CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Land is a scarce resource. Anambra State has a small landmass of approximately 4,416sq.km ranking among the smallest states in the country. Therefore, the need for effective management of land resource in the State to meet competing uses cannot be over emphasized. Land is a resource of primary importance upon which the economy of the state and indeed the nation hinges; hence any policy on land affects the economy of the state. Management of land in the state is structured under the Ministry of Lands, and Survey and Town Planning (Anambra Statistical year book, 2011).

Animal production in Nigeria has a very long history starting from domestication of local species to commercialization of improved varieties. Presently, there are many commercial livestock-rearing centers on both private and government-owned farms. Major species of livestock in the country with the potential to produce substantial quantity of manure are cattle, goats, sheep, pigs and chickens. Commercial chicken production predominates in the southern part of the country; although, the majority of urban and rural households in the country in general keep at least three poultry birds among other ruminant livestock. Therefore, livestock wastes from cattle, goats, pigs, sheep and poultry are considered as potential feedstock for biogas production in Nigeria due to their availability and production quantity (Suberu *et al.*, 2013).

Wastes generated from livestock housing rearing in Nigeria are usually dumped at waste dumping sites. As the global trend is advocating for a transition from fossil energy waste system to Renewable Energy (RE) based on several socio-economic and environmental justifications, the necessity to embark on a process to capture biogas for energy production is inevitable for Nigeria (Chukwuma *et al.*, 2013).

Animal manure and municipal solid waste in atmospherically unconfined locations emit gaseous chemical under the influence of some spontaneous reactions. These chemical substances, if allowed free escape into the atmosphere, can induce global warming scenario with the potential for greenhouse gases (GHGs) to rise into the atmosphere. However, capturing these gases, especially methane, can be useful for bioenergy production and prevention of environmental pollution. Furthermore, there are also some serious unfolding reports of global atmospheric pollution due to excessive burning of fossil energy sources. This has been noted in the form of emissions of harmful substance and the rise in global temperature resulting in the continuous depletion of ozone layers. An upward alteration in environmental temperature is scientifically known as Global Warming Potential (GWP). These two major expected catastrophes (energy crisis and atmospheric pollution) have to be combated before they reach a climax (Suberu *et al.,* 2013).

The twentieth century saw a dramatic increase in the production of urban solid waste, reflecting unprecedented global levels of economic activity. Most of the urban cities are facing problems of solid-waste collection, treatment, and disposal due to increasing population, rapid urbanization, industrialization, and commercialization (Gautam and Kumar, 2005). The growing concern for environmental issues and the goal of sustainable development have moved the management of solid waste to the forefront of the public discourse. Combustion of fossil fuels for urban and industrial energy needs has been a very common trend in the current global energy supply perception. More recent research efforts have pointed out that a higher percentage of world energy consumption has been obtained from fossil fuels over other conventional energy resources. Interestingly, Nigeria farming sector is still pretty undeveloped if compared to other developed countries of the world. Nigeria experienced major shift in economy from agricultural production to oil resource production. This is one of the legacies from past where agriculture was deemed not worthy of heavy investments as a result of oil boom. Farming sector, in general, is a big producer of manure and thus also a big producer of greenhouse gasses. Methane production from animals wastes should be seen as an opportunity in utilizing green and sustainable energy which would contribute to the reduction of greenhouse effect.

Poor manure management can result in GHG emissions as well as eutrophication of water bodies. Potential technical measures to reduce GHG emissions from farms are decreasing the number of animals, improving the feed conversion efficiency, increasing the nitrogen use efficiency and closing the nitrogen and energy cycles. However, because of the intimate link between energy intake, milk production and/or enteric CH_4 production, these methods usually have an inverse relation between enteric CH_4 and animal productivity. The reduction of enteric CH_4 would eventually be at the expense of animal productivity. Therefore, other ways of reducing GHG emissions associated with incentive livestock farming activities are needed (Kaparaju and Rintala 2011).

Biogas technology from which biogas is derived through anaerobic digestion of biomass, such as agricultural wastes, municipal and Industrial waste (water), is one such appropriate technology that Africa should adopt to ease its energy and environmental problems. Anaerobic manure digestion is a biochemical process by which organic matter is decomposed by bacteria in the absence of oxygen, producing methane and other byproducts. The complete mixture of this gas is called biogas (Al Seadi et al., 2008). Biogas can be used for heating, as fuel for engine generators that produce electricity, or flared into the atmosphere. Biogas consists of a mixture of methane, carbon dioxide, and other trace gases (eg. hydrogen sulfide). Global agitation for sustainable development advocates that both developed and developing countries entrench in RE exploitation, since it is not exclusive to any region. Biogas, which is bio-energy produced from biomass has several advantages over other forms of renewable energies (Nyagabona and Olomi, 2009; Sreenivas *et al*., 2009), hence the need to adopt biogas technology.

One of the biggest barriers in utilizing biogas potential in Anambra state is the dispersion of livestock farms across the states which are relatively small farms that lack the capability of having economical viable biogas production. Hence there is immense need for community biogas plants for biomass utilization in Anambra state farming sector. There is need for a methodological regional analysis of biogas potential of Anambra state with cost assessment of community biogas power plants considering transport distances, transport costs and size of the power plants as well as livestock farms to be involved in community biogas production. The value of finding Anambra state's farming sector biogas potential is also important since farms are consuming a lot of energy in their everyday operations and part of that energy consumption can be compensated from renewable energy source like biogas. Since various livestock are reared in the state, there are various substrates that can be used in co-digestion of biomass in the State.

Co–digestion offers several ecological, technological and economical advantages (Braun and Wellinger, 2002). The use of co-substrates usually improves the biogas yields from anaerobic digester due to positive synergisms established in the digestion medium and the supply of missing nutrients by the co-substrates (Mata-Alvarez et al., 2000). The Anaerobic Digestion (AD) of livestock waste in the State can reduce the GHG emission in two respects: reduction as compared with the baseline management, and reduction through providing alternative resources in terms of non-renewable fossil energy and materials (Liu et al., 2003). Denmark is a country that has developed many centralized digesters that receive manure from many farm sources and return digestate, the material left after production of biogas, back to the farm as animal manure. Digestate is spread on land, much like manure and has all of the nutrients but none of the pathogens of manure. In Denmark, most of the manure processing power plants are owned by farmer's cooperative units, i.e. they are owned by the farmers whose manure is processed for them (Ghafoori and Flynn, 2006).

