil. As stated before, this could be due to teething troubles for new pipelines or wear-and-tear on old pipelines. The age of the pipelines in Akwa-lbom is not known and so it is difficult to speculate if they are either new or old.

2.3.3 Consequences of Pipeline Accidents

In several cases, pipeline accident is meted with serious casualties. Apart from destruction of farmland, many lives are lost. The 1998 Jesse fire incident affected about 1000 lives who were either burnt to death or maimed for live. Apart from the valuable lives lost, the costs to the environment are certainly incalculable. These incidents portray the level of criminality in the society, negligence and craze indifference on the part of those charged with the business of securing the pipeline; particularly the failure of the Pipelines and Product Marketing Committee (PPMC) to maintain its aging pipelines as well as the failure of the security agencies to apprehend the vandals.

The consequences of pipeline accidents include environmental degradation, devastation, pollution and other form of ecological disaster in the area. These environmental problems are expressed in the forms of oil spillage, soil and water contamination, flooding, crumbling social infrastructure and poverty of the highest order. In order to control the incessant incidents of pipeline accidents and oil-spill, the oil companies, federal and state governments of the affected communities should make an in-depth analysis of the causes of oil-spills, with a view to facilitating more profound and dynamic control measures to the problem. Since environmental devastation is inevitable as long as oil exploitation continues, both the government and oil-producing companies should be involved in taking precautionary and remedial measures that can minimize the negative effects of pipeline failures. To achieve this, the implementers of the various policies relating to environmental management need to wake up to their assigned responsibilities.

2.3.4 Vandalism of Pipelines in Nigeria

The implementation of policies exploitative to the population in the oil and gas producing states in Nigeria, and the environmental degradation which results from exploration and production processes, is responsible for the vandalism of oil pipelines in Nigeria (Aaron, 2005).

Aprioku (2003) advocated a comprehensive environmental programme involving the government and other stakeholders, namely oil explorers and host communities, as a way out of the perennial vandalism of oil pipelines and the resultant spillage, which causes large scale socio-economic losses to all parties. According to Ikelegbe (2006), the

Nigerian economy, although not the cause of the ongoing agitation that has occasioned the incessant vandalism of oil pipelines, has underpinned its escalation.

Nwilo and Badejo (2006) argued that the discovery of oil in Nigeria in 1956 has progressively contributed suffering to the majority of Nigerians, especially in respect of the environmental consequences of oil exploration and exploitation. Yet the reverse should have been the case: the people should have been the beneficiaries, and not the victims, of oil exploration activities in Nigeria. Nevertheless, the situation is reversible with the involvement of the people in the preparation and eventual operation of a properly crafted plan for the management of the areas directly affected by the exploitation and distribution activities in Nigeria.

Omeje (2006) noted that the incidence of vandalism of oil pipelines is a case of theft of public goods and deliberate sabotage of national and international efforts at developing the oil industry in Nigeria. He canvassed the implementation of a commercialised security approach to the problem, but did not suggest any framework within which to achieve this noble goal.

Jackson (2007) identified political agitation for the control of the wealth derivable from oil exploration and criminality as reasons for the constant vandalism of oil pipelines in Nigeria. A framework that accommodates the genuine grievances of the people in such a way that they will begin to approach the development of oil and its related activities in the hope and spirit of a common heritage could count towards remedying the situation.

Furthermore, Olukoju (2004) identified petroleum pipeline vandalism as a contributory factor in the unreliable electricity situation in Nigeria, and one which has forced people to

choose electricity generating sets as alternative sources of energy. He further said that the situation is presently so bad that the people no longer expect power from the public source of supply.

Towards the end of the military rule in Nigeria, the vandalism of oil pipelines, especially the pipelines for premium motor spirit (PMS), came into the limelight. But in recent times it has assumed an alarming rate, because of the increase in the frequency of attacks on these pipelines, increased sophistication in the technology used, and concentration on the three axes that are crucial to petroleum products distribution in the country (Onuoha, 2008).

In Nigeria, oil terrorism includes such acts as the blowing up of oil pipelines, installations, and platforms with explosives, and the seizure of oil barges, oil wells, flow stations, support vessels, and other oil facilities in order to prevent the exploitation and/or distribution of crude oil or its refined products.

Some of the reported cases of the militants' attacks include the following:

i. On January 16th, 2005, a major pipeline supplying crude to the Forcados export terminal was blown up, cutting supplies by about 100,000 barrels per day.
ii. On March 18th, 2005, militants blew up an oil pipeline operated by an Italian company, reducing flow by 75,000 barrels per day.
iii. On October 3rd, 2006, militants struck at an oil vessel at Cawthorowe Channels, killing five soldiers who were escorting the vessel, and later sinking the vessel.
iv. On May 8th, 2007, MEND attacked three oil pipelines; two of these pipelines were in the territory of Akassa and the third in Twon-Brass.

These acts showed that the vandals and militants have developed both the tactics and weaponry that have enabled them to launch devastating attacks on onshore oil installations and near offshore rigs (Onuoha, 2008).

The problem of vandalism pervades the ROW of pipelines across the geographic landscape of the country. The communities along the ROW have suffered from incessant acts of pipeline vandalism. Some farming and fishing communities have lost arable lands and fishing ponds due to contamination caused by oil spill occasioned through vandalism. The impact of vandalism in these communities transcends the initial shock suffered when vandalised pipelines explode, causing infernos which on some occasions have razed substantial portions of communities, destroying valuables and in some extreme cases causing death; they also suffer greater long term effects of loss of means of livelihood. Post-vandalism trauma in the wake of spilled petroleum products has long term reverberations, because it may take months before the attention of the authorities is drawn to the scene.

Mejabi (2015) examined the compliance to regulations of ROW for NNPC pipeline Networks in Northern Nigeria. The researcher checked compliance to the ROW within five (5) kilometers in all the NNPC depots and pump stations within northern Nigeria using Landsat images. Findings from the research revealed that there were encroachments on the pipeline ROW by buildings and farmlands. The limitation of this research however, was that it only considered encroachments within 5 kilometer radius of the depots and pump stations and it neglected other encroachments along the pipeline ROW outside the depots.

The presence of negative social and environmental externalities as a result of business operations gives rise to a number of other problems which in the case of the Nigerian pipelines has resulted in what is now called pipeline vandalism (Onuoha, 2003). This also leads to chains of secondary effects, which in the context of ROW in Nigeria, have become a source of burden to host communities, but at the same time benefit other stakeholders, like the government and the multinational oil and gas companies (Frynas, 2000). A system must therefore be put in place for the management of pipelines and the associated ROW in Nigeria.

This chapter has shown that the challenges in the management of linear infrastructures manifest differently across national boundaries and application of the participatory utility of the GIS could engender a process that would enhance effective management of these infrastructures. Furthermore, this chapter has explained the challenges in the management of linear infrastructure, particularly petroleum pipelines, in a global context, pipeline accidents, causes and consequences. It reveals that the problem of pipeline ROW management is essentially a global one that manifests in various ways within national and regional boundaries.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter discussed the methodology used in this study. The study area, instrument for data collection, as well as the data analysis were also discussed here

3.2 THE STUDY AREA

3.2.1 Location

The length of the pipeline considered for this lies approximately between Latitudes 10°25'43" - 11°10'9"N and Longitudes 7°29'14" - 7°46'43"E. The pipeline traversed four (4) local government areas, they include Chikun, Igabi, Zaria and Sabon Gari Local Government Areas. A larger portion of the pipeline falls within Igabi Local Government Area, followed by Zaria, then Sabon Gari, and finally, Chikun Local Government Areas. The pipeline runs from the southern to the north-eastern parts of Kaduna state, connecting the Kaduna Refinery and Petrochemical Company (KRPC) to Kano and Gusau depots via the Zaria Pump Station (ZPS). Figure 3.1 is a map of the study area.

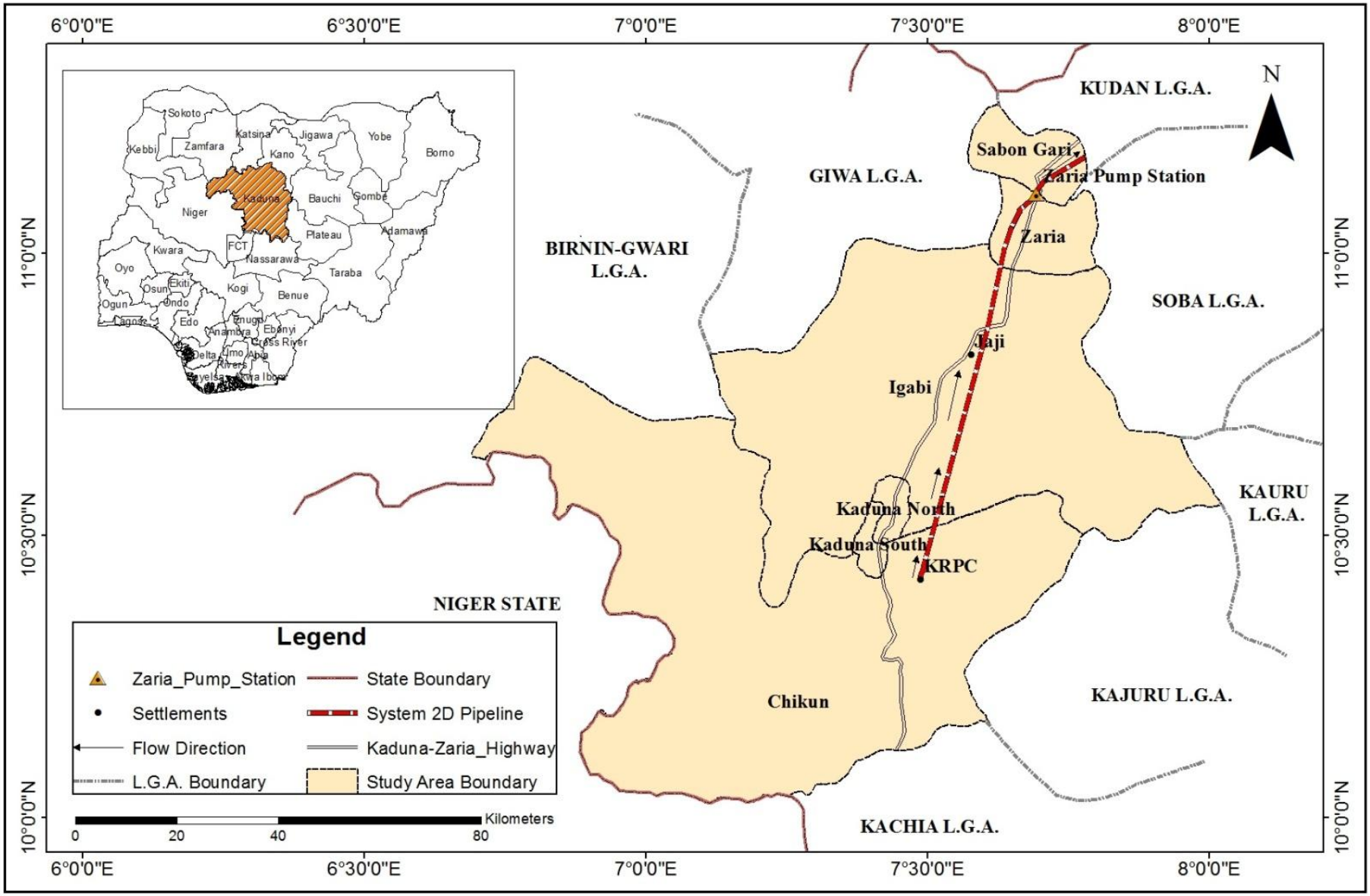


Figure 3.1: Map of Kaduna showing System 2D Pipeline and direction of flow
Source: Modified from NNPC (PPMC distribution map)

3.1.2 Climate

The study area has a tropical continental climate (Aw) with distinct wet and dry seasons, reflecting the influence of tropical maritime air mass (mT) and Tropical continental air mass (cT) which alternate over the country. When mT which originates from the Altantic Ocean, prevails over the area, it brings the rainy season while cT originates from the Sahara desert, it brings in the dry season with cold and dusty air that occasionally limits visibility and reduces solar radiation bringing in harmattan condition in the area. Northern Nigeria experiences four distinct seasons:

(i) Dry and Cold season – from end of November to February

(ii) Dry and Hot season – from March to beginning of May

(iii) Wet and Warm season – from mid May to beginning of October

(iv) Dry and Warm season – from mid October to mid November

Kaduna has mean monthly minimum and maximum temperatures of 15.9^{0}C and 35.35^{o}C with a range of about 19.45^{o}C. The highest temperatures are being recorded in March and April and the lowest are being recorded in December and January. Average annual rainfall in the area is about 1530mm; it ranges from 0.0mm from November to February and 825.0mm in August, which is the wettest month (World 66 Magazine, 2011).

3.1.3 Vegetation

The natural vegetation of the study area is that of the Northern Guinea Savannah with grass dominating and scattered trees hardly higher than 15ft with broad leaves. Meanwhile, the seasonal character of rainfall in the study area has influenced the vegetation which turns evergreen during the wet season and pale brown in the dry

season respectively. Thus, the dominant true species are *Isoberlina Doka, Dodoneaspp,* and grass communities consist of Hyperhenia and Andropgon species. In the city proper the vegetation is characterized by Silk cotton, Baobab and other protected trees. However, human activity has greatly affected the vegetation formation in the area, through activities like; bush burning, cultivation of crops, grazing, lumbering, urbanization and industrial activities among others. The vegetation formation varies and associated with distinct ecological site with particular regard to the nature of the soil (Oguntoyinbo, 1983).

3.1.4 Soils

The soils in the study area have been classified according to Hoores classification scheme for Africa as tropical ferruginous soil. They are zonal soils developed under climatic regimes with appreciable but seasonal rainfall of 500-1200mm and cover nearly half of Northern Nigeria (Oguntoyinbo, 1983). The soil material consists of several feet of deposited silt sand overlaying sedimentary decomposed rock. The soil is poorly drained because of the high percentage of fine textured materials in the upper layers, which results to water logging especially during the rainy season and tends to dry out and cracks during dry season. Alluvial soil is formed a long riversides (fadama). It is made up of several feet of grey white loamy coarse sand with layers of grey heavy molten occurring at varying depths within the profile. The alluvial soils are usually under intense cultivation of sugarcane and vegetables year-in year-out and as a result in farmers resort to using fertilizers to improve soil fertility.

3.1.8 Economy

The activities in the study area reflect the commercial, services, administrative, industrial, transport and professional needs of the state and northern Nigeria. The 1956 capital territory law created the limits of the present day Kaduna and set in motion, the rapid and dynamic physical, economic and social transformation of the town. This resulted to the establishment of modern infrastructural facilities such as electric power supply, pipe borne water, good roads, banks, telephone services and international airport.

These modern infrastructures were the backbone of the establishment of industries like; textile mills, breweries, bottling companies, flour mills, motor assembly plants, to mention a few. These have attracted many, especially the youths, to seek for employment and share in the economic development of the in the study area. These industrial growth and high rate of urbanization has attracted both national and international business men, and has make Kaduna one of the strongest commercial center in northern Nigeria and the country at large (Ali, 2004).

3.1.9 Population and Land Use Pattern

The 1991 census provisional result puts the population of Kaduna State at 3, 935618, while the census 2006 puts the population at 6.3 million (NPC, 2006). Although majority live and depend on the rural areas, about a third of the State's population are located in urban centres. However, the seasonal labour migration has no effect on agricultural labour demands in the rural traditional setting. Indeed, some of these seasonal migrants come to town to learn specific trade or acquire special training and eventually go back to establish in the rural areas as skilled workers (e.g. masons, technicians, tractor drivers, carpenters, motor mechanics, etc). Another major feature of the State's

population structure is the near 1:1 male/female ratio, not just for the state as a whole, but even among all the LGAs.

Kaduna is the third largest state with regards to population. More than 6 million people live within the state (Nigerian Population Census, 2006), and that population is growing at around 3.3% per annum according to the National Planning Commission (2006). Kaduna city is the capital of Kaduna state and it has a population of around 1.2 million (Max Lock Centre, 2008).

Kaduna city itself is beneficially located within the state; it is located near the geographical centre and benefits from close proximity of a river running horizontally across the territory. The area is characterised by a medium-low population density. A key issue facing the city is the religious tension between the major Muslim and Christian populations; unlike much of the rest of the north of Nigeria which is typically dominated by Muslims, Kaduna is somewhat apart from this in that there is also a sizeable Christian population. Religious tensions have existed in the area since the colonial period; this is significant as it was also during this time that much of the infrastructure of Kaduna was created. One of the most notable recent examples of the religious tensions is in the Christian-Muslim riots that took place in 2000 (Maier, 2000). However, there are also many other ethnic groups in Kaduna and tensions exist between many of them: some non-indigenous groups report that they are discriminated against in terms of education and are not able to purchase a home or land (Human Rights Watch, 2003; Thomas, 2009).

Even though most of the geographical area of Kaduna is north of the river, there has been faster growth in land use in the south in recent years. This is largely because the

location south of the river is better connected with the southern half of Nigeria. Most of the land use is concentrated on the north-south axis, with much of the industry, including the manufacturing centre, being to the south side of the city.

In terms of urban development, in recent decades this has taken place to the south of the river, as mentioned above. This has been in terms of both industry and residential suburbs. This means that the south of Kaduna is becoming increasingly urbanised and there is a growing demand for space and property in that area.

In terms of geography, the city of Kaduna has got a region of around 20,000 square kilometres. The city itself is approximately 25km long and its expansion has previously been hampered by the presence of the Kaduna river close by. Manufacturing makes up much of the economy of the city, but around 40% of the economy of Kaduna state is based on forestry and other agricultural pursuits (Fitch; Reuters Africa, 2010).

Residential land uses occupy the largest area in Kaduna city. This consists of low, medium and high residential neighborhoods that fall into different Local Climatic Zones (LCZ). The road and Agricultural land uses cut across all categories of slope. However, agricultural land uses are found majorly in the rural areas as more residential neighborhoods are springing up. With the increase in population, more pressure is being exerted on land as more people demand for land for residential, agricultural and other purposes. This was partly responsible for the encroachments on the pipeline ROW.

3.2 Research Methodology

3.2.1 Reconnaissance Survey

The researcher carried out a reconnaissance survey. This was to acquaint the researcher with the study area and help in preliminary field data collection. Some of the preliminary field data include pictures of warning signposts, broken pipeline markers as well as the path taken by these markers. Also, the researcher introduced himself to the PPMC staff with a letter from the department, as any activity around the pipeline markers is not allowed. Relevant documents backing up this study were collected from PPMC. The settlements through which the pipeline traverses were identified.

3.2.2 Data Types and Sources

The data required for this study was grouped and discussed based on their types and sources. The data was broadly classified into primary and secondary.

The primary data used for this study are as follows:

i. Location of pipelines (geographic coordinates of pipeline markers from the field) was used to determine the path taken by the pipeline and to generate the ROW layer.

ii. Satellite imageries (Google images) of the study area for 2003, 2009 and 2015 which were used to generate the land-use classes.

iii. Data on ROW awareness, encroachments, and accidents from questionnaire.

iv. Interviews with PPMC staff on ROW management practices and challenges from PPMC.

Secondary data were sourced from the following and used to develop the literature review and to provide support for findings in the course of discussion. These include;

i. Publications from PPMC (Petroleum Products Marketing Company).

ii. Previous documents on ROW management practices and challenges from PPMC.

iii. Administrative map of Kaduna State was obtained from Kaduna state Ministry for Land and Survey.

iv. Literature materials from journals, textbooks, articles, past projects, seminar papers, theses, reports and web references on dangers of ROW encroachments were used for literature review.