A systematic approach of farm waste management is a desirable solution, which can be achieved only by a strategic planning approach for achieving a clean, healthy, and sustainable environment (Gautam and Kumar, 2005). Effective planning of farm waste recycling programs is a substantial challenge for the current farm waste management systems in developing countries like Nigeria. Siting bioenergy plants in optimal locations at optimum capacities is a challenging task. Due to high geographical dependence of biomass feedstocks, implementation of spatial information technologies such as remote sensing and Geographical Information System (GIS) in addressing this issue appears to be an appropriate methodology (Kumar and Sultana, 2012). Although there are potential economy of scale for the centralized digester, manure transportation and handling costs can offset the economic savings if there are not sufficient suitable farmers willing to participate in close proximity to the proposed facility (ESA, 2011).

Urban planning is one of the main applications of GIS as urban planners use GIS both as a spatial database and as an analysis and modelling tool. Land suitability maps are very useful in the development of planning options. They can be used to identify the solution space for future development (Yeh and Chow 1996). The association of spatial optimization models with GIS can help to formulate and develop planning options which try to maximise or minimise some objective functions. Hence there is need for exploratory study that will specifically present a logical framework for guiding the process of identifying potential ADS sites, selecting the optimal sites for a given number of ADS using the potentials of GIS software.

1.2 Statement of Problems

Onitsha in Anambra State is a mixed farming region with some urban and industrial development. There is an organized system for collection and disposal of municipal urban waste in the major cities in the state, while agricultural waste generated by livestock farms and municipal abattoirs are neglected for energy potential. Suberu et al., (2013) provide a theoretical estimate of methane emissions from both livestock manure in Nigeria and municipal solid waste deposits in some of the country's major cities. The result of the study shows that Onitsha has the highest statistical Methane emission amongst the South-eastern mega cities except Port Harcourt.

The climax of methane emission from mismanagement of wastes is tending to a major catastrophe in the state, and since Onitsha, Awka and Nnewi are the most populous and urbanized regions of the state, there is urgent need to adopt appropriate waste management, treatment, and recycling strategies for wastes especially livestock bio-waste in the State. Preliminary investigation at several municipal abattoirs and livestock farms in the State shows heaps of animal waste without definite management, treatment and recycling strategy. These bio-wastes products are highly contaminated with pathogenic microorganisms and are therefore hazardous to animals and humans. The transmissions of pathogens present a potential threat to the health of workers, consumers as well as farm animals **(**Marchaim, 1992). Several researchers have reported on the poor management of animal wastes in municipal abattoirs in Nigeria (Ezeoha and Idike, 2007; Chukwu 2008; Chukwuma et al., 2012)**.** Large volumes of poultry droppings are generated daily across farms in the State, but the use of this waste and demand for animal waste has being restricted to farming operations only during farming season and this has resulted to pollution of the environment and under-utilization of this energy source. The impact of these wastes on land and water therefore emphasizes the need for appropriate strategies for efficient solid waste disposal and management in Nigeria public abattoirs, farms, and environs generally.

Siting of Centralized Biogas Plants (CBP) in strategic locations across the state would be the major means of combating the environmental challenges of increase in waste generation across the state. For food processing industries, centralized biogas plants represent an appropriate waste disposal and recycling possibility as this is safe, convenient and economically advantageous. However decisions on centralized location for biogas plant may be the most critical and most difficult of the decisions needed to realize an efficient waste management system. Facility location decisions, on the other hand, are often fixed and difficult to change even in the intermediate term. The location of a multi-million Naria centralized biogas plant cannot be changed as a result of changes in urbanization, transportation costs, or component prices. Modern distribution centers with millions of Naira of material handling equipment are also difficult, if not impossible, to relocate except in the long term. Inefficient locations of bio-production plants will result in excessive costs being incurred throughout the lifetime of the facilities, no matter how well the production plans, transportation options, inventory management, and information sharing decisions are optimized in response to changing conditions. Hence, for an optimal location of biogas plant in any region, location analysis should be embarked well ahead of time, to avoid the necessity for demolition and any resultant negative effects of poor siting to resident, natural reserves or any sensitive area within the region.

In addition to the above noted problem statement, the agricultural sector in the State, and eventually in the study areas is presently characterized with a lot of small private owned farms which do not represent economically viable biogas producers. These farms do not have significant biogas production potential and basically are waste of energy regarding biogas production. One of the obstacles to overcome in utilizing livestock bio-waste for bio-energy production lies in the region's bio-waste scattered geo-spatial placement and small sizes of these waste generation centres. Hence the need for proper location studies, for distance and transportation cost optimization of hauling of waste from generation centres to centralized treatment centres (biogas plant).

Also, of importance is the fact that on-site waste treatment cannot solve waste treatment problems for small and medium farms due to several reasons, such as pollution caused by the gas and difficulties in managing biogas systems. Furthermore, there are many widely dispersed small, medium and large scale bio-waste generating units throughout the study areas, which are often not properly located for bio-energy plant siting, being close to the rivers, urban settlement etc for on-site treatment. The municipal abattoirs are usually located in the center of the city for ease of transportation of processed meat to buyers, the location of biogas plants on-site in the these abattoirs may constitute environmental nuisance to dwellers and/or operations in the abattoirs. Hence, the need for off-site centralized location for waste treatment for the region.

Ghafoori and Flynn (2006) on biogas plant feasibility study in Red Deer County in Canada noted in their study that small farm based manure digesters are less cost effective than centralized units that receive manure from many producers. They noted that farmers that want to process manure and produce power are better off, to transport their manure than to process it on site. For the mixed farming area that they extensively studied, it was observed that even a feedlot with 7,500 beef cattle could not make power from manure as economically as a centralized digester, and the cost penalty is greater for smaller farms. The critical factor favouring a centralized digester they reported is the lower capital cost per unit of input/output realized in a large economically sized plant; this saving is greater than the cost of transporting manure to and digestate from the plant.

In the present day, the need, and practice of reclamation of bio-wastes produced from animal waste is gaining approval from developed and developing countries of the world as a result of the impact of climate change on the human environment. Small scale biogas plants are used on farm level across the country by few farmers. The current trend towards sustainable renewable energy in developing countries calls for a systematic approach of farm waste management and treatment, which can be achieved only by a strategic planning approach. A few of the key parameters influencing the viability of community biogas digesters in Anambra State will be the distances between bio-waste sources and central digesters, feed in tariffs, manure prices, willingness to invest in biogas production industry, maintenance cost etc.

Thus, the eventual solution for Anambra state agricultural sector considering specifically the study areas, would be optimal location(s) of bio-energy plant(s) considering urban settlement, land use policies, pollution of water sources and transportation distances and cost. Hence the basics for regional analysis of biogas potential density in the study area will be cost assessment of community biogas power plants considering transport distances, transport costs, and size of the power plants. The solution to environmental degradation as a result of increase in waste generation in the study regions, as noted in most developed countries of the world (like Denmark, Germany, China etc) is the adoption of suitable sites and building of central waste treatment plants.

1.3 Aim and Objectives of the Study

The aim of this study is to determine suitable location(s) for centralized agricultural bio-gas plants in Anambra State of Nigeria using economic tool and geospatial technology. The specific objectives are as follows:

I. To estimate livestock population and the biogas production potential of the study area considering agricultural wastes.

II. To perform a site suitability analysis to optimize biomass anaerobic digestion plants capacity, using GIS technology.

III. To develop a land suitability model for biomass-based facility development using Analytic Hierarchy Process (AHP) in order to integrate selected spatial and environmental criteria.

IV. To obtain from the high suitability index models, the optimal location(s) using location modeling technology.

V. To determine the economic viability of centralized biogas plant and its profitability for selected locations (both for single and multi-bioenergy plant facility) in the study area.

1.4 Scope of Work

The scope of the research work comprises both field work and several computer data analysis. The field work comprises the following: Use of questionnaire to determine manure management practises in livestock farms and municipal abattoirs (Excluding municipal waste) of the state; use of GPS technology in determining the geographical positions of the bio-waste sources. Computer operations carried out are GIS-based operations of spatial and aspatial data collection, processing and analysis. Anambra state covers several urban, semi-urban and rural areas. This thesis is confined in scope to Anambra state. The methodology adopted in the research areas could however be adapted to any region of other states in the country. Owing to the non-availability of some livestock statistical data in the State (Goat, pig and sheep statistical data) this dissertation is limited to agricultural waste from poultry production and abattoir centres of the state.

1.5 Justification for the Study

This study will be a veritable tool in biogas plant siting in the state. The numerous benefits of siting biogas plants includes but not limited to economic, environmental and social advantages.

1.6 The Study Area

Anambra State is the oldest state in South-Eastern Nigeria. The Capital and the Seat of Government is Awka. Onitsha and Nnewi are the biggest commercial and industrial cities, respectively. Boundaries are formed by Delta State to the west, Imo State and Rivers State to the south, Enugu State to the East and Kogi State to the North. The origin of the name is derived from the Anambra River (Omambala) which is a tributary of the famous River Niger.

1.6.1 Geographic Location

The stretch of more than 45 km between Oba and Amorka contains a cluster of numerous thickly populated villages and small towns giving the area an estimated density of 1,500–2,000 persons living within every square kilometer of the area. Onitsha one of the major cities in the study area is located between Latitudes $06^{0}02^{1}56^{11}$N and $06^{0}38^{1}34^{11}$N and Longitude $06^{0}37^{1}30^{11}$E and $06^{0}59^{1}30^{11}$E and covers Onitsha North and South Local Government Area and part of Obosi, Nkpor and Iyiowa Odekpe of Anambra State. It is bounded by Anambra West/East L.G.A. and Oyi in the North, Idemili-North/South in the East, Ogbaru L.G.A in the South and in the West by the River Niger. Nnewi lies between longitudes 6^{o} 91^{1}E and 6^{o} 55^{1} E and Latitudes 6^{o} 16^{1} N and 6^{o} 10^{1} N. As of 2006, Nnewi has an estimated population of 391,227 according to the Nigerian census. The city spans over 1,076.9 square miles (2,789 km^2) in Anambra State. It is the centre of industrial activities in the state where Tummy-Tummy Industries Limited, John White Industries Ltd, Uru Industries, Life Vegetable Oil Industry (a member of the Chicason Group), Godwin Kris Industry, Lippo table water factory, Innoson Motorcycle Manufacturing Industry, Chicason Industries Limited, Innoson Vehicle Manufacturing/Assembly Plant, Kotec Industries Ltd, to mention but a few are located. The map of Anambra State is shown in Figure 1.1:

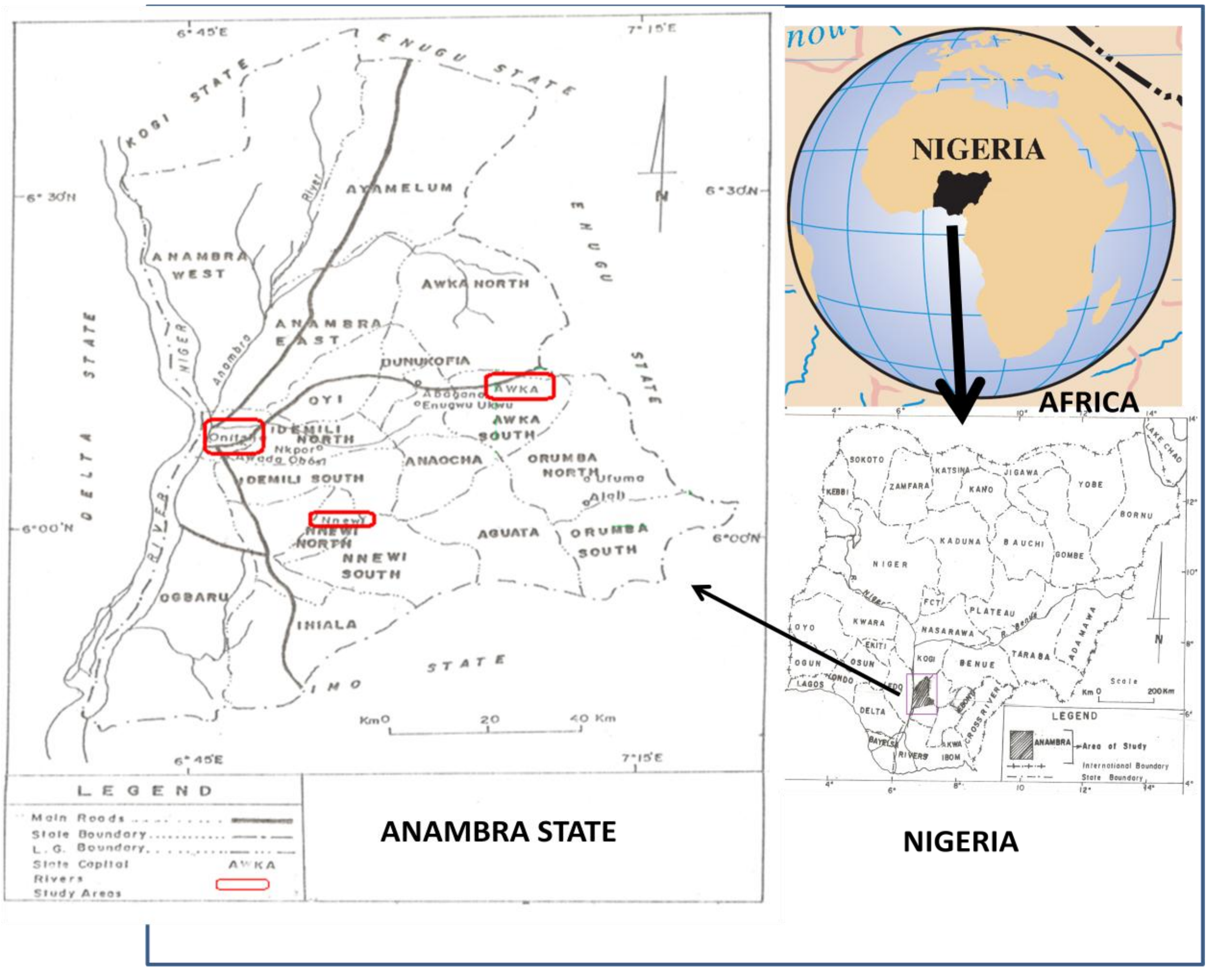

Figure 1.1: Map of the study area with major cities highlighted

1.6.2 Topography and Climate

The topography and climatic vegetation of the area make it very suitable for an extensive modern agricultural investment. It is endowed with 60% arable land which should be for large-scale farming. Data on topography of the study area sourced from Ministry of Lands, Survey and Town Planning as reported by Anambra statistical year book 2011 indicates that Anambra West has the greatest land mass of $613km^2$ with 15% highlands and 21% plainlands, while Orumba South has the least land mass of $24km^2$ with 0% highlands and 14% plainlands. The Study area has a total of $4887km^2$ landmass, 385% highland and 772% of plainlands. The climatic of the study area is the tropical rainforest, comprising of two seasons; the rainy and dry seasons. The rainy season lasts from March to October, while the dry season last from November to February. The annual rainfall is about 1300 mm, Peak rainfall occurs in June to July while the second Peak occurs in September to October rainy season with the two wet seasons normally separated by a drought (August-break). The rains could be mild or torrential and often causes flooding and erosion leading to the formation of gullies. Data from Federal Ministry of Aviation, Meteorological Department, Awka as reported in Anambra statistical year book 2009 and 2011 shows that the State experiences the hottest temperature in the month of March and the lowest minimum temperature in the month of December. Annual average temperature ranges from a minimum of 20.78^{oc} to maximum of 30.24^{oc}. Relative humidity ranges from annual minimum of 34% in dry season to a maximum of 89% in raining season.

1.6.3 Demographic Characteristics

Anambra is the eight most populated state in the Federal Republic of Nigeria and the second most densely populated state in Nigeria after Lagos State. Population wise, according to National Population Commission in 1991, the study area population is about 2,796,967 with 2.8% annual growth rate. The populations of the study were 4,751,967 and 4,886,447 in the year 2010 and 2011 respectively based on 2.83 growth rates. Anambra State Bureau of statistics, Awka as reported in Anambra statistical year book 2011 shows that the population density of the state varies widely across the various L.G.As. Orumba South has the highest population density of about 6751/km^2, while the least population densed L.G.A is Anambra East with a population density of about 242/km^{2}for the year 2011.

1.6.4 Agriculture and Livestock

The study area consists mainly of urban, semi-urban and rural areas. The populate engages in agricultural activities that includes: livestock farming/production, crop production, fisheries etc Livestock such as poultry, goats, and sheep under free range system are kept in the rural areas of the study area. However, poultry keeping in confirmed system is becoming popular with numerous well established large poultry farms in the urban and semi-urban areas of the state. Crop grown in the state includes but not limited to cassava, yam, cocoyam, oil palm, plantain/banana, melon and vegetables. Rice is grown in large quantity in the wetland areas. Table showing livestock waste production capacity of all the L.G.As of the state is shown in Appendix B.

CHAPTER TWO

LITERATURE REVIEW

2.1 Biogas Production

Anaerobic digestion (AD) consists of several interdependent, complex sequential and parallel biological actions in the absence of oxygen, during which the products from one group of microorganisms serve as the substrates for the next, resulting in transformation of organic matter (biomass) mainly into a mixture of methane and carbon dioxide (Aworanti, et al., 2011; Parawira, 2004). Biogas, which is bio-energy produced from biomass has advantages over the other renewable energies (Sreenivas, et al., 2009; Chae, et al., 2002; Molinuevo, et al., 2009): Key by-products of anaerobic digestion include digested solids and liquids, which may be used as soil amendments or liquid fertilizers (Buendía, et al., 2009; Salminen and Rintala, 2002); The anaerobic fermentation of waste of biogas production does not reduce its value as a fertilizer supplement, as available nitrogen and other substances remain in the treated sludge (Alvarez and Lide, 2008; Salminen and Rintala, 2002; Braun and Wellinger, 2002; Molinuevo, et al., 2009) and most of the pathogens are destroyed in the process of anaerobic digestion (Molinuevo, et al., 2009). The constantly increasing demand for biogas as an environmentally friendly fuel implies an increasing demand for biogas plants, which need to be efficient, properly located to reduce transportation cost and to produce biogas with high methane content.