3.2.3 Software Used

The software used in this study include:

i. Erdas Imagine 9.2 was used for image processing and land-use classification.

ii. ArcGIS 10.1 was used for buffering and overlay operations.

3.2.4 Sample Size and Sampling Technique

Purposive sampling technique was adapted in selecting the respondents for questionnaire administration. Since this study focused on the settlements that fall within the pipeline ROW, a convenient sample of twenty (20) respondents were selected from the population whose properties encroached on the pipeline ROW. However, there were settlements that had only vegetation encroaching on the ROW, hence, no questionnaire was administered there. Also, the rate of encroachments in each of the settlements differ,

therefore, the number of copies of the questionnaire administered depended on the observed encroachments.

3.2.5 Questionnaire Administration

The questionnaire was used to obtain the opinions of the various respondents in each of the communities where there are cases of encroachments on the ROW. It was administered to property owners whose property fell within the 25m buffer left and right of the pipeline markers. The questionnaire elicited data on ROW awareness, encroachments, factors responsible for ROW encroachments, and past pipeline accidents. The questionnaire was administered by the researcher with the aid of two (2) research assistants. For the respondents who could not read or write, the researcher and the assistants helped them by asking them the questions in Hausa language and ticking the option that best fits their opinion.

The questionnaire were administered to each of the settlements that had buildings encroaching on the ROW, except for Keke and Zaria Pump Station. This was because of outright opposition and resistance by the respondents in these areas for fear of demolition. The number of questionnaire administered in each settlement depended on the observed encroachments and is given in Table 3.1. The other settlements where questionnaire was not administered had farmlands or bare lands.

Table 3.1: Names of Settlements and Number of Questionnaires administered

Name of Settlement	No. of Questionnaires
Refinery Junction	20
Mahuta	10
Kamazou	20
Bagado	10
Kakura	-
Keke	-
Kangimi	-
Kargo	-
Rigachukun	-
Jaji	-
Sabon Yelwa	-
Saye	10
Kufena	10
Zaria Pump Station	-
Hanwa	20
Dogarawa	20
Total	**120**

Source: Author's compilation

Interview technique was used to get the opinion of the PPMC staff on ROW management methods, challenges, intervals of ROW checks as well as the extent of compliance in the communities.

3.2.6 Data Processing

The coordinates of the pipeline markers from the Global Positioning System (GPS) was transferred into Microsoft Excel worksheet and stored for easy transfer into ArcGIS environment.

Google imageries of the study area for 2003, 2009 and 2015 were used for the analysis. Pre-processing operations were carried out on the images. Pre-processing functions involve those operations that are normally required prior to the main data analysis and extraction of information, and are generally grouped as radiometric or

geometric corrections. Radiometric corrections were carried out to correct the data for sensor irregularities and unwanted sensor or atmospheric noise, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor. Geometric corrections were carried out to correct for geometric distortions due to sensor-Earth geometry variations.

After importing the images, each of them was georeferenced in order to define its existence in physical space, that is, establishing its location in terms of map projections or coordinate systems. This is the process of registering the images to a common coordinate system to establish the relationship between page coordinates on a planar map and real-world coordinates. The coordinates from the GPS was used to georeference the images.

Data from the questionnaire on ROW awareness and encroachment issues was coded and saved in Microsoft Excel and prepared it for data analysis. The map of the study area was obtained and georeferenced in ArcGIS 10.1 to prepare it for further analysis.

3.3 Data Analysis

The processed data obtained were analyzed in order to achieve the set objectives of the study.

Objective 1: To identify and map the ROW

The ROW was traced with the help of the pipeline markers. The GPS was used to pick waypoints on the pipeline markers that can be seen and accessed, which will be used to establish the route taken by the pipeline. The collected GPS coordinates was saved in Microsoft Excel as a .csv file and imported into the ArcGIS 10.1 environment. The

coordinates were stored and imported as a point feature, and a line feature class was used to connect the points. The output is a vector (linear) layer showing the route taken by the pipelines.

Activating the buffer tool in ArcGIS, a 50m buffer depicting the statutory ROW of the pipelines was created along the pipeline route. This action resulted in highlighting area 25m to the left and 25m to the right of the pipeline delineating the ROW. The buffer was activated around the linear feature (pipeline) and saved as the Right of Way (ROW) layer.

Objective 2: To determine the extent of encroachment on ROW

An overlay operation was carried out to achieve this objective. The ROW layer was overlaid on the Google imageries for each of the years. The land uses that fall within the buffer zone are those that have encroached on the pipeline ROW. The extent of encroachment was obtained by calculating how much of the ROW was encroached upon by the different land uses.

Objective 3: To examine the land uses that have encroached on the ROW

The Google images of the study area were georeferenced and digitized onscreen, visual classification was used to classify the land uses using the ArcGIS10.1 editor tool into the following layers or land uses:

i. Built up

ii. Bare land

iii. Vegetation

iv. Water bodies

The ROW layer was then overlaid (polygon-on-polygon overlay) on the digitized satellite images of the study area for each of the years and the land uses that fell within the buffered zone were considered as those that have encroached on the pipeline ROW.

Objective 4: To examine the effects of encroachments

This will be generated from the questionnaire which were distributed to the sampled population of the property owners whose property encroached on the ROW.

The questionnaire elicited information on people's awareness of pipeline ROW, the risks associated with encroachments on the ROW as to whether or not they have experienced any fire outbreaks or environmental pollution in the past, and possibly why they do not take to the NNPC caution on ROW encroachment serious. The extent of damage to lives and property loss due to pipeline accidents showed the effect of these encroachments. Responses from the questionnaire were extracted and coded in SPSS. These were analyzed using descriptive analysis.

Objective 5: To examine the factors responsible for encroachments on pipeline ROW

This objective was achieved by engaging the PPMC staff who are in charge of maintaining the pipeline ROW in a structured oral interview to get their views on the factors responsible for these encroachments. Also, part of the questions in the questionnaire for the respondents covered factors they think were responsible for these encroachments. The responses were analyzed using frequency tables and charts.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION OF FINDINGS

4.1 Introduction

This chapter presents the results of the findings in this study as well as the discussion of the results. The table presented in this section shows the area of land of the ROW covered by either vegetation or buildings in hectares for the period considered in this study. The satellite images presented have been overlaid and encroachments were differentiated using colours for each of the years. The white patches or areas on the images imply no encroachments. Each of the settlements and the type of encroachments is discussed independently. The results are presented based on the objectives of the study.

4.2 Identification and Mapping of the ROW

The red line in figure 4.1 delineates the ROW from Kaduna Refinery to Dogarawa. The settlements through which the pipeline traverses and the land uses that encroached on the ROW were discussed individually.

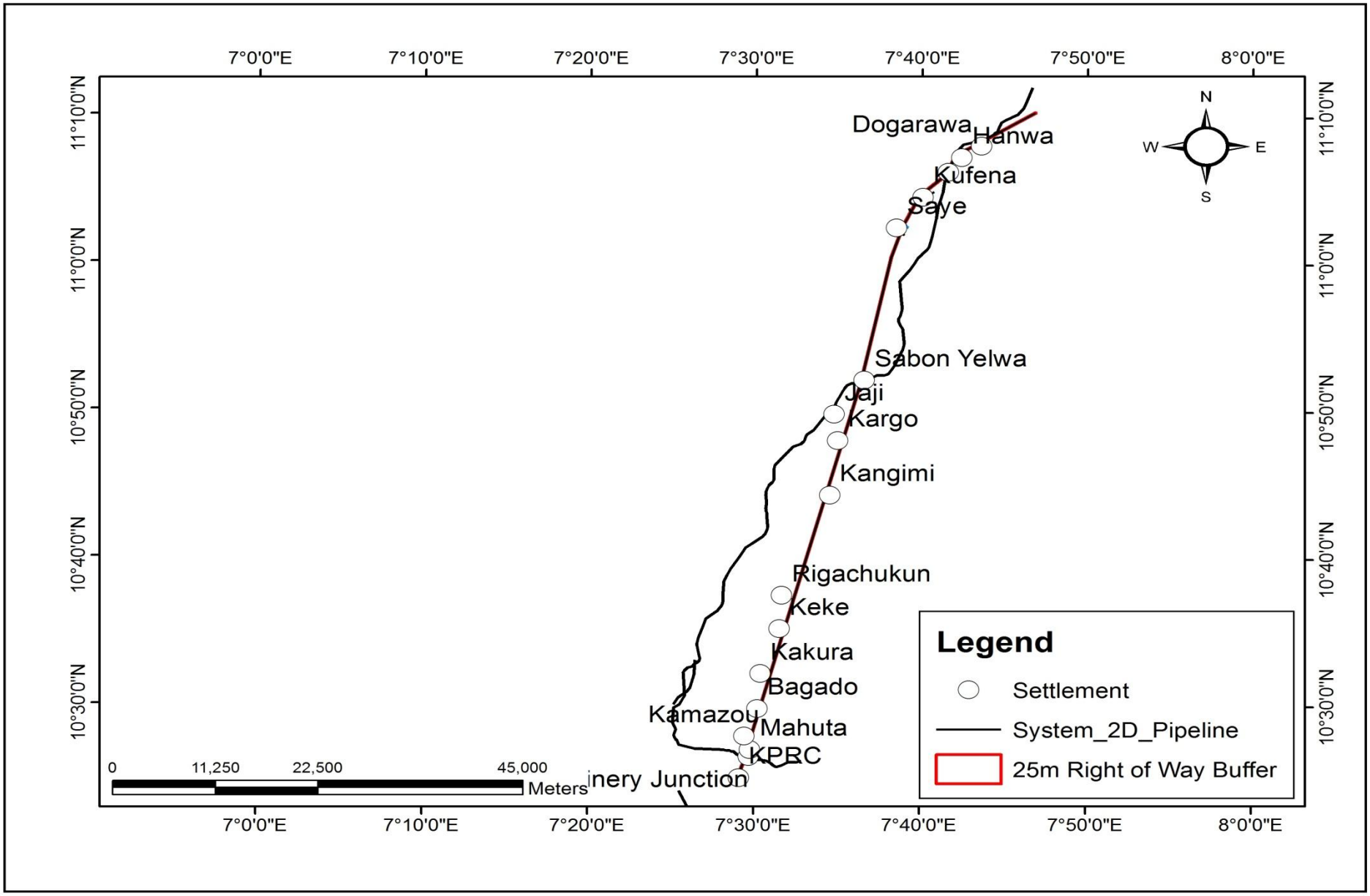


Figure 4.0 Mapping of Pipeline ROW.
Source: Author's Analysis

4.3 Extent of encroachment on the ROW

The extent of encroachment was determined by overlaying the ROW layer on the classified land use map of the study area for each of the years. The total area encroached upon by buildings was 36.96, 47.06 and 58.48 hectares for 2003, 2009 and 2015 respectively, while the area encroached upon by farm land was 190.94, 186.25 and 182.25 hectares for 2003, 2009 and 2015 respectively. The results are given below.

Table 4.1a Encroachments on Pipeline ROW by built-up areas and farmlands in hectares

S/N		Built-up (Ha)			Farmland (Ha)		
	NAME	**2003**	**2009**	**2015**	**2003**	**2009**	**2015**
1.	Refinery Junction	3.02	5.27	6.19	0	0	0
2.	Mahuta	1	2.33	2.72	6.77	5.44	5.05
3.	Kamazou	7.48	7.68	10.44	0	0	0
4.	Bagado	1.33	1.9	2.82	11.17	10.61	9.69
5.	Kakura	0	0	0.00	27.26	27.26	27.26
6.	Keke	0.41	0.6	2.04	7.28	6.27	4.84
7.	Kangimi	0	0	0.00	18.01	18.01	18.01
8.	Kargo	0	0	0.00	12.34	12.34	12.34
9.	Rigachukun	0	0	0.00	26.23	26.23	26.23
10.	Jaji	0	0	0.00	23.17	23.17	23.17
11.	Sabon Yelwa	0	0	0.00	20.69	20.69	20.69
12.	Saye	1.72	2.3	2.44	4.01	3.44	3.3
13.	Kufena	2.71	2.91	3.20	4.62	4.42	4.13
14.	Zaria Pump Station	0.17	0.17	0.19	3.16	3.16	3.15
15.	Hanwa	8.51	12.27	15.99	0	0	0
16.	Dogarawa	10.61	11.63	12.45	26.23	25.21	24.39
	Total	**36.96**	**47.06**	**58.48**	**190.94**	**186.25**	**182.25**

Source: Author's Analysis, 2015

From table 4.1a above, it is clear that the encroachments on pipeline ROW by built up had increased while encroachments by farmlands had decreased. This therefore implies that more buildings were constructed on the pipeline ROW in areas where there were none or in areas that were farmlands. The above table is further summarized as shown below:

Table 4.1b: Summary of Encroachments on pipeline ROW for 2003, 2009 and 2015

Encroachments	2003	Percentage (%)	2009	Percentage (%)	2015	Percentage (%)
Built up (Ha)	36.39	15.97	47.06	20.17	58.48	24.29
Farmland (Ha)	190.94	84.03	186.25	79.83	182.25	75.71
Total	**227.9**	**100**	**233.31**	**100**	**240.73**	**100**

From the table above, it is clear that the total encroachments on pipeline ROW by built up and farmlands was on the increase. The increase in encroachments between 2003 and 2009 was 5.41 hectares, while the increase in encroachments between 2009 and 2015 was 6.69 hectares. This shows that the degree of encroachments on pipeline ROW has increased. The implication of the figures in table 4.1b is that more buildings were encroaching in the pipeline ROW as the built up increased geometrically from 15.97% to 20.17%, and 24.29% for the years 2003, 2009 and 2015 respectively. The encroachments by farmlands decreased from 84.03% to 79.83% and 75.71% within the same time period, as shown in table 4.1b.

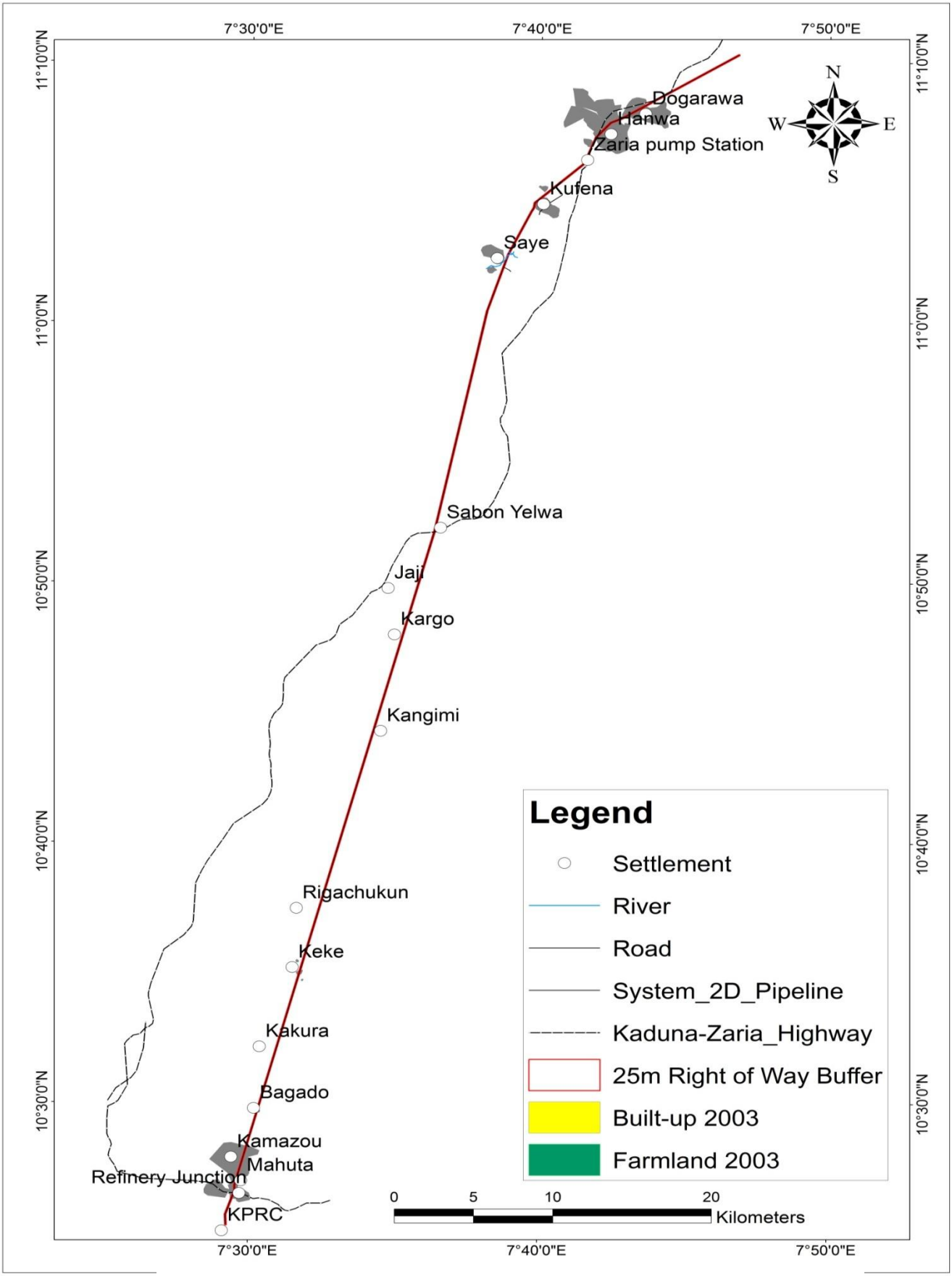


Figure 4.01 Extent of encroachments on pipeline ROW as at 2003
Source: Author's analysis

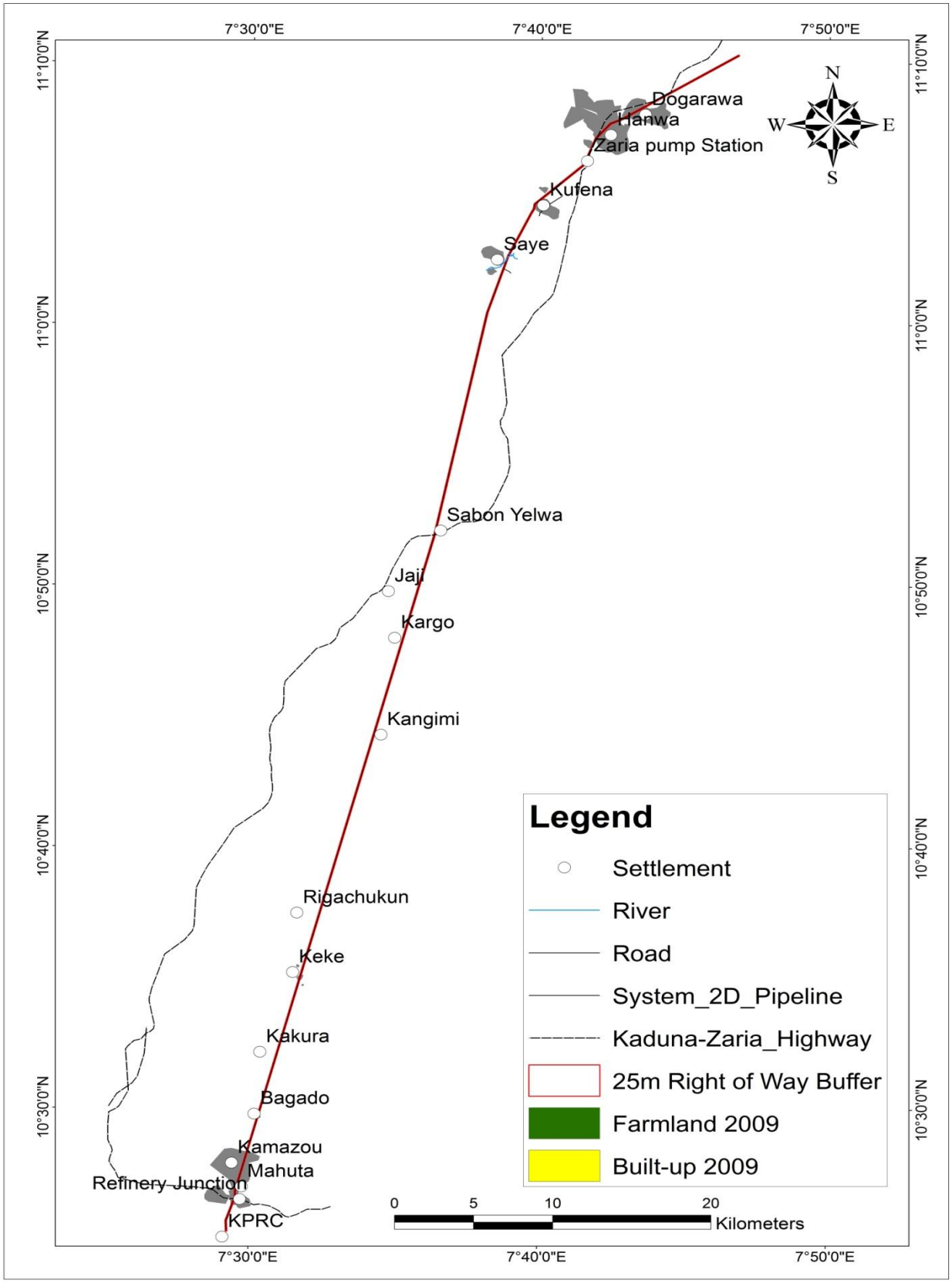


Figure 4.02 Extent of encroachments on pipeline ROW as at 2009
Source: Author's analysis