2.2 Biogas Production- State of Art and Potentials

The world markets for biogas increased considerably during the last few years and many countries developed modern biogas technologies and competitive national biogas markets throughout the decade, with intensive research and development complemented by substantial governmental and public support. The European biogas sector counts thousands of biogas installations, and countries like Germany, Austria, Denmark and Sweden are among the technical forerunners, with the largest number of modern biogas plants. Today there are some 4,242 farm-scale and more than 26 centralised biogas plants in EU, but with wide differences from one EU member state to another. The annual biogas production from agricultural biogas plants in Europe by mid 2007 is estimated at $1.85x10^9$ m^3 of biogas (containing 65% methane). The total profitability in a typical EU farm-scale biogas plant is € ÷32,238, and in a typical EU centralised plant € ÷572,467. Monetary yields include value of the biogas itself in the form of heat and electricity and value of increased field effect of nitrogen in livestock manure (Birkmose et al., 2007).

Important numbers of biogas installations are operating also in other parts of the world. In China, it is estimated that up to 18 million rural household biogas digesters were operating in 2006, and the total Chinese biogas potential is estimated to be of 145 billion cubic meters while in India approximately 5 million small-scale biogas plants are currently in operation. Other countries like Nepal and Vietnam have also considerable numbers of very small scale, family owned biogas installations (Al Seadi, 2000).

Most biogas plants in Asia are using simple technologies, and are therefore easy to design and reproduce. Other countries like USA, Canada and many Latin American countries are on the way of developing modern biogas sectors and favorable political frameworks are implemented alongside, to support this development. Utilization of biogas for combined heat and power production (CHP) is a standard application for the main part of the modern biogas technologies in Europe. Figure 2.1 shows a CHP device used in generating heat and electricity from biomass anaerobic digestion process. An engine based CHP power plant has an efficiency of up to 90% and produces 35% electricity and 65% heat. The produced electricity from biogas can be used as process energy for electrical equipment such as pumps, control systems and stirrers, while the heat can be used by industry processes, agricultural activities or for space heating.

Figure 2.1: Combined heat and power production facility

Source: Rutz et al., (2008)

Biogas is also upgraded and used as renewable bio-fuel for transport in countries like Sweden, Switzerland and Germany, where networks of gas upgrading and filling stations are established and operated. Biogas upgrading and feeding into natural gas grid is a relatively new application but the first installations, in Germany and Austria, are feeding "bio-methane" into the national gas grids. A relatively new utilisation of biogas, in fuel cells, is close to the commercial maturity in Europe and USA. Integrated production of bio-fuels (biogas, bio-ethanol and biodiesel) alongside with food and raw materials for industry, known as the concept of bio-refineries, is one important research area today, where biogas provides process energy for liquid bio-fuel production and uses the effluent materials of the other processes as feedstock for AD. The integrated bio-refinery concept is expected to offer a number of advantages related to energy efficiency, economic performance and reduction of GHG emissions. A number of bio-refinery pilot projects have been implemented in Europe and around the world, and full scale results will be available in the years to come (Al Seadi et al., 2008).

The existing biomass resources on our planet can give us an idea of the global potential of biogas production. This potential was estimated by different experts and scientists, on the base of various scenarios and assumptions. Regardless of the results of these estimations, the overall conclusion was always, that only a very small part of this potential is utilized today, thus there is a real possibility to increase the actual production of biogas significantly. The European Biomass Association (AEBIOM) estimates that the European production of biomass based energy can be increased from the 72 million tones in 2004 to 220 Mtoe in 2020. The largest potential lies in biomass originating from agriculture, where biogas is an important player. According to AEBIOM, up to 20 to 40 million hectares of land can be used for energy production in the European Union alone, without affecting the European food supply (Al Seadi et al., 2008).

2.3 Agricultural Biogas Plants

The agricultural biogas plants are considered those plants which are processing feedstock of agricultural origin. The most common feedstock types for this kind of plants are animal manure and slurries, vegetable residues and vegetable by products, dedicated energy crops, but also various residues from food and fishing industries etc. Animal manure and slurries, from cattle and pig production, are the basic feedstock for most agricultural biogas plants in Europe. The design and technology of biogas plants differ from country to country, depending on climatic conditions and national frameworks (legislation and energy policies), energy availability and affordability. Based on their relative sizes, functions and locations, agricultural AD plants can be classified as:

a. Family scale biogas plants (very small scale)

b. Farm scale biogas plants (small or medium to large scale)

c. Centralised/ joint co-digestion plants (medium to large scale)

2.3.1 Family Scale Biogas Plants

Today, farm-based manure facilities are perhaps the most common use of AD-technology. Six to eight million family-sized low-technology digesters are used in the far East (Peoples Republic of China and India) to provide biogas for cooking and lighting. There are now over 800 farm-based digesters operating in Europe and North America (Task 24, 2005). In Countries like Nepal, China or India operates millions of family scale biogas plants, utilizing very simple technologies. The AD feedstock used in these biogas plants originate from the household and/or their small farming activity and the produced biogas is used for the family cooking and lighting needs. The digesters are simple, cheap, robust, easy to operate and maintain, and can be constructed with local produced materials. Usually, there are no control instruments and no process heating (psychrophilic or mesophilic operation temperatures), as many of these digesters operate in warmer climates and have long hydraulic retention time. The Chinese type (Figure 2.2a) is an underground reactor of typically 6 to 8 m³.

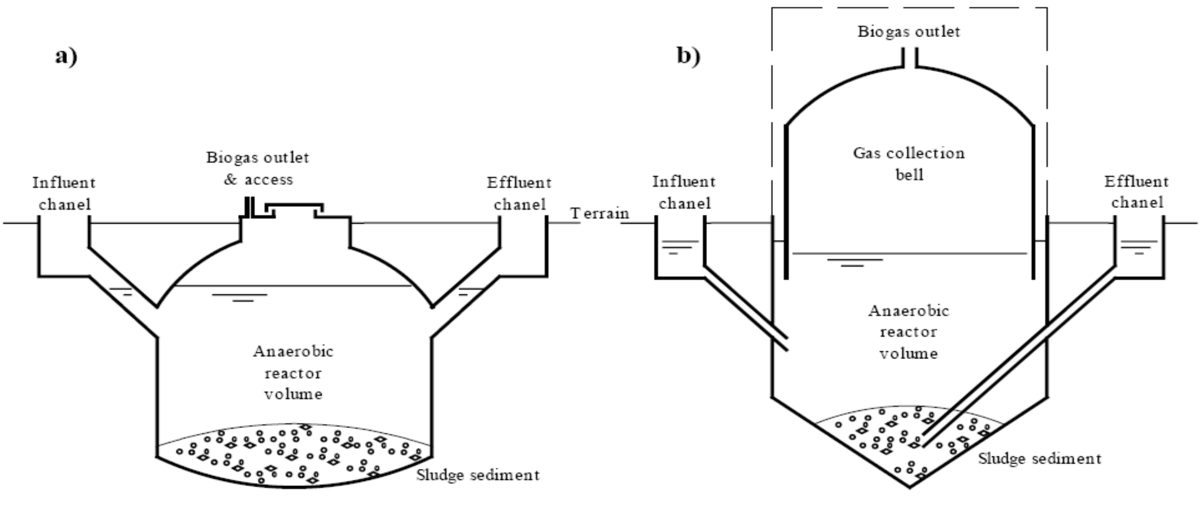

Figure 2.2: Biogas reactor types: a) Chinese type; b) Indian type (Angelidaki, 2004)

It is supplied with household sewage, animal manure and organic household waste. The reactor is operated in a semi-continuous mode, where new substrate is added once a day and a similar amount of decanted mixed liquid is removed once a day. The reactor is not stirred, so the sedimentation of suspended solids must be removed 2-3 times per year, occasion when a large portion of the substrate is removed and a small part (about one fifth of the reactor content) is left as inoculum. The Indian type (Figure 2.2b) is similar to the Chinese type as it is a simple underground reactor for domestic and small farming waste. The difference is that the effluent is collected at the bottom of the reactor and a floating gas bell functions as a biogas reservoir (Al Seadi et al., 2008).

2.3.2 Farm-Scale Biogas Plants

A farm scale biogas plant is named the plant attached to only one farm, digesting the feedstock produced on that farm. Many farm scale plants co-digest also small amounts of methane rich substrates (e.g. oily wastes from fish industries or vegetable oil residues), aiming to increase the biogas yield. It is also possible that a farm scale biogas plant receives and processes animal slurries from one or two neighbouring farms (e.g. via pipelines, connecting those farms to the respective AD unit). The farm scale biogas plants have various sizes, designs and technologies. Some are very small and technologically simple, while others are rather large and complex, similar to the centralized co-digestion plants. Nevertheless, they all have a common principle layout: manure is collected in a pre-storage tank, close to the digester and pumped into the digester, which is a gas-tight tank, made of steel or concrete, insulated to maintain a constant process temperature. Digesters can be horizontal (see Figure 2.3 below) or vertical, usually with stirring systems, responsible for mixing and homogenizing the substrate, and minimizing risks of swimming-layers and sediment formation. The average HRT is commonly of 20 to 40 days, depending on the type of substrate and digestion temperature. Digestate is used as fertiliser on the farm and the surplus is sold to plant farms in the nearby area. The produced biogas is used in a gas engine, for electricity and heat production. About 10 to 30% of the produced heat and electricity is used to operate the biogas plant and for domestic needs of the farmer, while the surplus is sold to power companies and respectively to neighboring heat consumers (Reinhard et al., 2010; Al Seadi et al., 2008).

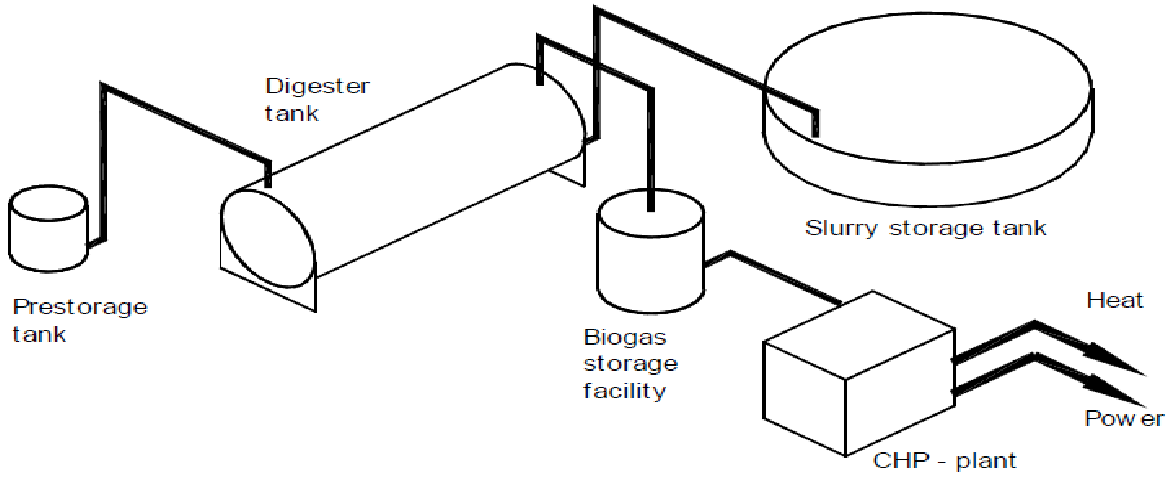

Figure 2.3: Schematic representation of a farm scale biogas plant, with horizontal digester of steel.

Source: (Hjort-Gregersen, 1999)

2.3.3 Centralized (Joint) Co-Digestion Plants

Centralized co-digestion is a concept based on digesting animal manure and slurries, collected from several farms, in a biogas plant centrally located in the manure collection area. The central location of the biogas plant aims to reduce costs, time and manpower for the transport of biomass to and from the biogas plant. Centralized AD plants co-digest animal manure with a variety of other suitable co-substrates (e.g. digestible residues from agriculture, food- and fish industries, separately collected organic household wastes, sewage sludge) (Al Seadi et al., 2008; Reinhard et al., 2010). The main purposes of centralized biogas plant and other early centralised plants appeared to be energy production. It later emerged that centralised biogas plants make a significant contribution to solving a number of environmental problems in the fields of agriculture, waste recycling and greenhouse gas reduction. In recognition of this, several governments have supported the development in different ways: an appropriate legislative framework, research and development programmes, investment grants and other subsidies. As a result, 20 centralised biogas plants are in operation in Denmark today (Hjort-Gregersen, 1999).