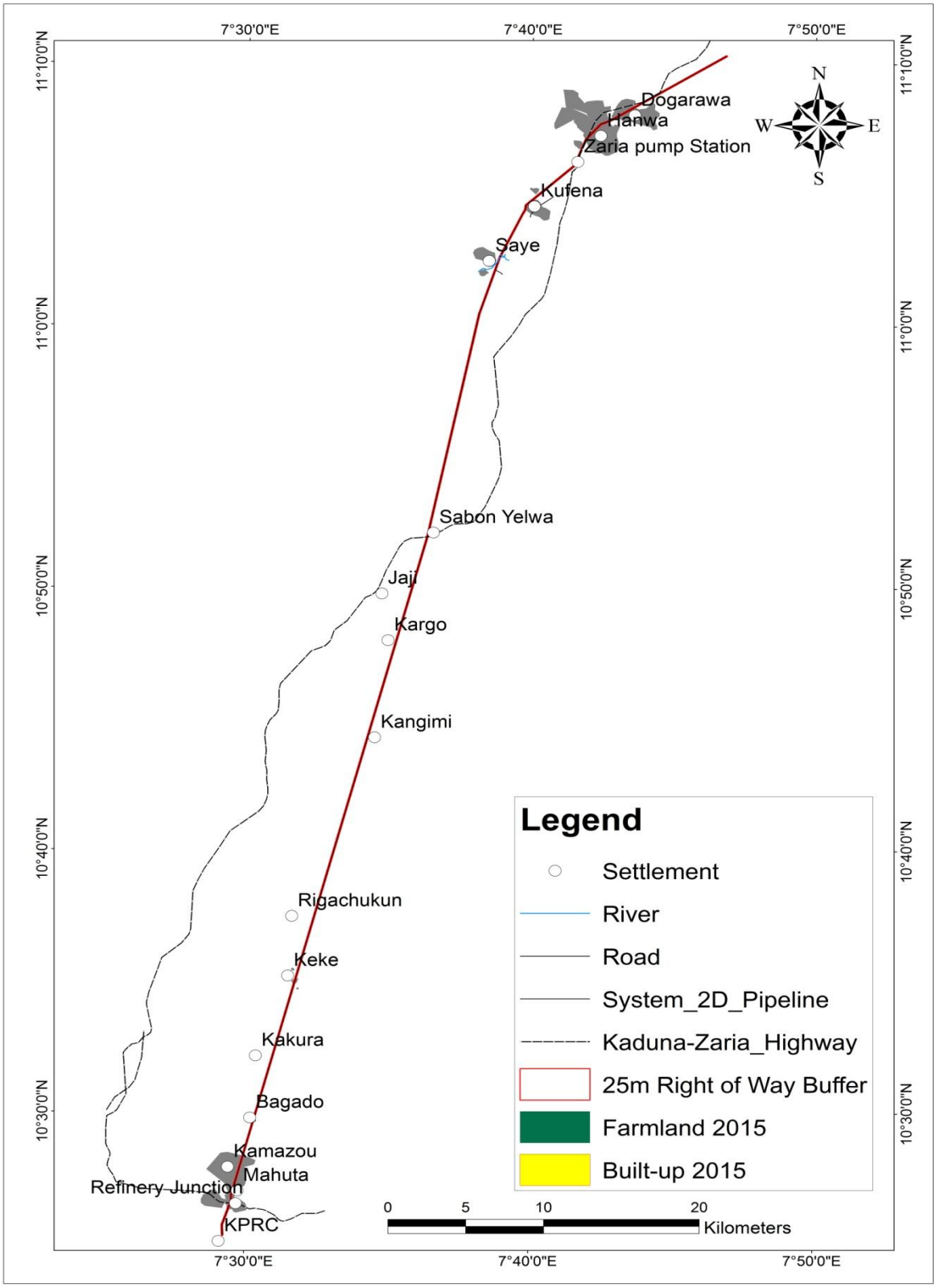


Figure 4.03 Extent of encroachments on pipeline ROW as at 2015
Source: Author's analysis

4.4 LAND USES THAT ENCROACHED ON THE PIPELINE ROW

4.4.1 Encroachments at Refinery Junction

From table 4.1, the encroachments on the pipeline ROW by buildings was 3.02, 5.27 and 6.77 hectares for 2003, 2009 and 2015 respectively. There was an increase in the amount of land encroached upon by residential areas. This was because of the increasing demand for land for economic and residential purposes in the area. This is shown in figure 4.1.

This settlement is about two kilometers from the Kaduna Refinery, and one will expect that the encroachments around the refinery should be less or highly controlled, but it is not so. There are residential buildings that have fully encroached on the pipeline ROW. Most of the property owners did not give the researcher a listening ear probably because they know their offence or because they are comfortable with the situation and want the status quo maintained.

There was an oxy-acetylene welding shop on the pipeline ROW, and after attempting to administer the questionnaire, they were not willing to respond, the researcher engaged them in a discussion on the dangers of welding on the pipeline ROW. Their response was dogmatic, implying that they were fully conscious of the risks involved in their activities. One of them responded by saying, “everybody will die with time, so whether we weld close to the pipeline or not, it does not change the fact that we will all pass away someday”. The welders did not in any way show any sign of caution since they feel no pipeline accidents had ever occurred there in the past. Plate 1 shows the welding shop as well as other residential buildings that have encroached on the pipeline ROW at the Refinery Junction.

Marketing activities are increasing around the refinery junction. This is a major pull factor that is responsible for the encroachments observed in the area. The image covers from the head of the System 2D pipeline to the road that links the refinery to Kamazou.

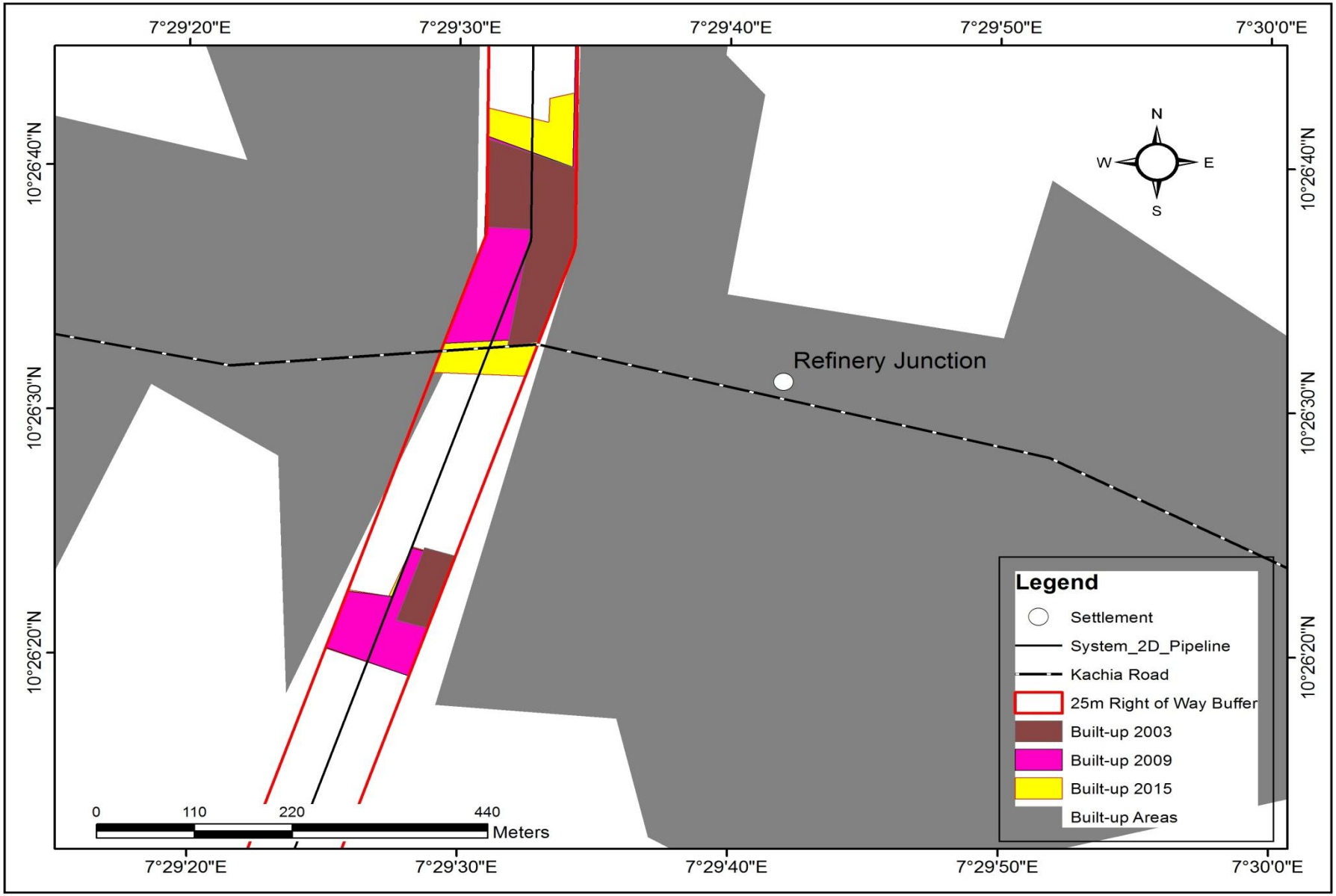


Figure 4.1 Encroachments on pipeline Row at Refinery Junction for 2003, 2009 and 2015
Source: Author's Analysis



Plate1: Oxy-acetylene welding on the pipeline ROW at the Refinery Junction
Source: PPMC, gallery 2015



Plate2: Retail Kerosine seller on the ROW at the Refinery Junction

Source: PPMC gallery 2015.

4.4.2 Encroachments at Mahuta

The System 2D pipeline traverses Mahuta, a settlement directly opposite the refinery junction. Mahuta is a developing residential area hence, most of the buildings are for residential purposes. The encroachments observed in this area is a combination of both residential buildings and farmland. The encroachments were 1.0, 2.33, and 2.72 hectares in 2003, 2009 and 2015 respectively. This shows a progressive increase in the area being encroached upon by buildings. On the other hand, the encroachments by farmlands were 6.77, 5.44 and 5.05 hectares for 2003, 2009 and 2015 respectively. This implied that some part of the ROW that was covered by vegetation have been converted to buildings, hence the decrease in the area covered by vegetation. A larger portion of the ROW in Mahuta is covered by bushes, as can be seen on the satellite images below. Some of the pipeline markers in most of the places may have been uprooted or broken by the property owners as only few can be seen, and buildings have been erected on the ROW. Plate 2 shows encroachments in Mahuta.

Observations in Mahuta revealed that new residential buildings are springing up very close to the pipeline markers and if no precautionary measure is taken, more residential buildings will encroach on the pipeline ROW.

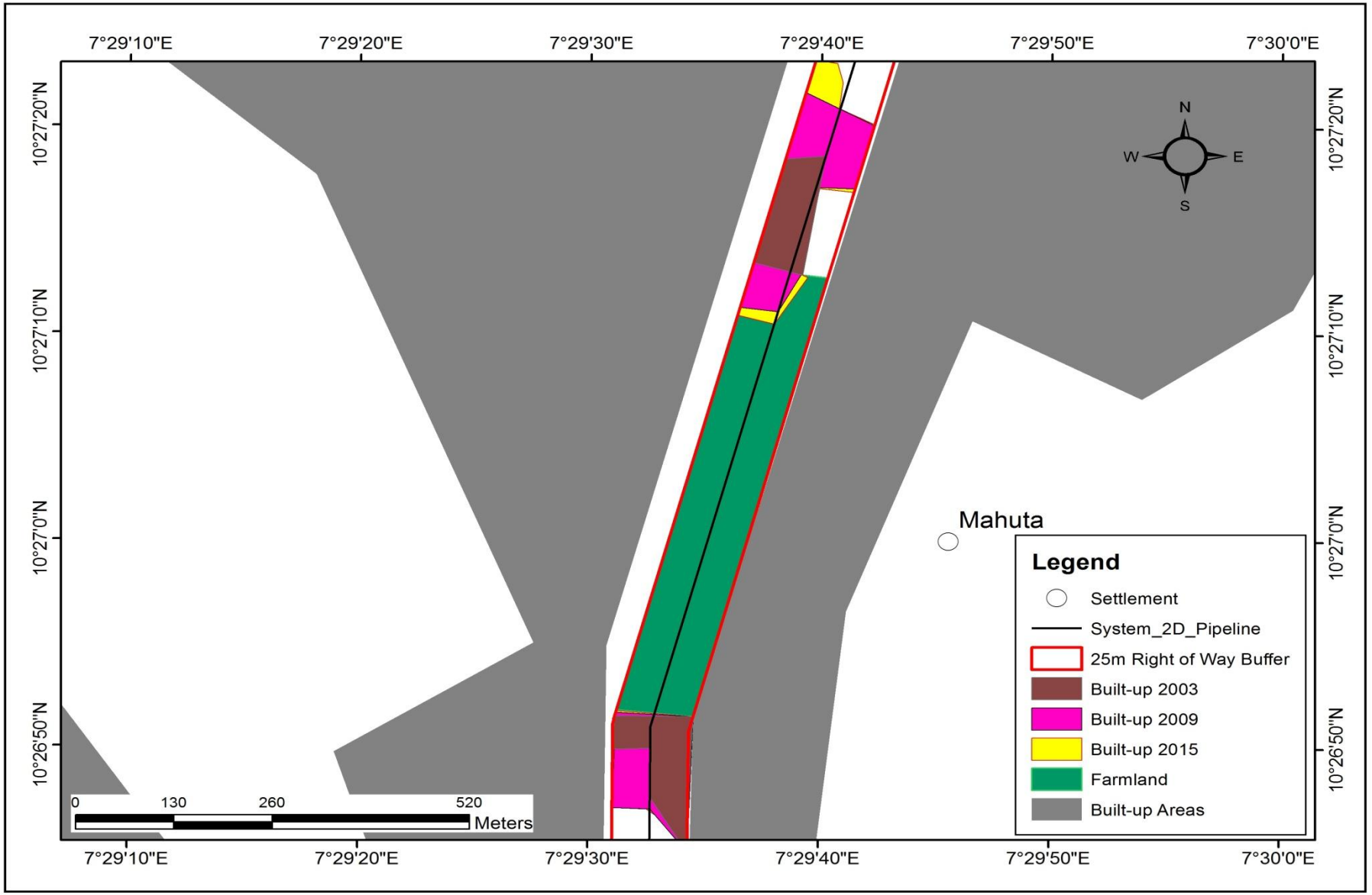


Figure 4.2 Encroachments on pipeline Row at Mahuta for 2003, 2009 and 2015
Source: Author's Analysis



Plate 3: Encroachments on the ROW at Mahuta

Source: Field Survey, 2015.

4.4.3 Encroachments at Kamazou

Kamazou is the next settlement to Mahuta on the pipeline route. It is a large and developing residential settlement. Here, it is obvious that some of the residential buildings that have encroached on the pipeline ROW had been marked for demolition by PPMC, hence the strong resistance and opposition experienced by the researcher in administering the questionnaire in this area. The area that encroached on the ROW is popularly called "pipeline". The residents are fully aware of the fact that they are not safe in the event of any pipeline accidents, but were not willing to do anything about it. There was a building that was less than 2 metres from the pipeline marker (plate 2), and the residents were not ready to hear anything like a research that involves pipeline. This was because there were houses that had been marked for demolition by PPMC, and they were scared of the fact that the governor of Kaduna State had embarked on

demolition of structures that encroached into any government property. Hence, the researcher was seen as a threat.

The encroachments were 7.48, 7.68 and 10.44 hectares for the years 2003, 2009 and 2015. The encroachment between 2003 to 2009 was less than one hectare, while the encroachment between 2009 and 2015 is 2.76 hectares. This implied that more buildings are encroaching on the pipeline ROW. Kamazou was one of the settlements that had the highest encroachments as at the time of this research. The PPMC/NNPC were doing their best in replacing broken pipeline markers and broken sign posts. This does not change the fact that there were encroachments on the pipeline ROW and more structures were still being constructed on the ROW despite the houses that had been marked for demolition. Figure 4.3 and plate 2 shows the nature of encroachments on the ROW in Kamazou.

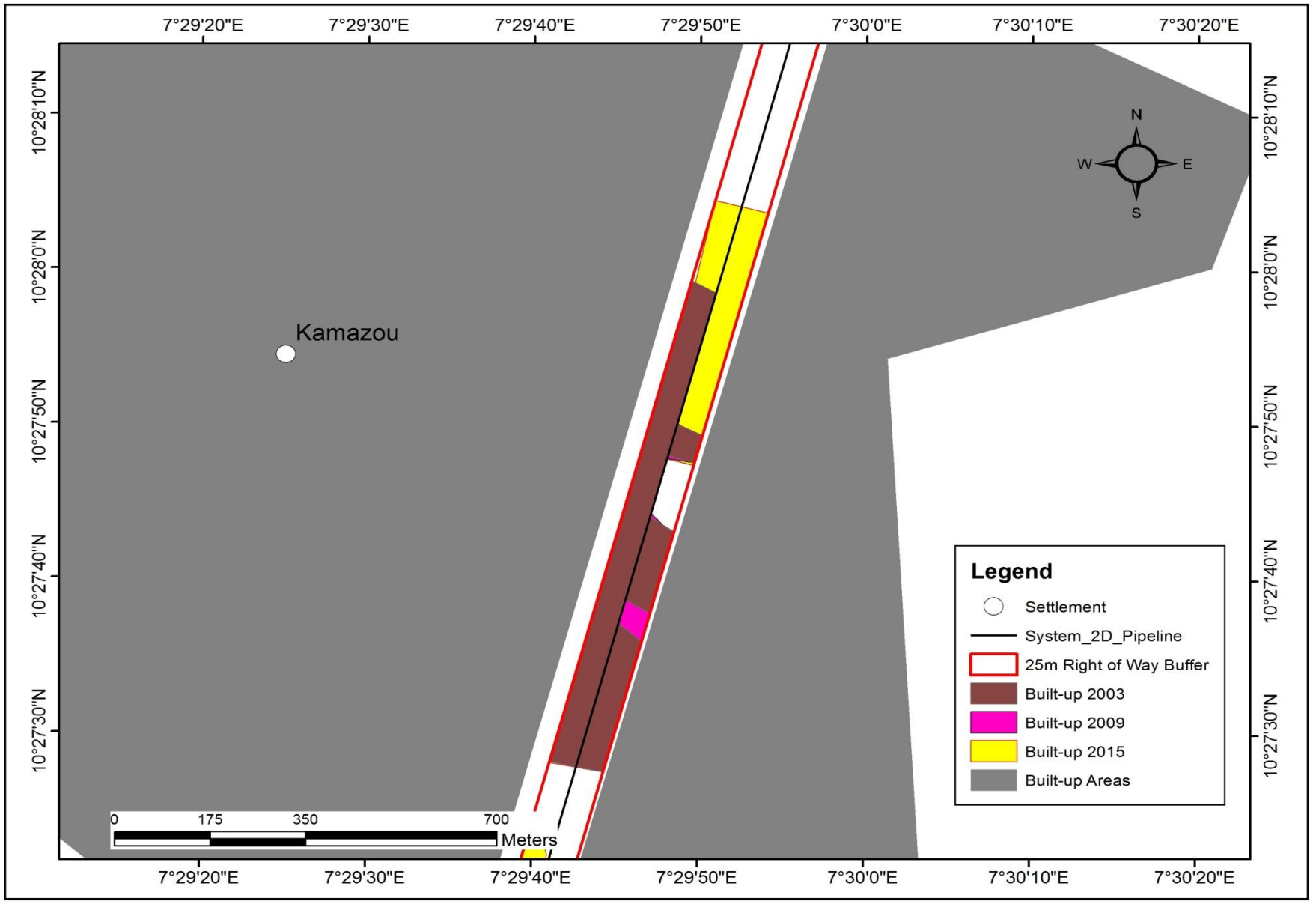


Figure 4.3 Encroachments on pipeline ROW at Kamazou for 2003, 2009 and 2015

Source: Author's Analysis



Plate 4: Encroachments on the ROW in Kamazou

Source: Field Survey, 2015



Plate 5: Residential buildings on the ROW in Kamazou

Source: Field Survey, 2015

4.4.4 Encroachments at Bagado

Bagado is the next settlement to Kamazou on the pipeline. The encroachments on pipeline ROW by buildings was 1.33, 1.9 and 2.82 hectares for the years 2003, 2009 and 2015 respectively. The encroachments by farmlands was 11.17, 10.61 and 9.69 hectares for the years 2003, 2009 and 2015 respectively. This shows that while the encroachments on the ROW by buildings was increasing, the farmland on was decreasing.

Bagado is an upcoming settlement that has more of vegetation than buildings, though the buildings encroached on the pipeline ROW. There was a church that was very close to a pipeline marker. This is very risky as the condition of the pipeline is questionable due to poor maintenance (Ekwo, 2011). The encroachments in this settlement can be controlled since there are fewer buildings than other settlements. Residential buildings were constructed right on the ROW and people are comfortably settled probably because no pipeline accident or maintenance had affected them in the past. Buildings were constructed without any caution, provided the land was available and affordable.

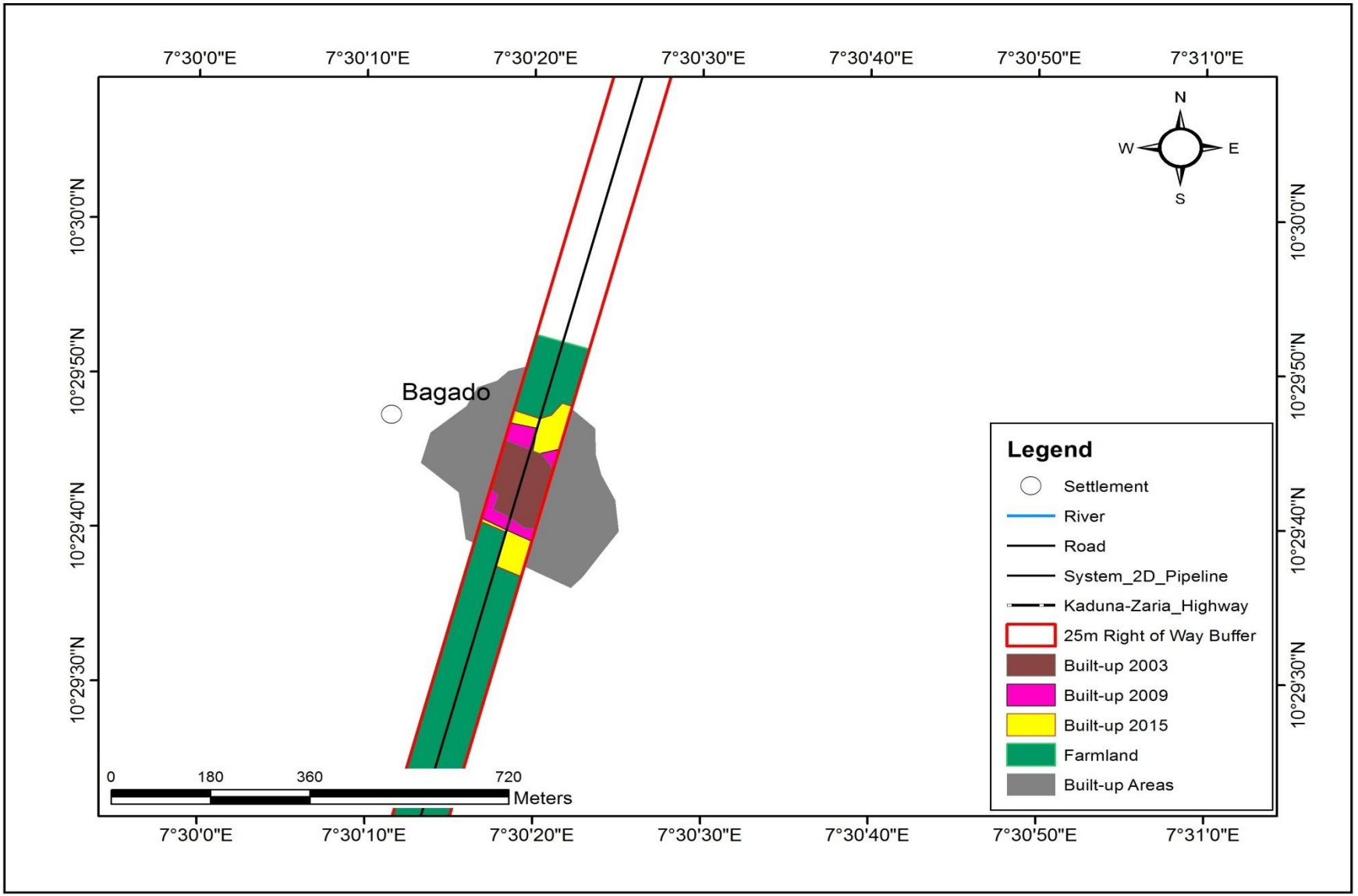


Figure 4.4 Encroachments on pipeline ROW at Bagado for 2003, 2009 and 2015
Source: Author's Analysis



Plate 6: A place of worship on the ROW in Kamazou

Source: Field Survey, 2015



Plate 7: A Residential building on ROW
Source: Field Survey, 2015

4.4.5 Encroachments at Kakura

Kakura is a remote settlement that is very close to the eastern bypass in Kaduna. The portion of the pipeline ROW that traverses Kakura was only encroached upon by farmlands, hence, there is need to check further encroachments as these farmlands gradually converts to build up areas. The total area that encroached on the pipeline ROW was 27.26 hectares. No buildings were found on the pipeline ROW for 2003, 2009 and 2015. It was difficult locating most of the pipeline markers here because growing crops as well as thick bushes covered them. Most of the encroachments here was by human-induced vegetation.

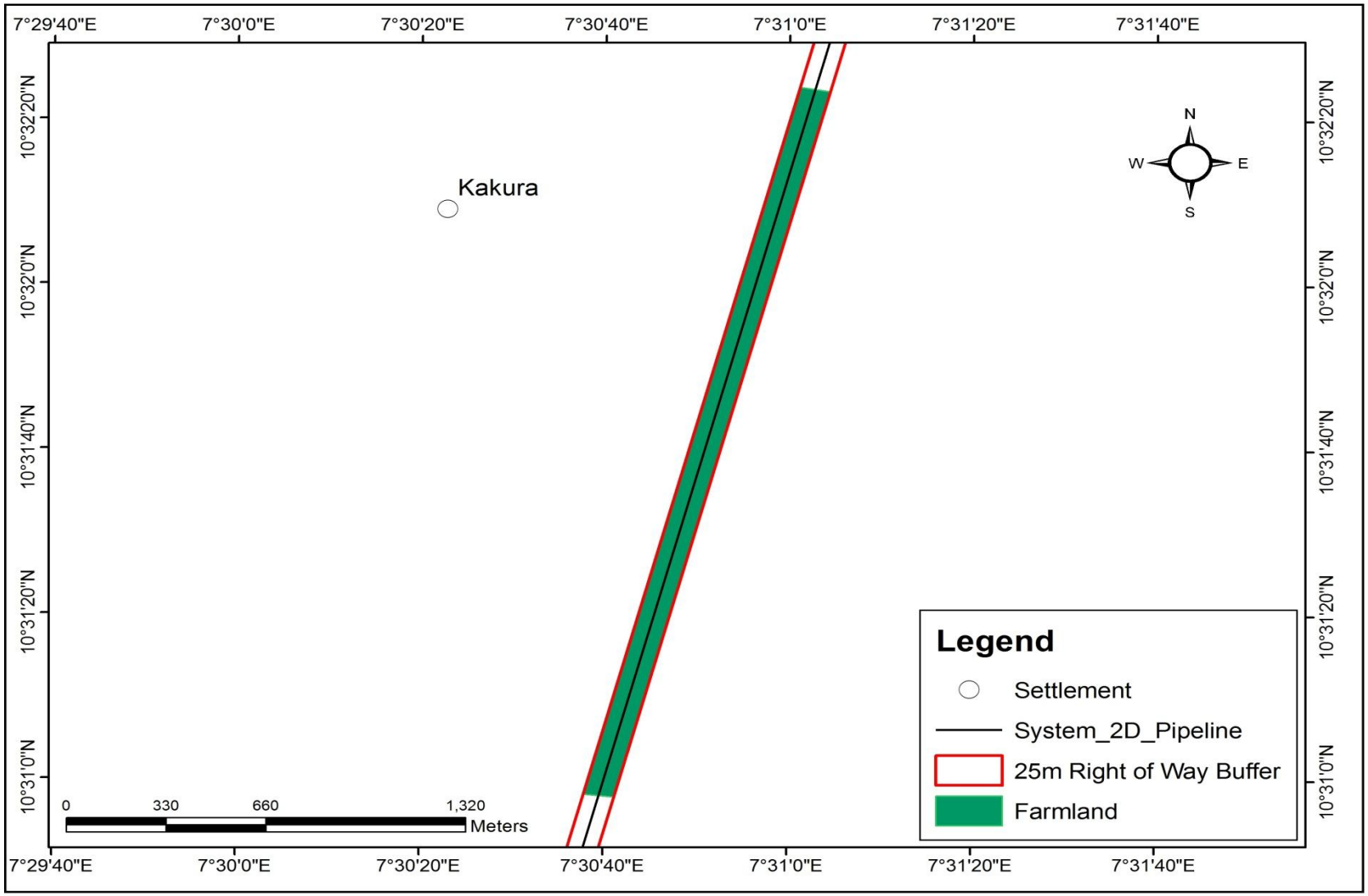


Figure 4.5 Figure 4.4 Encroachments on pipeline ROW at Kakura for 2003, 2009 and 2015

Source: Author's Analysis

4.4.6 Encroachments at Keke

This is a growing settlement with much of the encroachments on pipeline ROW being vegetation. The encroachments for buildings were 0.41, 0.6 and 2.04 hectares for 2003, 2009 and 2015 respectively. There was a sharp increase in the buildup areas that have encroached on the pipeline ROW. It was observed that from most of the new structures were constructed mostly on the pipeline ROW. In other words, less attention is paid to the issue of encroachment on the ROW as more buildings were being built. It can therefore be implied from the image that if no precautionary measures are taken, and if nothing happens to checkmate these encroachments, more buildings will take over the ROW in no distant time, as more land is being converted to buildings.

The farmlands on the pipeline ROW was 7.28, 6.27 and 4.82 hectares. This shows a continuous decrease in the farmland on the pipeline ROW corridor, as more buildings are coming up. Most of the vegetation were farmlands.

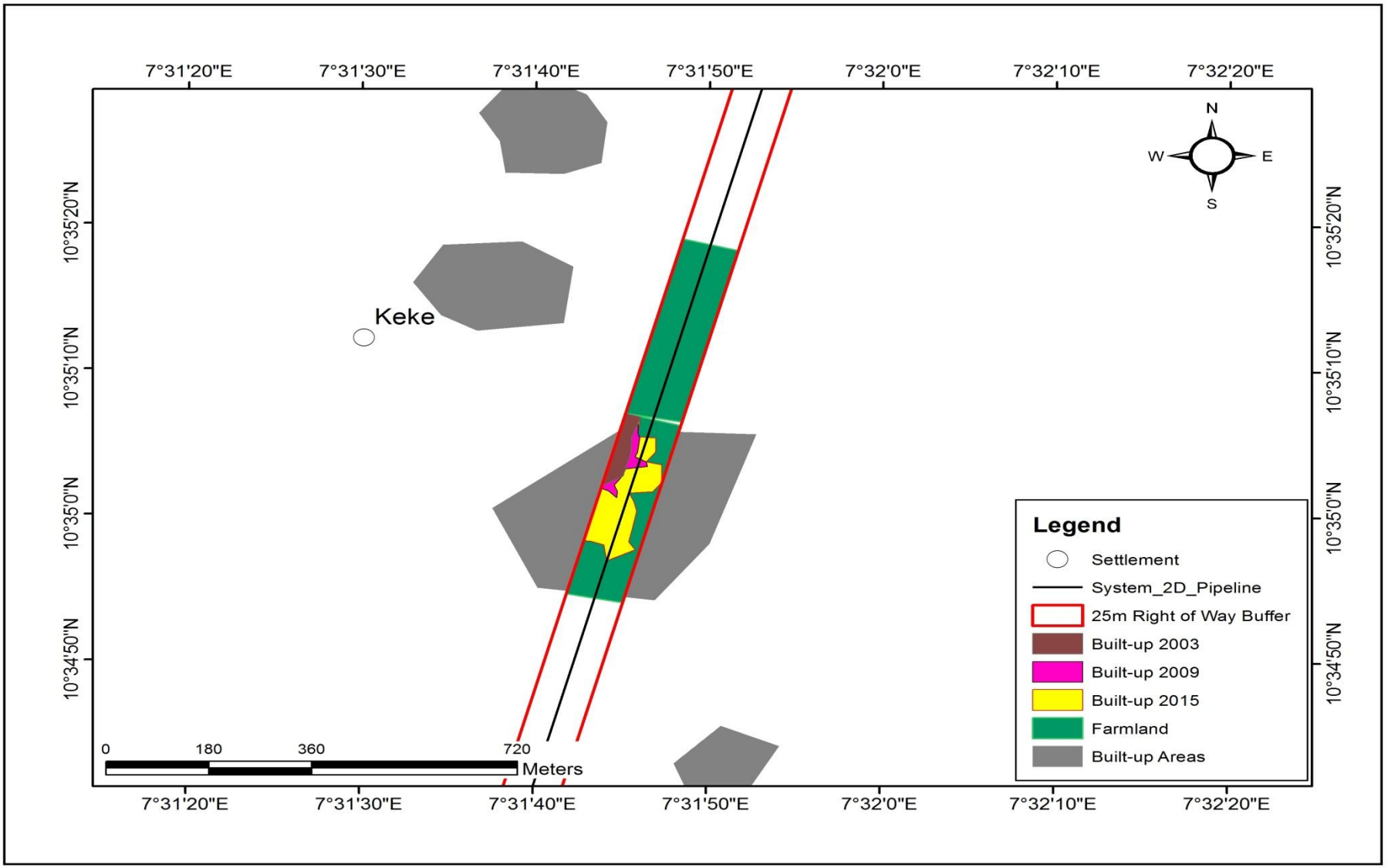


Figure 4.6 Figure 4.4 Encroachments on pipeline ROW at Keke for 2003, 2009 and 2015
Source: Author's Analysis



Plate 8: Encroachments on the ROW in Keke

Source: Field Survey, 2015

4.4.7 Encroachments at Kangimi

The encroachments observed here were mostly vegetation, as can be seen from the satellite image. There were no buildings on the pipeline ROW in 2003, 2009, and 2015, the encroachments were majorly farmlands covering a total of 18.1hectares for each of the years. Most of the green areas were farmlands. There was intense farming on the ROW.

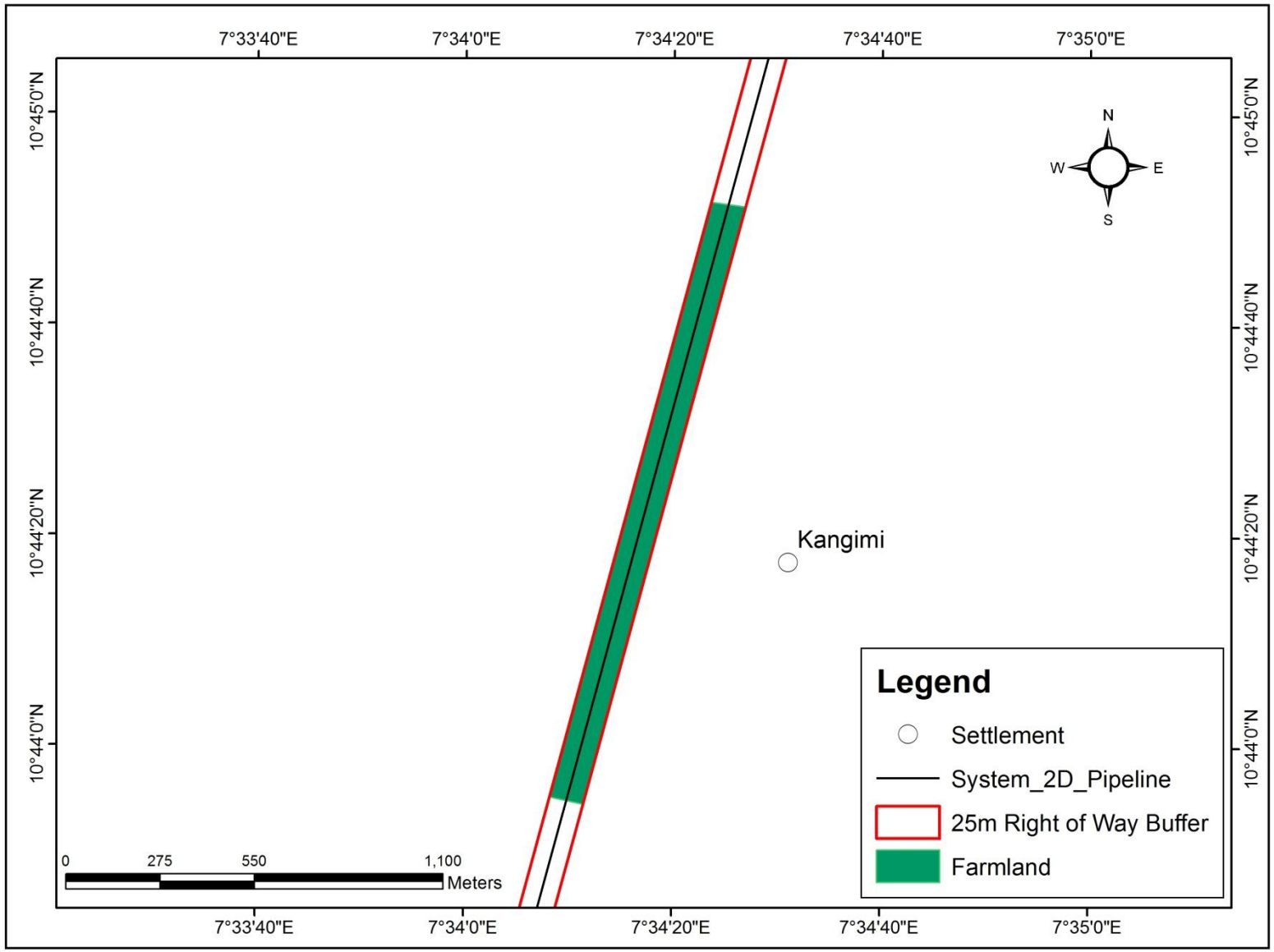


Figure 4.7 Encroachments on pipeline ROW at Kangimi for 2003, 2009 and 2015
Source: Author's Analysis

4.4.8 Encroachments at Kargo

In Kargo, the major encroachments observed were farmland, mostly farmlands, with a total area coverage of 12.34 hectares for 2003, 2009 and 2015 respectively. From the image, it can be seen that the buildup area is not very far from encroaching into the ROW, hence, protective and preventive measures need to be put in place to check further encroachments by residential buildings in the near future.