Nutrient management planning are set of actions which must include on-site minimization of limiting components outflow rates (e.g., water, nutrients and heavy metals); soil fertilization planning; analysis of economical costs; and analysis of feasible treatments applicable in order to improve manure management. When in a geographical area the amount of nutrients offered is higher than demanded, the complexity of the system makes necessary to account for a greater level of planning, which means a change in the scale, from individual to collective. The differentiation between individual and collective management planning is thus the key factor for later implementations of individual – farm-scale – or collective – large scale – treatment facilities. When there is nutrients excess at area scale (joining farmers and agricultural land owners) it requires a collective management planning which can conclude in the building up of a centralized processing system or in a combined solution (Flotats et al., 2009).

2.3.3.1 Centralized co-digestion plant development and the integrated concept

In 1984, the first CBP was established in Demark. This plant, like most of its successors, was equipped with combined heat and power production facilities, as heat was supplied to a nearby village and electricity was sold to the electricity grid (Hjort-Gregersen, 1999). In European countries such as Denmark and Germany, the centralized biogas plants have been developed since 1980s and proved to be economically viable [Kurt 2002; Weiland 2003]. On a yearly basis roughly 35 – 40 million tonnes of animal manure is produced in Denmark. Consequently, manure form a considerable resource for biogas production. The Danish centralized biogas concept was developed because manure should account for the major part of biomass treated in the plants. As a consequence of livestock production, many food processing industries are to be found in the same areas. For food processing industries, centralized biogas plants represent an appropriate waste disposal and recycling possibility as this is safe, convenient and economically advantageous. From the farmers' point of view, centralized biogas plants make it a lot easier to meet the legislative demands. The biogas company provides the storage facility; investments and farmers then rent the capacity they need. Moreover, if the storage tanks are placed near the fields where the manure is end-used as a fertilizer, farmers obtain considerable cost savings from manure transportation in times of spreading. The manure is transported from the farms to the biogas plant and returned to the storage tanks. The biogas plant takes care of this transportation in its own vehicles. Analyses showed that farmers gain considerable economic advantages from improved nutrient utilisation and cost savings when they participate in centralised biogas plants (Hjort-Gregersen, 1999).

In all cases, digestate is integrated in the fertilization plan of the farm, replacing mineral fertilizers, closing the cycle of carbon and nutrient recycling. More and more biogas plants are also equipped with installations for separation of digestate in liquid and solid fractions. This way, centralized co-digestion represents an integrated system of renewable energy production, organic waste treatment and nutrient recycling. Experience shows that the system is capable to generate agricultural, environmental and economic benefits for the farmers involved and for the overall society (Al Seadi et al., 2008). An integrated concept of centralised co-digestion plant is shown in Figure 2.4.

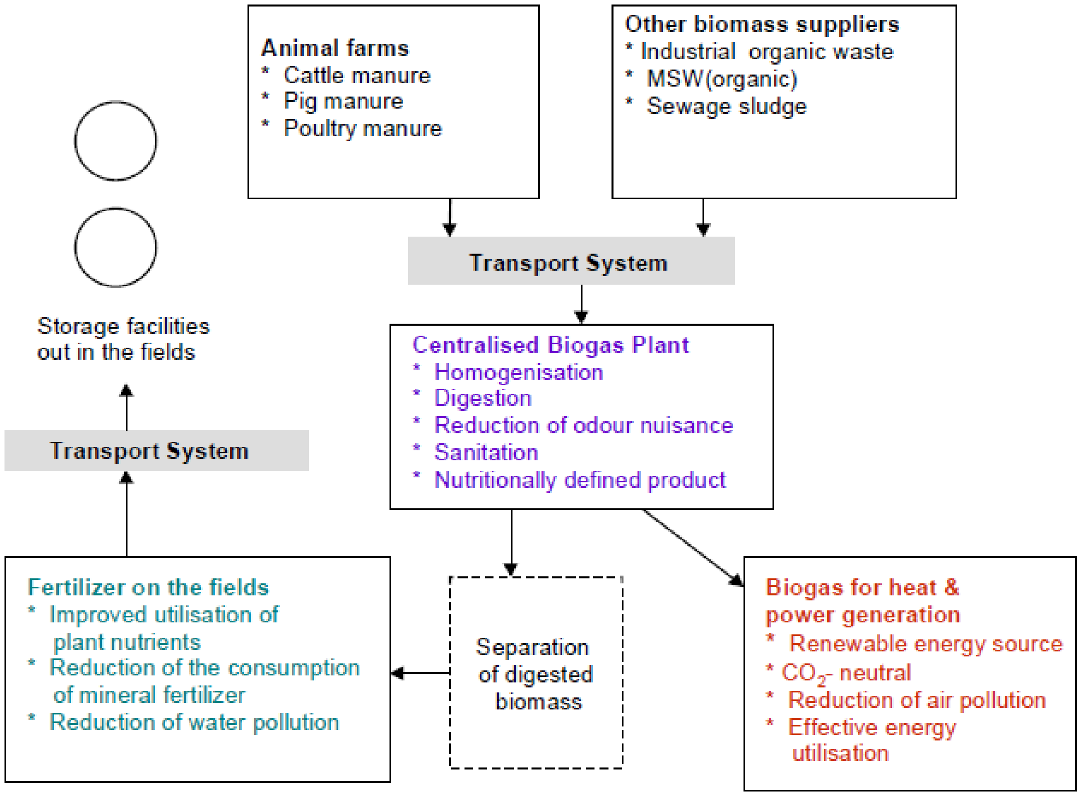

Figure 2.4: The integrated concept of centralised co-digestion plant

Source: Al Seadi et al., (2008)

2.3.3.2 Case studies of economic viability of centralized biogas plants

Biogas industry development in China has featured with household biogas and large-scale and middle biogas projects (LMBP) over the past sixty years. LMBP is the typical decentralized biogas project model which is owned and operated by the livestock farm itself and only treats organic residues from own farm. Due to the relatively small sizes of LMBP, the quantity of biogas produced by LMBP does not meet the required scale of 500KW installed electricity capacity. For most LMBP, the incomes from selling the biogas or biogas converted energy are very limited. So the efficiency of biogas yields has no strong influence on the profitability of an LMBP (Yan et al., 2013). To tackle the drawbacks of LMBP, Yan et al., (2013) reported that he considered centralized biogas plant (CBP) as an alternative to China's LMBP biogas model which is under construction in