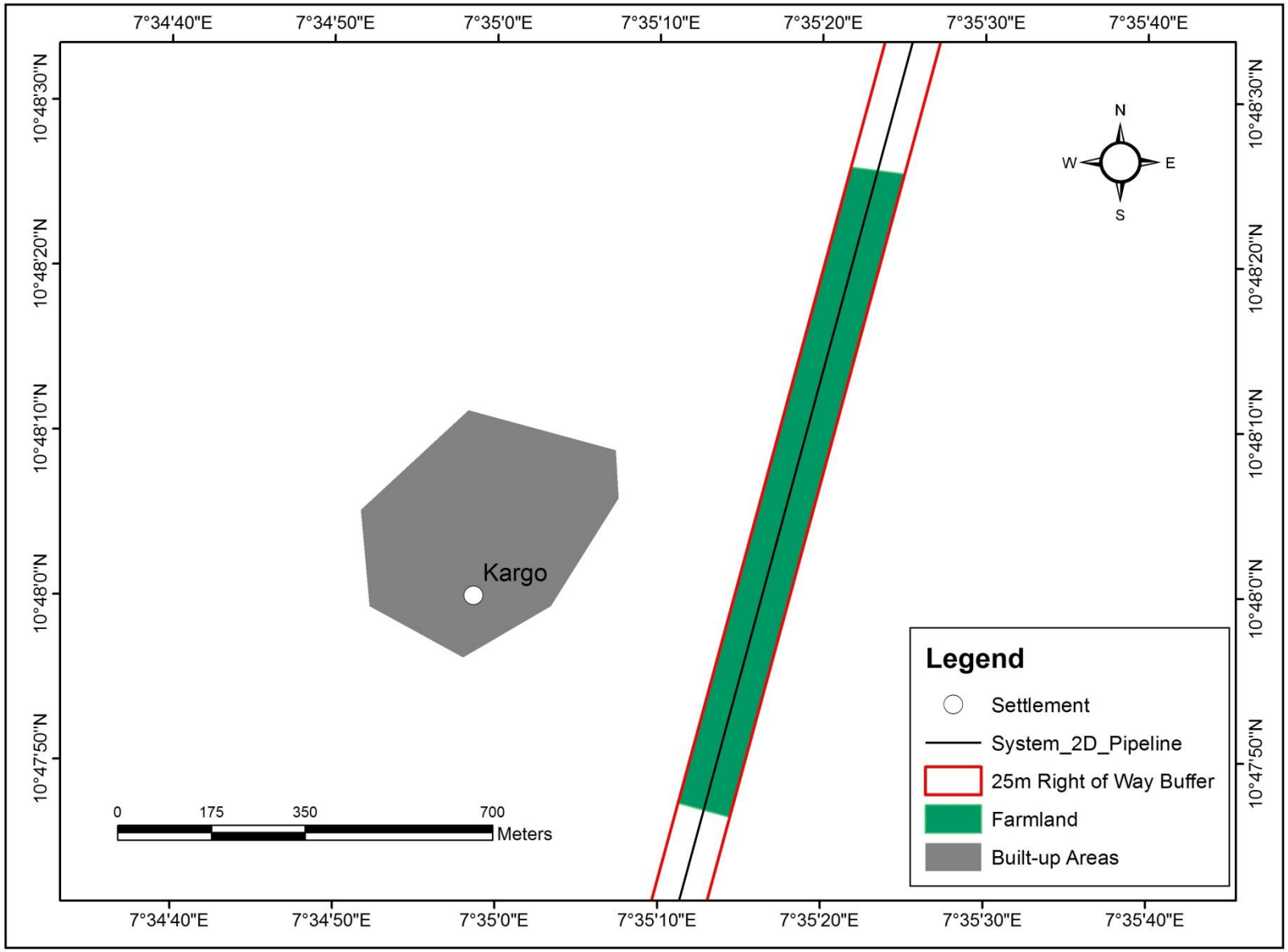


Figure 4.8 Encroachments on pipeline ROW at Kargo for 2003, 2009 and 2015
Source: Author's Analysis

4.4.9 Encroachments at Rigachukun

The pipeline traverses Rigachukun far away from the buildup area, hence the encroachments here are farmlands as can be seen on the image below. The area of land encroached upon by vegetation was 26.23 hectares in 2003, 2009 and 2015 respectively. Intense farming activities were observed on the pipeline ROW, this ought to be checked, as the depth of the buried pipelines is 1metre (Ogundele, 2007). Hence, intense farming could expose the pipelines thereby encouraging vandalism of the pipelines and exposing the pipelines.

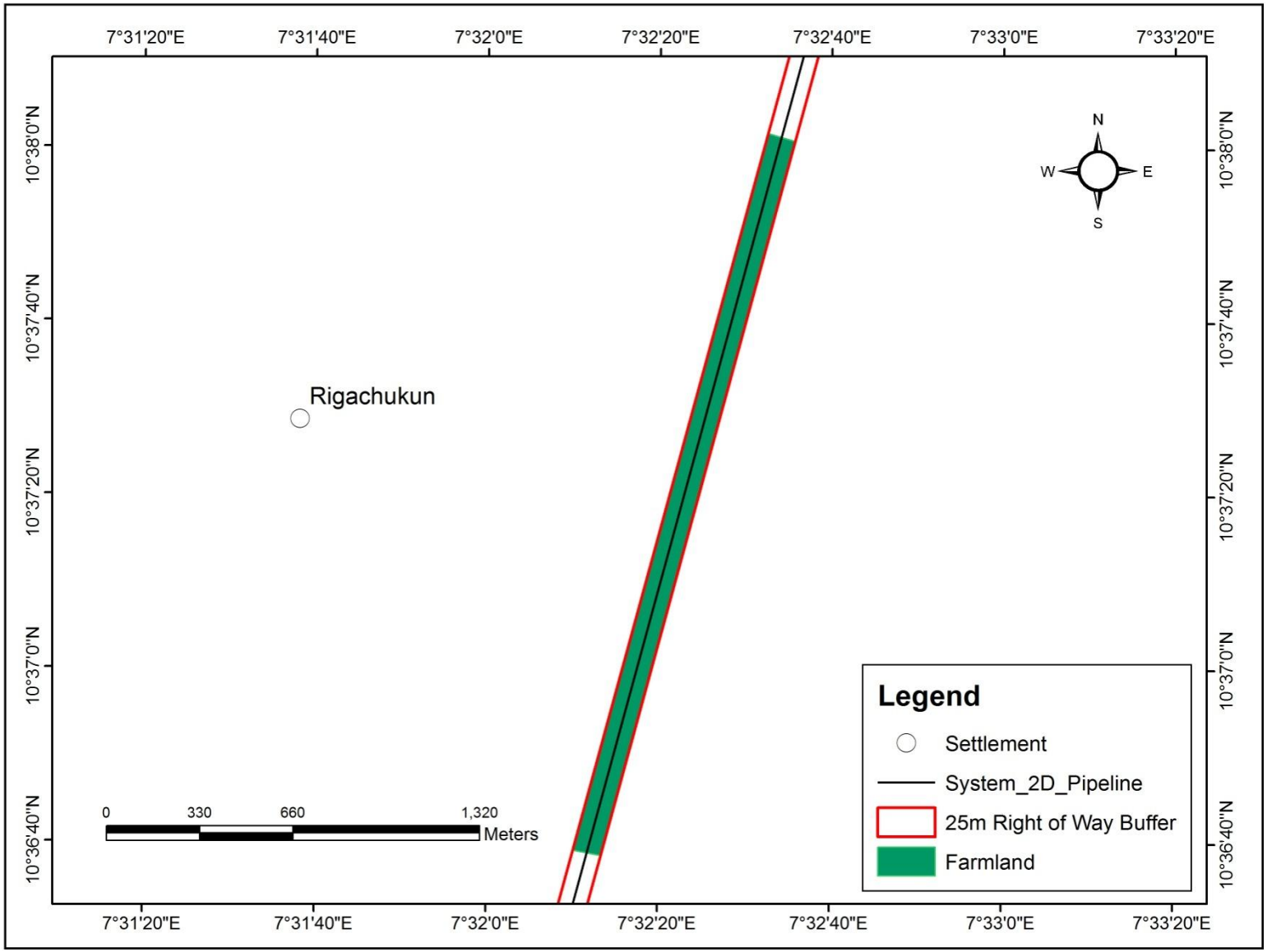


Figure 4.9 Encroachments on pipeline ROW at Rigachukun for 2003, 2009 and 2015
Source: Author's Analysis

4.4.10 Encroachments at Jaji

The pipelines in Jaji are still far away from the built up area, hence the encroachments is mostly by vegetation. The total area covered by vegetation was 23.17 hectares in 2003, 3009 and 2015 respectively. The encroachments in jaji are mostly farmlands, with a few nomadic settlements close to the pipeline ROW. It was observed here that most of the portions of the pipeline ROW were used as roads in the bushes. This too is a hazardous practice as heavy vehicles ply the ROW and this could affect the performance of the pipeline.

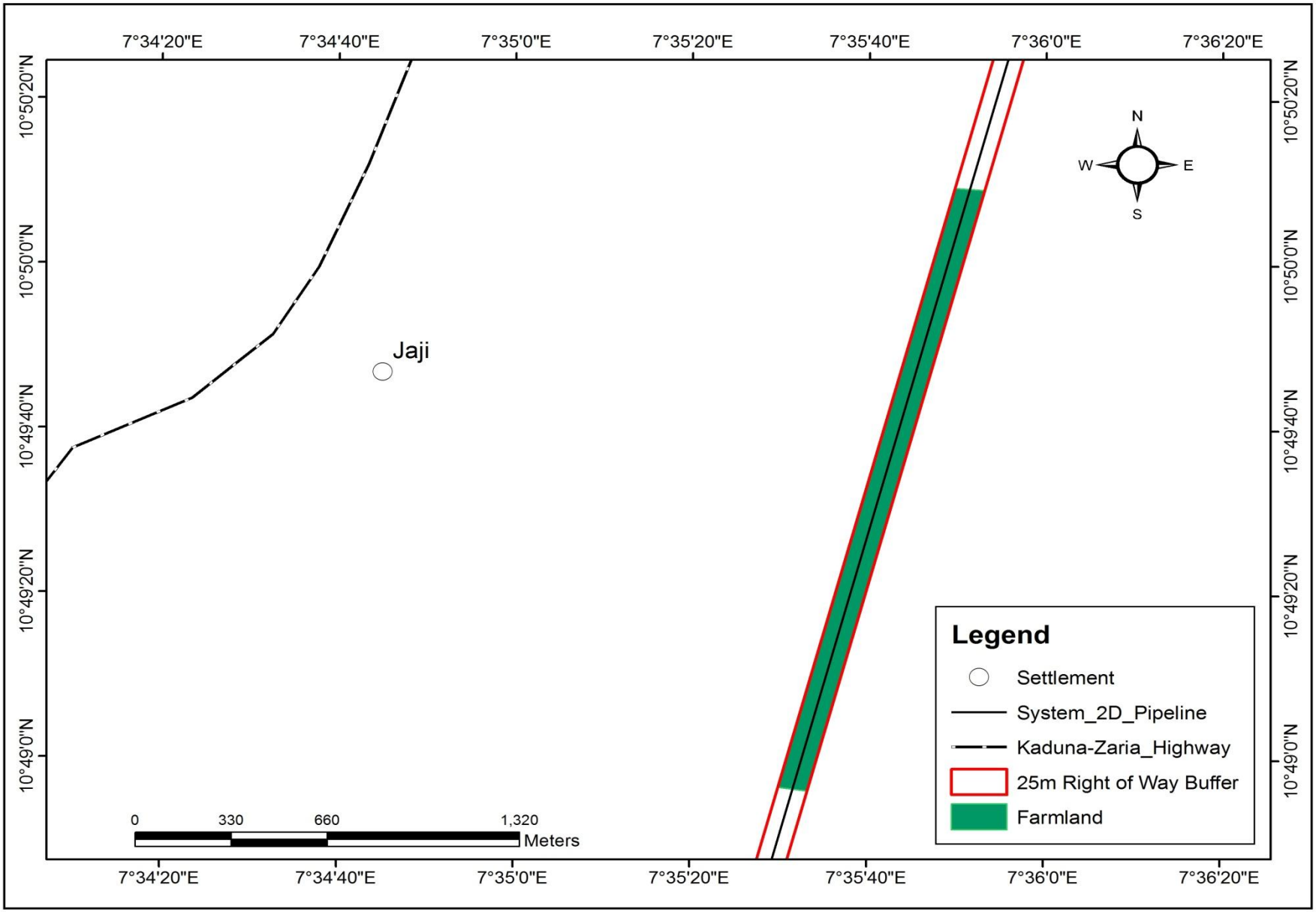


Figure 4.10 Encroachments on pipeline ROW at Jaji for 2003, 2009 and 2015
Source: Author's Analysis

4.4.11 Encroachments at Sabon Yelwa

This is the next settlement to Jaji on the pipeline, with a total encroachment of 20.69 hectares by vegetation in 2003, 2009 and 2015 respectively. The encroachments were mostly farmlands, majorly sugarcane farms, among other crops that were cultivated on the ROW. The built up area is not far away from the pipeline hence, proper encroachment control measures need to be put in place to check the infiltration of buildings into the pipeline ROW.

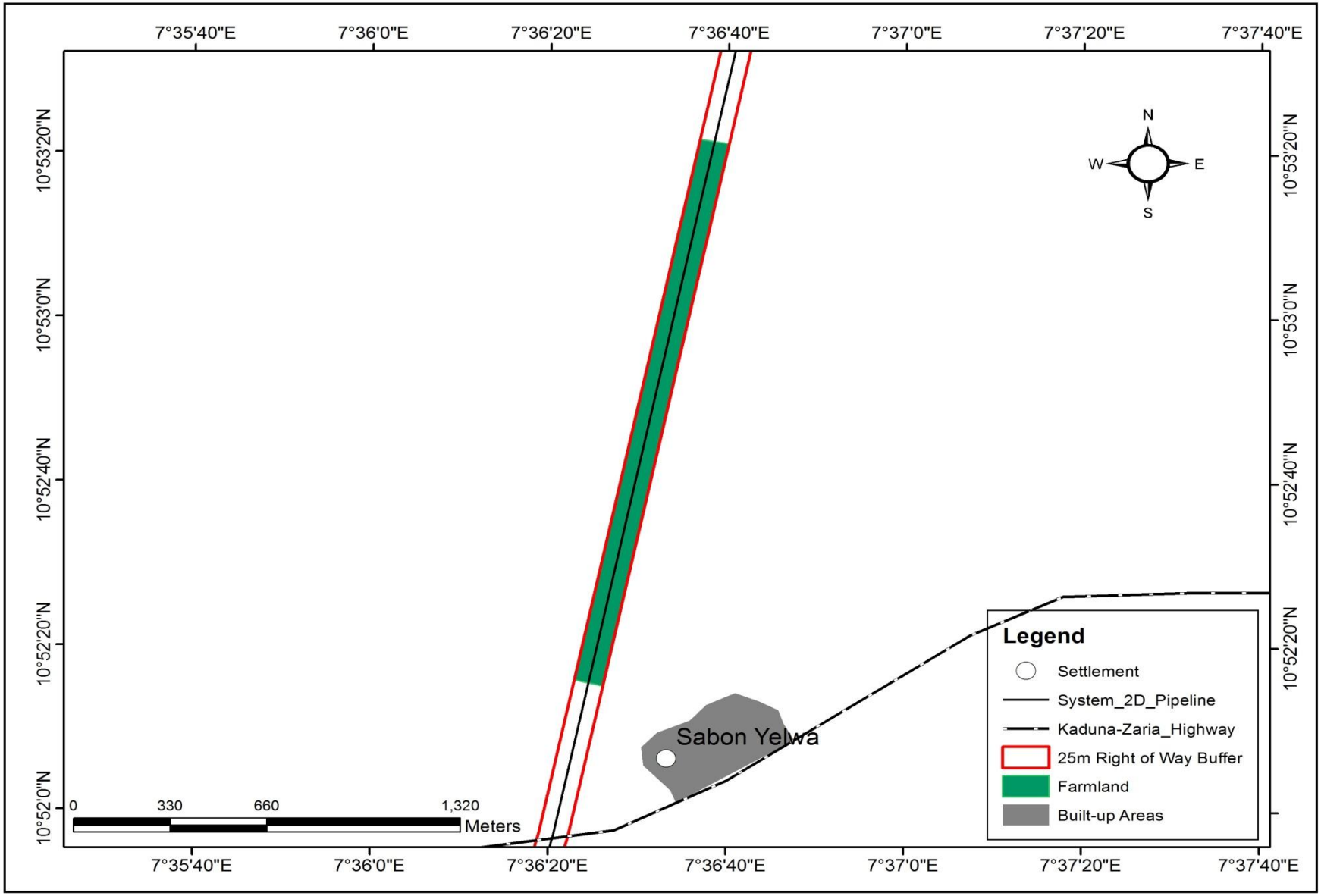


Figure 4.11 Figure 4.4 Encroachments on pipeline ROW at Sabon Yelwa for 2003, 2009 and 2015
Source: Author's Analysis

4.4.12 Encroachments at Saye

This is the next settlement to Sabon Yelwa on the pipeline with a mixture of both buildings and farmlands encroaching on the pipeline ROW. The encroachments by built up areas were 1.72, 2.3 and 2.44 hectares in 2003, 2009 and 2015 respectively, while the encroachments by vegetation were 4.01, 3.44 and 3.3 hectares within the same period respectively. This shows that there is a steady increase in the conversion of the vegetative cover on the ROW to buildings. There are a few residential buildings on the ROW here and most of the encroachments are crops that made most of the pipeline markers inaccessible except for few that are close to the road.

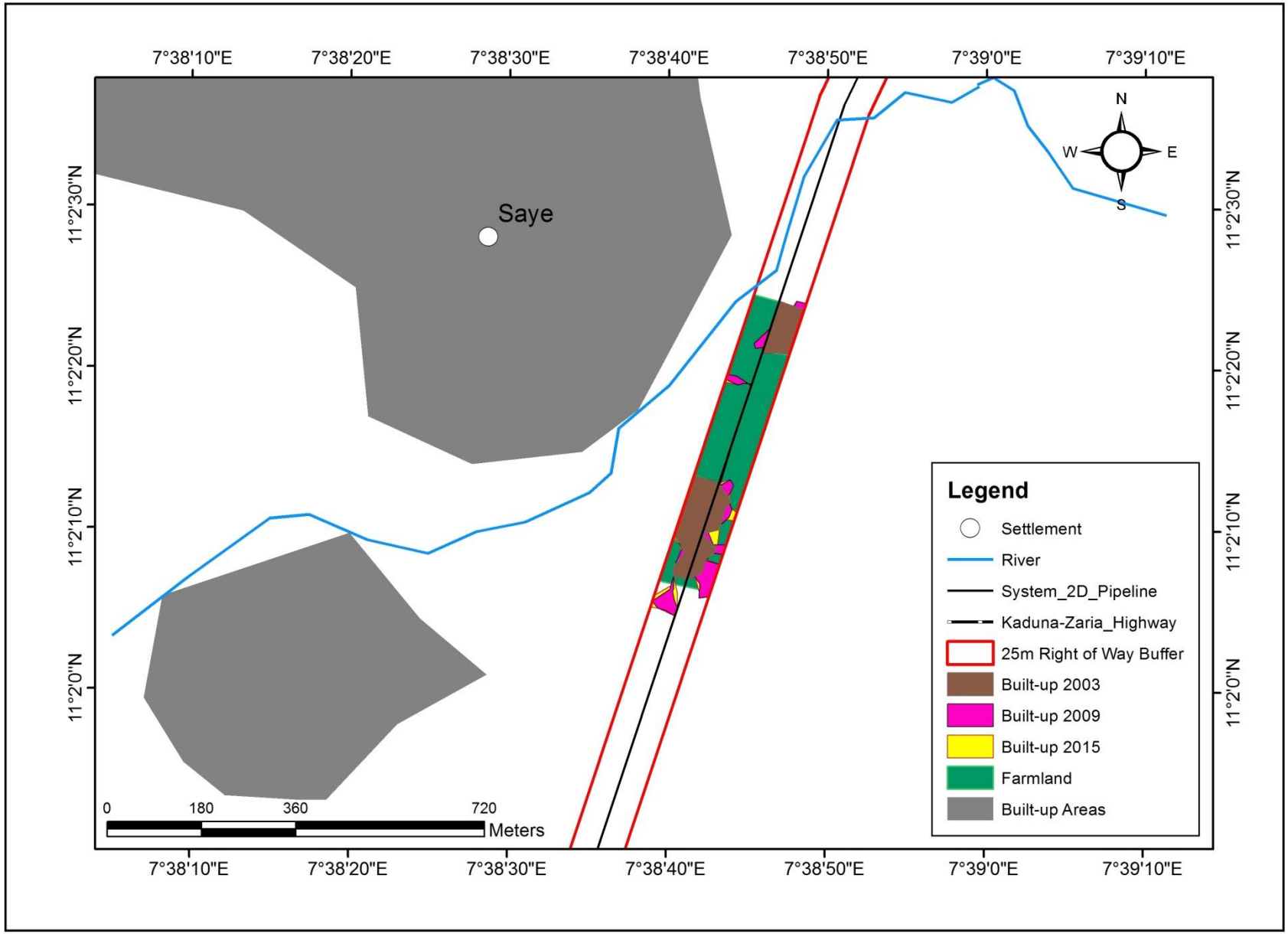


Figure 4.12 Encroachments on pipeline ROW at Saye for 2003, 2009 and 2015
Source: Author's Analysis

4.4.13 Encroachments at Kufena

The area of the pipeline ROW encroached upon by buildings was 2.71, 2.91, and 3.20 hectares for 2003, 2009 and 2015 respectively, while the encroachments by farmlands was 4,01, 3.44, and 3.3 hectares within the same time period. Part of the Science Secondary School Kufena encroached on the pipeline Row. This is very risky, as the lives and property within it are at stake in the event of any pipeline accidents.

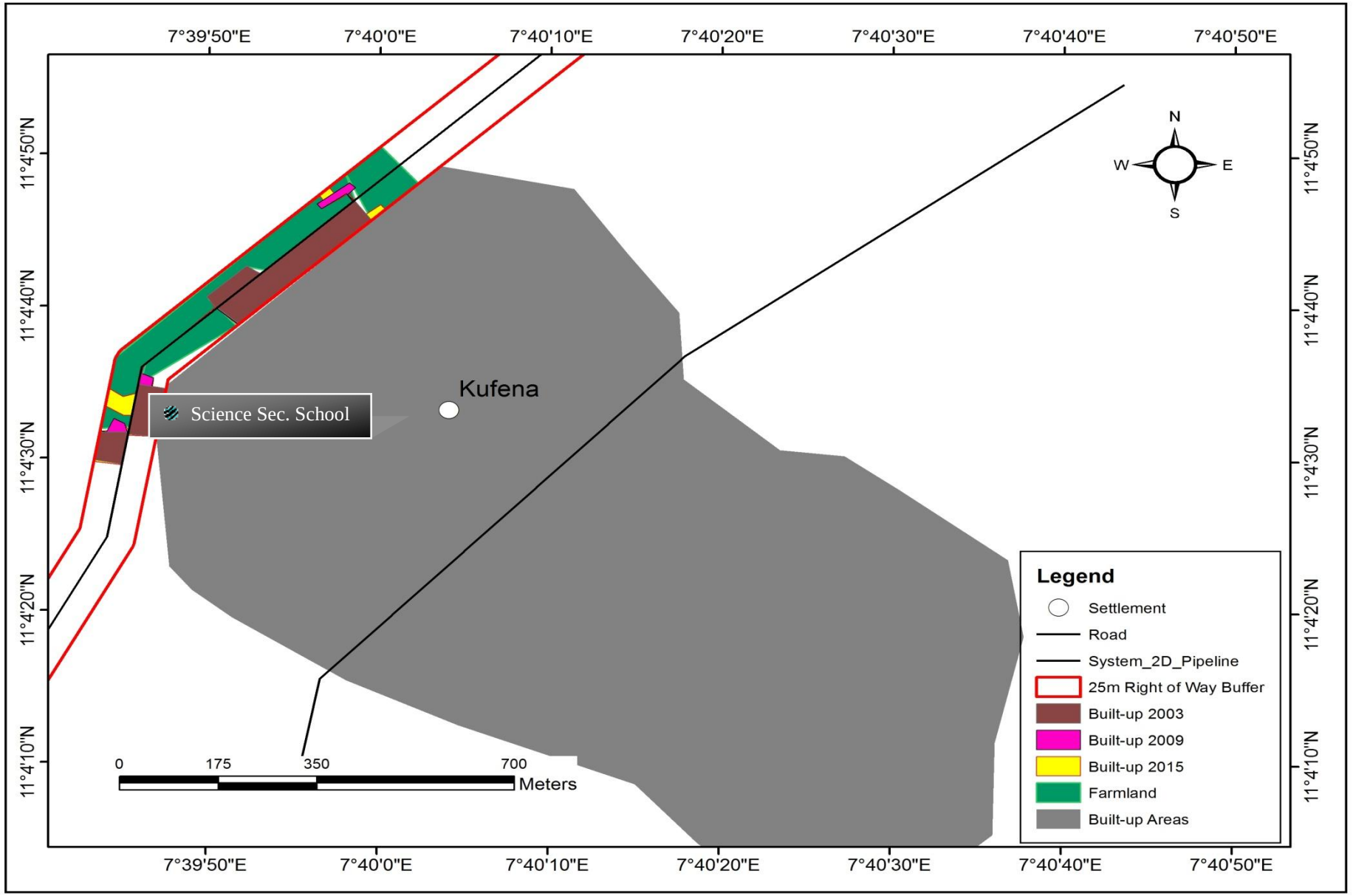


Figure 4.13 Encroachments on pipeline ROW at Kufena for 2003, 2009 and 2015
Source: Author's Analysis

4.4.14 Encroachments at Zaria Pump Station

This showed the encroachments on the pipeline ROW around the pump station. The area encroached into by buildings was 0.17, 0.17 and 0.19 in 2003, 2009 and 2015 respectively, while farmlands 3.16, 3.16 and 3.14 hectares respectively within the same period. This shows an increase in the built up areas around the pump station. New buildings were being constructed around the Zaria Pump Station as at the time of this study and most of them were being constructed on the ROW.

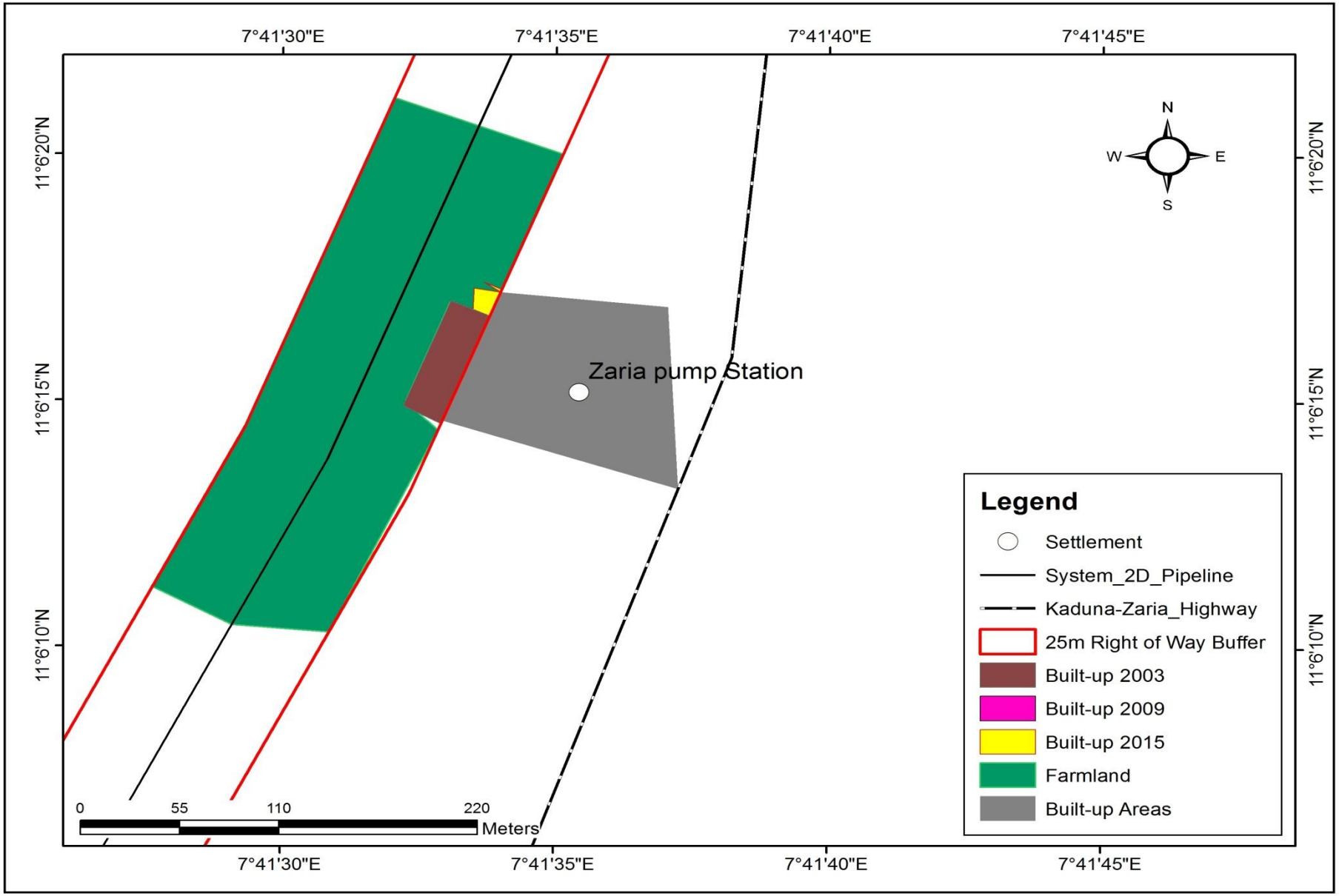


Figure 4.14 Encroachments on pipeline ROW at Zaria Pump Station for 2003, 2009 and 2015
Source: Author's Analysis

4.4.15 Encroachments at Hanwa

Hanwa area covers from Yan Karfe down to Hanwa GRA and Yangoro Market. This is the settlement that had the highest encroachments on pipeline ROW by buildings. The area encroached upon by buildings was 8.51, 12.27 and 15.99 hectares in 2003, 2009 and 2015 respectively. This implies that there are more buildings still being erected on the pipeline ROW. The Yangoro market is completely on the pipeline ROW as can be seen from the plates, the pipeline markers have been broken and commercial activities were carried out on the ROW.

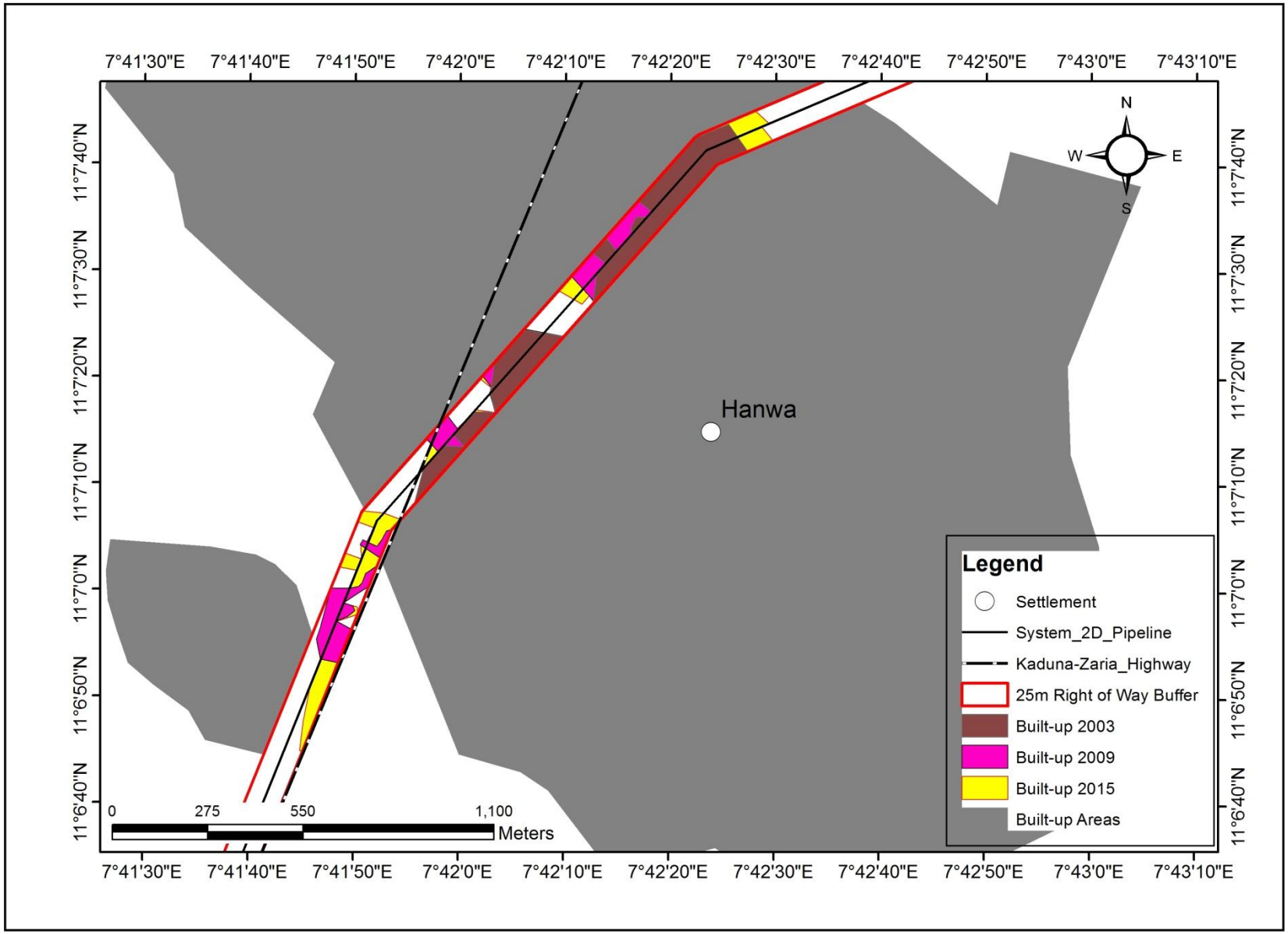


Figure 4.15 Encroachments on pipeline ROW at Hanwa for 2003, 2009 and 2015

Source: Author's Analysis



Plate 9: Encroachments on the ROW at Yangoro Market, Hanwa

Source: Field Survey, 2015



Plate 10: Encroachments on the ROW in Yangoro by auto-mechanics, Hanwa

Source: Field Survey, 2015

4.4.16 Encroachments at Dogarawa

This is the area around the Sabon Gari Local Government Secretariat down to the Kaduna-Kano express road. The total portion of the ROW occupied by buildings was 10.61, 11.63 and 12.45 hectares in 2003, 2009 and 2015 respectively. This shows massive encroachments on the pipeline ROW by buildings. It was observed that there was a Mosque that had a pipeline marker enclosed in its fence. This could be very dangerous and risky in the event of any pipeline failure in that area. It was very difficult locating the pipeline markers here as most buildings had taken over the pipeline ROW. There were auto-mechanics and welders who had their shops encroaching on the pipeline ROW.

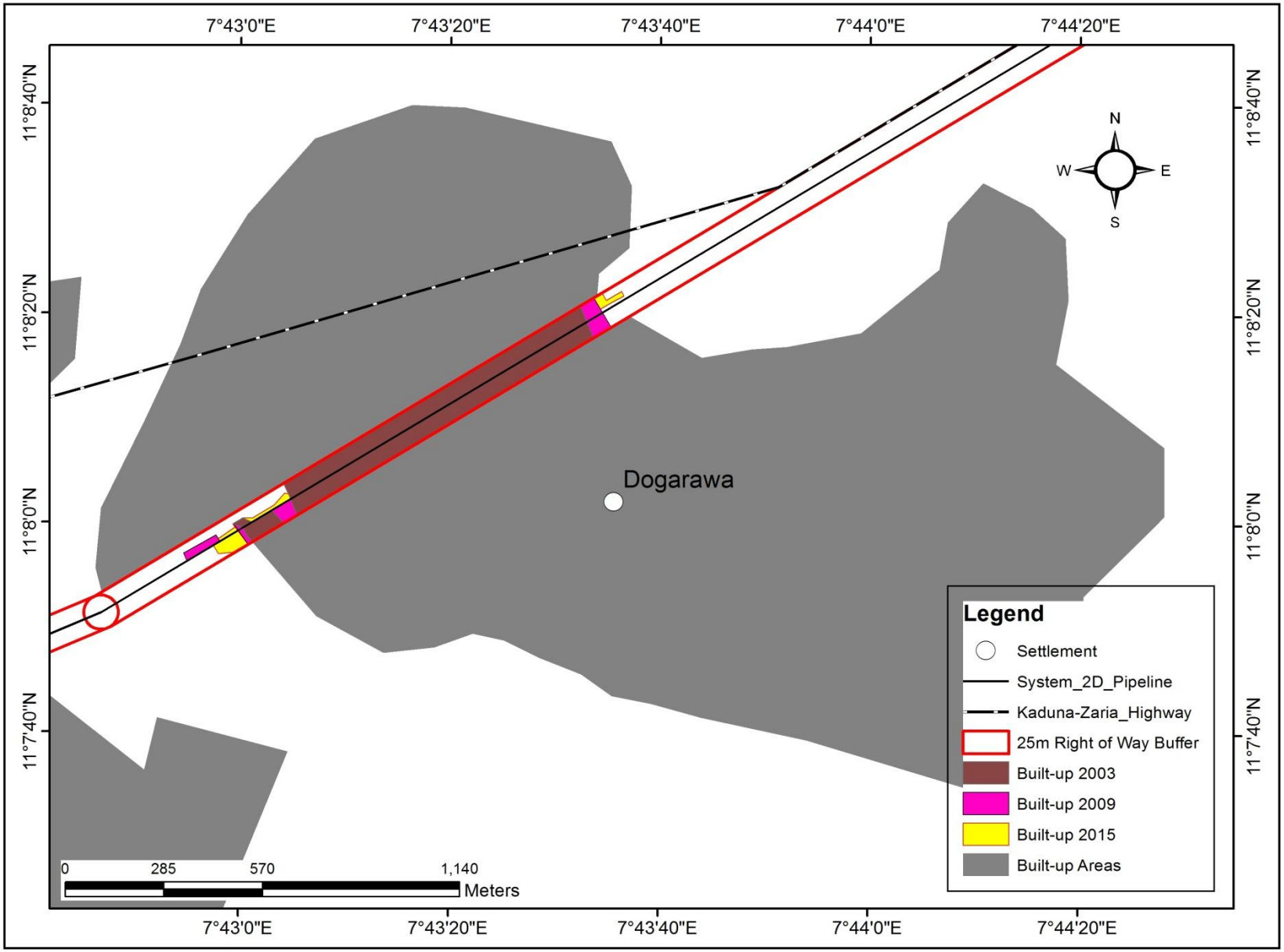


Figure 4.15 Encroachments on pipeline ROW at Dogarawa for 2003, 2009 and 2015
Source: Author's Analysis



Plate 11: Encroachments on the ROW by residential buildings at Dogarawa
Source: Fieldwork, 2015



Plate 12: Encroachments on the ROW by mechanics at Dogarawa
Source: Fieldwork, 2015

4.5 Factors Responsible for Encroachments on ROW

Questionnaire Analysis

Out of the one hundred and twenty questionnaire administered in the study area, only one hundred and ten (110) were fully completed and returned. Table 4.5 gives the number of questionnaire retrieved from each settlement.

Table 4.5: Names of Settlements and Number of Questionnaire completed and returned

Name of Settlement	No. of Questionnaires
Refinery Junction	10
Mahuta	10
Kamazou	20
Bagado	10
Kakura	-
Keke	-
Kangimi	-
Kargo	-
Rigachukun	-
Jaji	-
Sabon Yelwa	-
Saye	10
Kufena	10
Zaria Pump Station	-
Hanwa	20
Dogarawa	20
Total	**110**

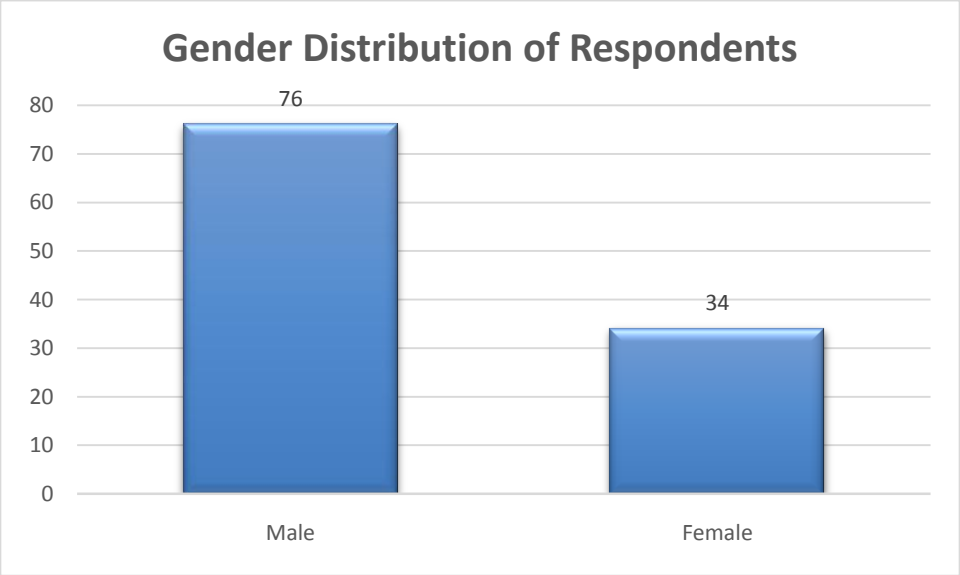
4.5.1 Socio-demographic characteristics of Respondents

Table 4.15 Age of the Respondents

Age category	Frequency	Percentage
18-25 years	22	20.0
26-35 years	50	45.5
36-45 years	28	25.5
46-55 years	8	7.2
56 years and above	2	1.8
Total	110	100.0

From the table above, majority of the respondents were between ages 18 and 45 years. This implied that all the respondents were adults who are knowledgeable about the subject of discuss.

Figure 4.2 Gender Distribution



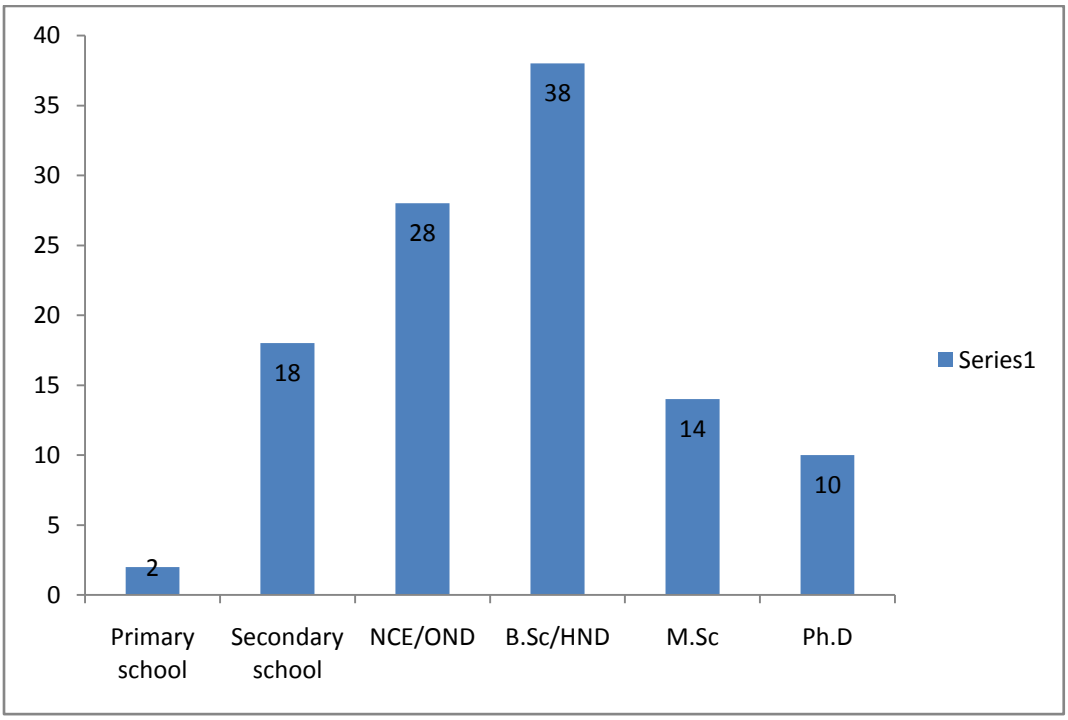
The gender distribution of the respondents showed that there were more male respondents than females. The males were more open to discussions than the females and this could be attributed to restrictions placed on females by culture and religion.

Table 4.17 Occupation of Respondents

Occupation	Frequency	Percentage
Farming	25	22.7
Business/Trading	22	20.0
Civil servant	41	37.3
Others	22	20.0
Total	110	100.0

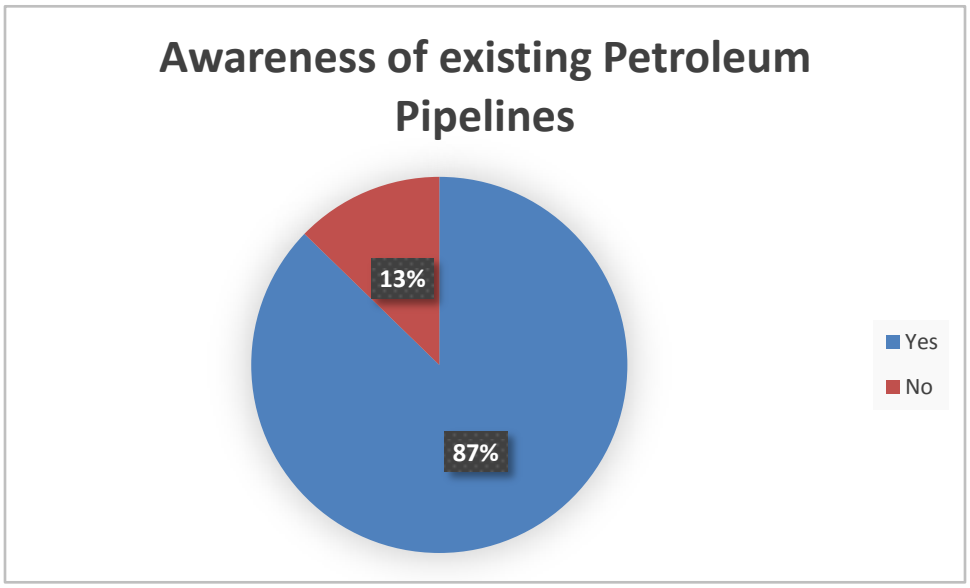
Majority of the respondents were civil servants, this means that they could at least read and write and they actually understood the writings on the PPMC signposts warning against encroachments on pipeline ROW and who had at one point or the other been contacted by the public relations department of PPMC, sensitizing them on the risks involved in encroaching on the pipeline ROW.

Figure 4.18 Educational Qualification



The figure above showed that majority of the respondents were educated above primary school level. This implies that they are knowledgeable about safety practices and the risks involved in violating them.

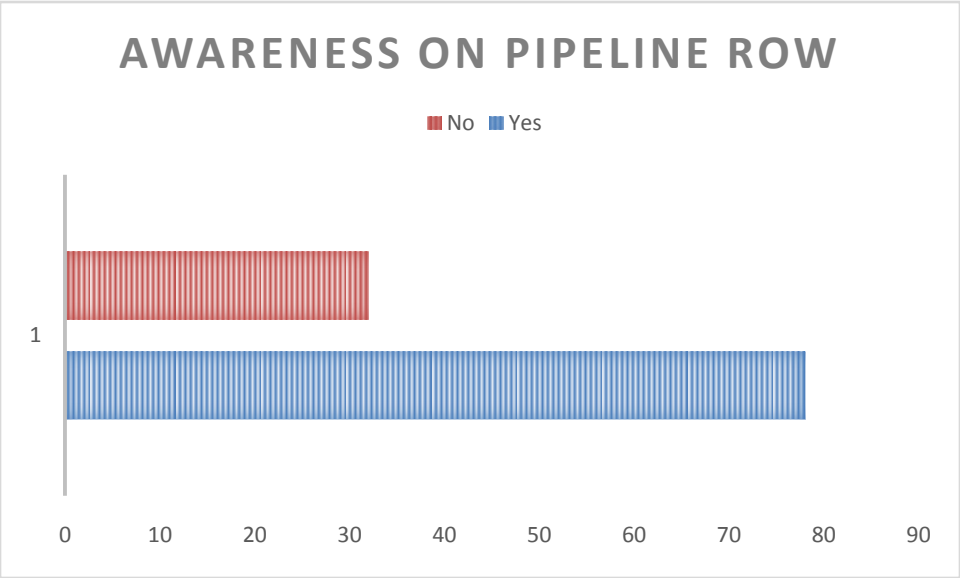
Figure 4.3 Awareness of existing petroleum pipelines



From the figure above, only about one tent of the respondents claimed they were not aware of the existence of a pipeline in traversing their community. This showed that about 90% of the respondents are aware of the existence of a pipeline in their community.

Table 4.20 Awareness on Pipeline Right of Way

Feedback	Frequency	Percentage
Yes	78	70.9
No	32	29.1
Total	110	100.0



The responses showed that above 70% of the respondents know what a Pipeline ROW is.

Table 4.21 Experience of pipeline failure

Feedback	Frequency	Percentage
Yes	-	-
No	110	100%
Total	110	100.0

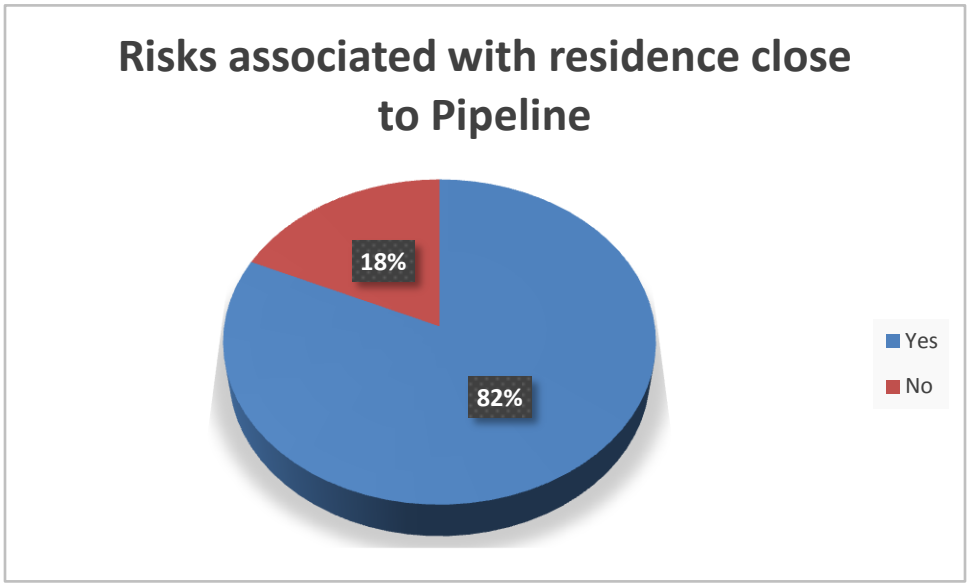
From the table above, 100% of the respondents had never experienced pipeline failure in their communities. This implies that all the respondents had never experienced any pipeline accidents/failures in the past, hence the reason for more encroachments on the pipeline ROW.

Table 4.23 Experience of pipeline vandalism

Response	Frequency	Percentage
Yes	-	-
No	70	63.6
don't know	40	36.4
Total	110	100.0

The table showed that no issues of pipeline vandalism had been recorded in the area based on the responses above.

Figure 4.27 Risk associated with transactions/residence close to petroleum pipelines



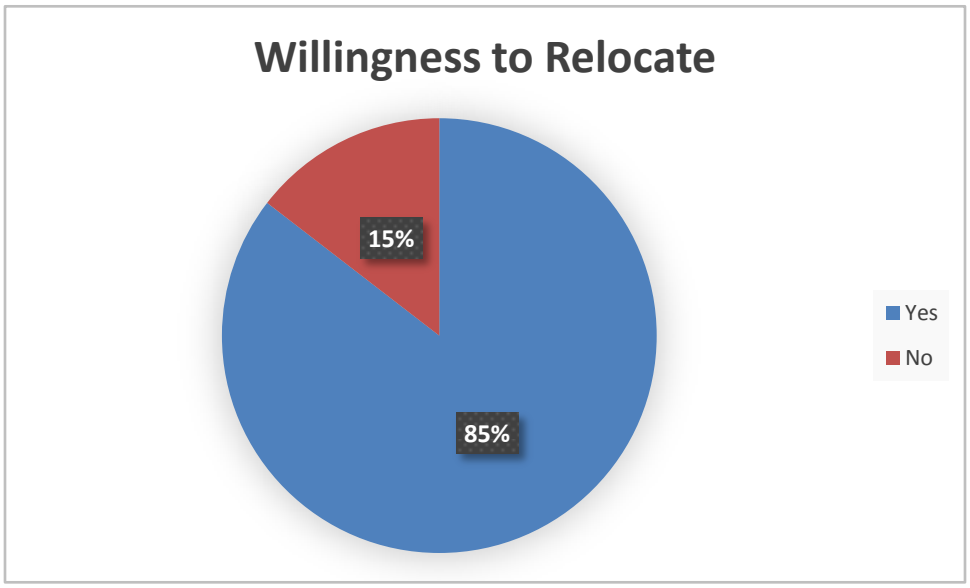
The pie chart showed that majority of the respondents were aware of the risks in carrying out transactions or settling close to a functioning oil and gas pipeline, but are not willing to live by what they know, probably because they had never experienced any accidents in the past.

Table 4.28 Reasons to no risk associated with transactions on ROW

Response	Frequency	Percentage
Because no fire outbreak or any accidents has occurred in the past	4	20
This pipeline is not functioning	10	50
I don't have any option as this is my means of livelihood/residence	2	10
Petroleum pipeline are well designed and cannot just fail	4	20
Total	20	100

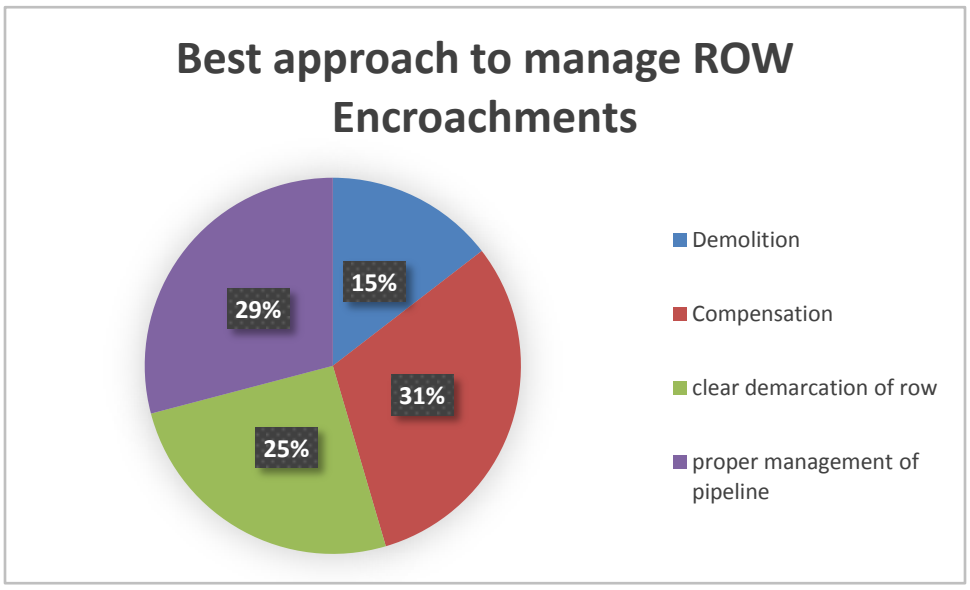
The researcher further sought to know why the respondents answered 'No' to the item on any risk associated with transactions close to pipelines. From the table, 20% of the respondents think it is safe because they had never experienced any pipeline failure or fire outbreaks in the past, 50% believed that the pipeline is not functioning, hence it is safe, 10% of the respondents just believed it is safe and they have no options or alternatives, while 20% believed that the pipelines are well designed and cannot fail for whatsoever reason. All these are costly assumptions and are very dangerous and wrong.

Figure 4.29 Willingness to relocate?



The pie chart implies that most of the respondents reside on the pipeline ROW because they have no options probably because of economic hardship, among other prevailing circumstances.

Figure 4.30 Best approach to manage encroachment



The pie chart sought the respondent's opinions on the best way they to manage encroachments on pipeline ROW. From the responses, 15% suggested demolition of structures raised on the ROW, 31% suggested compensation of the residents on the ROW, 25% responded to clear structural demarcation of the ROW, while 29% responded to proper management of pipelines.

The result of the study showed that Refinery Junction, Mahuta, Kamazou, Bagado, Keke, Saye, Kufena, Zaria Pump Station, Hanwa and Dogarawa had built up areas that encroached on the ROW, while Kakura, Kangimi, Kargo, Rigachukun, Jaji and Sabon Yelwa have encroachments on the pipeline ROW by farmlands. Hanwa had the highest encroachments on the ROW by buildings as at 2015, covering an area of 15.99 hectares, while Kakura had the highest encroachments on the pipeline ROW by farmlands, which is 27.26 hectares.

The analysis of the questionnaire revealed that most of the respondents were fully aware of the existence of a pipeline close to their residence, but care less about the dangers and consequences of encroaching on the ROW as there has not been any pipeline accidents recorded along this pipeline. These pipes were buried in 1976 and were already forty (40) years old as at the time of this research. The conditions of these pipes cannot be predicted due to the epileptic nature of the functioning and maintenance of our refineries in Nigeria. The inconsistency of the functioning or usage of the pipeline may accounted for these encroachments as the refineries were not always at work, hence there were less patrols.

From the analysis above, 85% of the respondents were willing to relocate if given an option of relocating away from the ROW, while 15% were not willing to move. This shows that the respondents know the risk of encroaching on the ROW and most them were educated about this and were willing to relocate.

On the respondent's opinion on the best way to manage encroachments on pipeline ROW, 30.9% agreed that the property owners should be compensated, while 29.1% saw proper pipeline maintenance as the way out. Only 14.5% subscribed to demolition as the remedy to encroaching lives and properties. If the property owners will be compensated, this will encourage more encroachments as more structures will be constructed in anticipation of compensation from PPMC.

There are clear warnings signs by PPMC warning people not to buy or rent any structure or property on the pipeline ROW. The community relations department of PPMC is in charge of this awareness and is doing a great job in sensitizing people on the dangers of encroaching on the pipeline ROW, but it is as if their efforts and campaigns are falling on deaf ears. With the recent population explosion in urban centres (Kaduna in particular) people are moving out from the centre of the town outwardly in search for residential land. This is a major factor responsible for the encroachments on pipeline ROW.

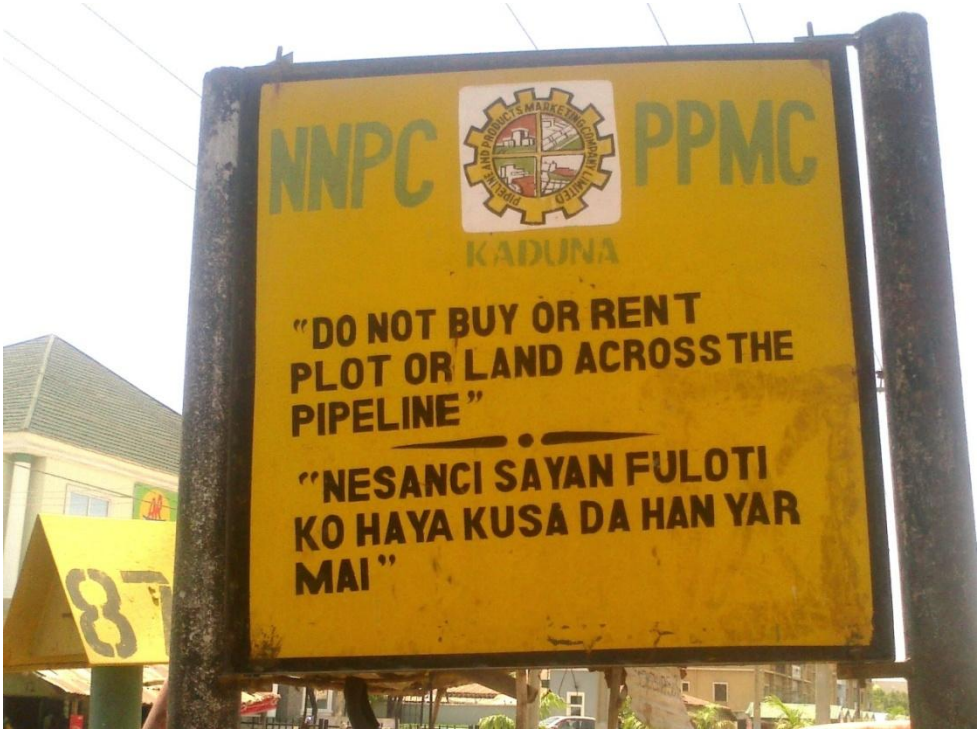


Plate13: Warning Signpost against encroachments on pipeline ROW

Source: Field Survey, 2015

The warning sign above was written in both English and Hausa languages, warning people not to buy or rent any plots or land within or around the pipeline. The encroachments on the ROW place lives and property at risks in the event of any fire outbreak that may be caused either by pipeline vandals or pipeline failure.

From the interview with the PPMC staff, it was gathered that the ROW was not clearly demarcated with any structures. It was just the warning signs that were placed and the pipeline markers, hence people will either assume they did not see the signpost or they break them to raise their structures. The staff also responded that, "no pipeline accidents had been recorded on the System 2D pipeline so far, except for a maintenance work that was carried out on a farm in Sabon Yelwa". The major challenge encountered by the staff on ROW management was people's indifference and lackadaisical response

to the risks involved in settling on the ROW. On the frequency of checks of people's compliance to ROW, there was no set calendar timing for this, but the Public Relations Department of the PPMC has been going out on regular campaigns to sensitize and educate people about the risks of ROW encroachments.

4.6 Effects of Encroachments on the ROW

4.6.1 Environmental Implications of encroachments on pipeline ROW

Degradation of the environment is one of the worst disasters that have befallen the areas where pipelines have been vandalized or where pipeline accidents had been experienced. Raging fires have destroyed lives, property, farmlands and forests thereby reducing arable land for farming. Spills into waterways destroy marine and aquatic life, flora, fauna, resort centers, and result in the pollution of potable water (Badejo and Nwilo, 2007). Pipeline failure compounds oil spillages from other sources and exacerbates the problems of environmental degradation and pollution of waterways (Ogbuefin, 2007).

With the passage of time and as more residential buildings are being constructed on the pipeline ROW, there is the likelihood that lives, crops and property within this corridor stand a high risk of being lost to any pipeline accidents. These pipelines were laid in 1976 and have not been properly maintained, hence the risk in encroaching on the pipeline ROW.

4.6.2 Maintenance Implications of encroachments on Pipeline ROW

When diminished pipeline integrity and the aging process of the pipes cause pipeline ruptures, and/or sabotage (in form of oil bunkering, pipeline vandalism/oil scooping, and oil terrorism) cause pipeline damages, there is usually an urgent need to

repair and regularly inspect/maintain the pipeline networks and keep the environment clean of any oil spill. Repair of the pipelines and cleaning up of oil spills in the environment involves huge capital expenditure. Therefore, pipeline damage and ruptures require that the oil companies and the Federal Government spends more money on improving the integrity and safety of pipelines and the environment by overhauling aging pipelines, frequently checking pipeline integrity (e.g., using cathodic protection devices to monitor steel pipes for corrosion), improving surveillance and introduction of aerial/satellite monitoring of pipeline installations. There was maintenance of a section of the System 2D pipeline that involved clearing a sugarcane farm that encroached on the ROW. A large portion of the farm had to be cleared because of the maintenance as shown in plate 14.



Plate 14: Pipeline maintenance being carried out on a farm that encroached on the pipeline ROW
Source: PPMC Encroachment Gallery, 2015

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter highlights the summary of findings, conclusion and the recommendation made in other to check the encroachments on pipeline ROW.

5.2 Summary of Findings

This research took a geospatial approach to analyze the encroachments on pipeline ROW and its effects on the environment along System 2D pipeline between 2003 and 2015 in intervals of six years. The study area traverses four Local Government Areas in Kaduna State: Chikun, Igabi, Zaria and Sabon Gari. The pipeline passes through sixteen (16) settlements: Refinery Junction, Mahuta, Kamazou, Bagado, Kakura, Keke, Kargo, Kangimi, Rigachukun, Jaji, Sabon Yelwa, Saye, Kufena, Zaria Pump Station, Hanwa and Dogarawa. Google images of these areas for 2003, 2009 and 2015 were obtained, radiometric and geometric corrections were carried out on them.

The three images were overlaid on each other and colours were used to show the encroachments on the ROW for each of the years and for each of the settlements. The result of the study showed that Refinery Junction, Mahuta, Kamazou, Bagado, Keke, Saye, Kufena, Zaria Pump Station, Hanwa and Dogarawa had built up areas that encroached on the ROW, while Kakura, Kangimi, Kargo, Rigachukun, Jaji and Sabon Yelwa had encroachments on the pipeline ROW by farmlands. Hanwa had the highest encroachments on the ROW by buildings as at 2015, covering an area of 15.99 hectares, while Kakura had the highest encroachments on the pipeline ROW by farmlands, which is 27.26 hectares.

Hence, the major findings of this research are summarized thus:

1. The Pipelines and their associated ROW were not demarcated by any physical structures except for the pipeline markers and warning signposts.
2. There was encroachment on the pipeline ROW in all of the sixteen (16) settlements traversed by the pipeline.
3. The major land uses that have encroached on the pipeline ROW were buildings and farmlands
4. A farmland was affected by pipeline maintenance in Sabon Yelwa, this resulted in the loss of growing crops.
5. The major factor responsible for encroachments on pipeline ROW was uncontrolled development.

5.3 Conclusion

From the findings of the study, it was observed that the major factor responsible for these encroachments was uncontrolled urban growth as well as the absence of a clear demarcating structures to inhibit people from encroaching into the pipeline ROW. More residential buildings are springing up in areas very close to the pipeline ROW, hence, more protective measures need to be put in place to checkmate further encroachments by these upcoming structures.

5.4 Contribution to Knowledge

This research has contributed to the existing body of knowledge in the following ways:

1. it has established that encroachments on pipeline ROW were as a result of the fact that no accidents had occurred on the System 2D pipeline.
2. It has established that the encroachments on pipeline ROW was due to lack of clear demarcating structures.

5.5 Recommendations

1. Clear demarcating structures should be put in place to demarcate the pipeline ROW and to checkmate future encroachments.
2. The Pipeline ROW should be properly cleared. Kaduna State Urban Planning and Development Authority (KASUPDA) should give the property owners that encroached on the ROW time to relocate so that the ROW will be cleared and properly monitored.
3. Enlightenment on the Dangers of Encroachments on Pipeline ROW

   There should also be an increased enlightenment on the adverse consequences of encroaching on the pipeline ROW, and the disaster of fire outbreaks when scooping fuel from vandalized pipelines, this can be achieved through the media. Also, the depth of buried Pipelines is one metre from the surface of the earth. Considering the undulating nature of the terrain, farming activities exposes the pipes to dangers of being vandalized easily. Hence, serious action should be taken on farmlands that have encroached on the pipeline ROW.
4. **Frequent Checks for Pipeline Integrity and Complete Overhaul of Aging Pipelines:**

   There should be frequent checks for pipeline condition and integrity to prevent pipeline

rupture. The goal of any pipeline integrity program is to prevent structural integrity problems from having a significant effect on public safety, the environment, or business operations by identifying and performing the most effective inspection, monitoring, and repair activities. Pipeline integrity methods include visual inspection, depth of cover survey, external non-destructive testing (NDT), cathodic protection monitoring, coating disbondment and damage survey, hydrostatic testing, in-line inspection (ILI) tools, and ultrasonic in-line inspection tools. Other testing methods are used to detect pipe and pipe membrane defects. These procedures help identify specific types of defects, such as:

i. corrosion (the wastage or thinning of the pipe wall due to a chemical or electrochemical attack),
ii. gouging (the mechanical removal of metal from a local area on the surface of the pipe),
iii. metallurgical anomalies like hard spots, laminations, slivers, scabs and inclusions, and
iv. cracks due to fatigue stress corrosion and weld defects.

Aging pipelines are easily amenable to defects; hence, there should be complete overhaul of aging pipelines.

5. **Improved Surveillance and Introduction of Aerial/Satellite Monitoring of Pipeline ROW:** The threats that emanate from a poorly monitored, inspected, and maintained pipelines can result in financial losses, loss of lives and property. Hence, pipelines and pipeline transport should be designed and monitored in real time using Global Positioning System (GPS) maps, this can be done through the use of improved surveillance and introduction of aerial/satellite monitoring of pipeline installations to prevent and control

encroachments on pipeline ROW. Security agencies in collaboration with youth and community leaders should be deployed to patrol oil and gas pipeline ROW. This collaboration will help secure the ROW and create job opportunities for communities where the pipelines traversed. Therefore, it is essential that pipeline management firms have the very best software applications and upgrade modules to perform the best pipeline inspections.

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5.6 Limitations of the Study

1. Accessing information from the PPMC on pipeline activities was not an easy task, as any issue that relates to pipeline is treated with strictness. It took a period of about twelve weeks of thorough consultation and security clearance before the researcher was allowed access to some documents.
2. The administration of the questionnaire to settlements that had built-up areas encroaching on the pipeline ROW came at a time when the Governor of Kaduna State (Mal. Nasiru El-Rufai) embarked on demolition of buildings that encroached into any government landed property in the state. The researcher was therefore seen as a government agent who has come to pre-inform them of the likelihood of their buildings being demolished. Hence, there was strong opposition in responding to the questionnaire or giving out any further information that could have enriched this research further.
3. In the course of taking pipeline coordinates in the field, the researcher encountered strong opposition from security personnel who were in charge of monitoring the pipelines in the bushes. No activity whatsoever is permitted within or around the pipeline markers, hence it was difficult getting all the coordinates of the pipeline from the field as some of the

locations were fully manned by armed security personnel, while some pipeline markers were inaccessible.

5.7 Suggestion for Further Studies

Pipeline GIS is a research field that has many applications in the economic and security spheres, hence more research needs to be carried out to contribute to knowledge and national development.

1. Time series analysis can be carried out on encroachments on the ROW of other pipeline systems.
2. Pipeline Condition Assessment (PCA) of oil and gas pipelines using geospatial techniques can be carried out.

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APPENDICES
APPENDIX A

DEPARTMENT OF GEOGRAPHY
AHMADU BELLO UNIVERSITY, ZARIA
FEDERAL REPUBLIC OF NIGERIA

Vice Chancellor: Prof. Ibrahim Garba, B.Sc. M.Sc.(AB). Ph.D., DIC. Imperial College. (London) FNMGS. MCOMEG
Head of Department: Dr. I.M. Jaro, B.Sc. (Hons) BUK. M.A. Ph.D (ABU). MANG. MIMC

Secretary - 08051316343
Head of Dept.- 08039682515

GEO/STA.7

17th August, 2015

TO WHOM IT MAY CONCERN

This is to introduce the bearer **Daniel Julius Kundi** an M.Sc. student with registration number M.Sc./SCIEN/1449/2011 - 2012 of the Department of Geography, Ahmadu Bello University Zaria. He is presently carrying out a research on "*Geospatial Analysis of Encroachments on Oil and Gas Pipeline Right of Way* (ROW) *and its Effects on the Environment Along System 2D Pipeline"* and she needs data on **Encroachment on Pipeline Right of Way and its Effects on the Environment** for his project. Kindly assist him.

Thank you.

Yours faithfully,

Francis Ameh
Secretary
for: Head of Department

Website: www.edu.ng
e-mail: geographyabu@mail.com

APPENDIX B
QUESTIONNAIRE

Department of Geography
Ahmadu Bello University
Zaria
24th November 2014.

Dear Respondent

REQUEST TO FILL QUESTIONNAIRE

The researcher is a Masters degree student of the above named Department and institution currently carrying out a research titled "Encroachment on Pipeline Right of Way and its Effect on the Environment Using Geospatial Techniques". Please kindly fill this questionnaire and answer the questions as accurately as possible by ticking the option that best describes your opinion. All information provided will be treated in strict confidence and used for academic purpose only.

Thank you
Daniel Julius Kundi
M.Sc/Sci/1449/2011-2012

DEMOGRAPHIC DATA

1. Name of Location : ……..
2. Age: 18 – 25 [ ] 26 – 35 [ ] 36 – 45 [ ] 46 – 55 [ ] 56 and above [ ]
3. Sex: Male [ ] Female [ ]
4. Occupation
   a. Farming [ ]
   b. Business/Trading [ ]
   c. Civil servant [ ]
   d. Artisan [ ]

e. Others (specify) ……

5. Educational qualification

a. Primary school [ ]

b. Secondary school [ ]

c. NCE/OND [ ]

d. B.Sc/HND [ ]

e. M.Sc [ ]

f. Ph.D [ ]

g. Others (specify) ……..

SECTION B: PETROLEUM PIPELINES AWARENESS AND ENCROACHMENT

6. Are you aware of the existence of petroleum pipeline passing through your community?

(a) Yes [ ] (b) No [ ]

7. Are you aware of what a right of way is?

a. Yes [ ] (b) No [ ]

8. Are you aware of any law protecting the right of way of petroleum pipeline in Nigeria?

(a) Yes [ ] (b) No [ ]

8. How close is your house/shop/farmland to petroleum pipeline?

(a) Less than 12.5 meter [ ] (b) More than 12.5 meter [ ] (c) Don't know[ ]

9. Do you cross pipeline rights of way in the course of your daily activities?

(a) Yes [ ] (b) No [ ]

10. Has there been any fire outbreak due to pipeline failure in your community?

a. Yes [ ] (b) No [ ]

11. Have you lost property to petroleum pipelines accidents?

(a) Yes [ ] (b) No [ ]

12. Have you lost loved ones to petroleum pipelines accidents?

a. Yes [ ] (b) No [ ]

13. What caused the accident?

a. Pipeline failure [ ]

b. Excavation damage to pipeline [ ]

c. Pipeline vandalism [ ]

14. Has your community experienced petroleum pipeline vandalism before?

(a) Yes [ ] (b) No [ ] (c) Don't know [ ]

15. If your response to question 15 is yes, what was responsible?

(a) My community [ ] (b) People from elsewhere [ ] (c) Don't know[ ]

16. Is there any risk associated with transactions close to petroleum pipelines?

(a). Yes [ ] b. No [ ] c. I do not care [ ]

17. Give reasons why you think it is not risky to carry out activities on the right of way?

a. Because no fire outbreak or any accidents had occurred in the past [ ]

b. I don't think this pipeline is functional [ ]

c. I don't have any option as this is my means of livelihood [ ]

d. Petroleum pipelines are well designed and cannot just fail [ ]

18. If you have an option will you be willing to vacate the right of way?

a. Yes [ ] b. No [ ]

19. What do you think is the best approach to manage encroachments on pipeline right of way?

a. Demolition [ ]

b. Compensation by PPMC [ ]

c. Clear demarcation of ROW [ ]

d. Proper management of pipeline [ ]

20. What other way can you suggest that will aid the proper management of pipeline ROW? _____

_____

_____

_____

APPENDIX C

Interview Guide

1. Rank : …….
2. How long have your been on this job?
   a. 2 – 5 years [ ]
   b. 6 – 10 years [ ]
   c. 11 – 15 years [ ]
   d. 16 – 20 years [ ]
   e. 21 – 25 years [ ]
   f. 26 years and above [ ]
3. Is the ROW of pipelines clearly demarcated?
4. What are the methods employed in the management of ROW?
5. Has there been any pipeline accident along the System 2D pipeline network?
6. Was there any loss of lives and property as a result of the accident(s)?
7. What are the major challenges encountered in the management of ROW?
8. How often do you check the compliance to ROW maintenance?
9. What is the compliance level by the communities?
10. What other information do you have that could be useful to the researcher?