China in the past few years. Yan et al., (2013) reported that the advantage of developing CBP in China is that the scale of a CBP at least reaches the minimum requirement for selling electricity to the grid; It co-digests mainly manure from different livestock farms, together with other organic waste from households and food market, kitchen waste of restaurants and organic residues of food processing enterprises and also higher gas productivity is obtained in CBP than LMBP. Its products include grid connected electricity or bio-methane extracted from biogas, heat from cogeneration, and organic fertilizer from digester. The greater energy efficiency and variety of products provides CBP a more stable profitability. Case studies and the experiences of nations in the European Union indicate that community ADS are technically and economically feasible (Wang et al., 2013). The Lemvig Biogas facility in Denmark is 100% privately owned by a cooperative of 69 local farmers and receives slurry from 75 farms and a variety of other producers of organic by-products suitable for co-digestion. The plant has been in operation since 1992, processes 500 t of manure and 120 t of organic by-products per day, produces 21 million kWh of electricity annually, and has stable economic performance that is comfortably better than break even (Task 37, 2013). To illustrate the potential use of biogas in transport vehicles, a 10-farm cooperative in Indiana with six digesters has adapted their tractor trailer milk hauling fleet, carrying 300,000 gallons of milk a day, to be fueled by compressed biomethane from the digesters (Callahan, 2011).

Centralized co-digestion plants can be organised as co-operative companies, with farmers supplying manure as energy consumers, as shareholders and owners. The management of the biogas plant is undertaken by a board of directors, which also employs the necessary personnel and is responsible for economic and legal binding agreements concerning the construction of the plant, the feedstock supply, the distribution and sale of digestate, the sale of biogas or/and energy and the financing activities. The co-operative company proved to be a functional organizational structure, economically feasible in countries like Denmark, but other organization forms like limited companies or municipally owned companies are also frequent (Al Seadi et al., 2008). A brand new plant constructed in Nysted Denmark in 1998 is shown in Figure 2.5 below. 35 farmers are involved in this plant which is operated at mesophilic temperatures (approx. 35°C). The biomass feedstock primarily consists of pig slurry.

Figure 2.5: Nysted Centralized Biogas Plant

Source: (Hjort-Gregersen, 1999).

2.4 The Major Driving Factors In Centralized Biogas Plants

The benefits of CBP include but are not limited to economies of scale and profitability of the project. Other major interest includes energy production, reduction in environmental degradation and economic interest, these are detailed below:

2.4.1 Energy Interests

Beside of water, energy is the crucial resource demanded for the further development in many parts of the world and especially in developing countries. In order to prevent further climate change the growth of the energy market should be based on renewable sources (Plöchl and Heiermann, 2006). Biogas is a renewable energy source based on various domestic organic waste resources. Since the oil crises in the early seventies, there has been general awareness that renewable energy technologies must be developed. Dependency on fossil fuels must be reduced as future oil crises may occur and world-wide fossil fuel resources become scarce in the long run (Hjort-Gregersen, 1999).

2.4.2 Environmental Interests

Centralized biogas plants are well-suited for recycling various types of organic waste as long as the waste does not contain elements that may restrict the end use of digested biomass as a fertilizer. It is of major environmental interest that nutrient losses from manure application are minimised. Anaerobic treatment in a biogas plant reduces odour nuisances in times of slurry application - a side-effect welcomed by many farmers (Hjort-Gregersen, 1999). They reduce the potency of greenhouse gases (GHG) released into the atmosphere as a result of animal rearing by capturing and combusting methane, a GHG that has 21 times as much atmospheric warming potential as CO_2 (EPA,2010).

2.5 Factors That Support Application of Centralized Bio-Energy Plant

Although there are potential economies of scale for the centralized digester, manure transportation and handling costs can offset the economic savings if there are not sufficient suitable farmers willing to participate in close proximity to the proposed facility (ESA, 2011). Other factors that could affect the application of CBP are substrate availability, spatial distribution of manure of bio-waste sources etc. Factors that support on-farm-scale or centralized biogas plant technology adoption is shown on Table 2.1 below:

Table 2.1: Factors influencing decision on centralized or on-farm-scale approach

Collective/centralized Management and Treatment	On-farm management and treatment
Economical profile of the area: industrial and farming	Economical profile of the area: tourism, services and residential
High farming density and intensity	High impact of manure transportation
Low general impact of manure transportation	Involvement of farmer
Existence of strong farmers leadership	Potential uses of biogas plants products
Existence of other organic waste to help plant economy (co-digestion)	Existence of professional technology suppliers and consultants
Potential uses of in plant uses in the area	Treatment facilities fully integrated in the farm
Existence of professional technology suppliers and consultants	Technological simplicity, ease of maintenance and operation
Centralized treatment as a service to the collective management	
Social variables: ease in involving farmers in a common project	

Source: Flotats et al., (2009)

Some critical factors that influence CBP adoption are considered below:

2.5.1 Transportation Cost

Biomass feedstock is a distributed resource with a low energy density, meaning that transport can make up a significant proportion of cost, as well as requiring fossil fuel use and associated emissions (Powlson et al., 2005). Transportation cost may become an important bottleneck when planning manure management. It varies with respect to the distance per unit of volume transported. Biomass transportation accounted for 35–50% of the total operating costs in the Danish centralized biogas plants, representing a large saving potential if distances were optimized and loading facilities in farms were improved (DEA, 1995). Transportation cost provides a simple criterion to decide when a manure processing technology can be adopted. In this context, processing can be attractive if the global net cost of treatment, transportation and soil application of effluents is less than the cost of transportation and application of raw manure to available soils at an adequate nutrients dosage (Campos et al., 2004). Centralized management of transportation allows optimizing time of service and mortgage costs, and therefore, it results in a better economical evaluation. Centralized fertilization management of available arable lands was in such case an interesting alternative due to the optimization of logistics and requirements for manure processing.

Zubaryeva et al., (2012) first objective in their research work 'Spatially explicit assessment of local biomass availability for distributed biogas production via anaerobic co-digestion-Mediterranean case study' had economic endpoint integrating distances from sources and sinks of biomass and energy, respectively, with a total of six factors. The distance to major roads, gas pipelines and power lines were selected to minimize the energy transportation costs and environmental impact of new infrastructures and overall traffic reduction; factor of distance to sewage plants was included as the potential for further inclusion of this biogas source in the analysis; while distances to industrial areas and caves would be beneficial to the goal of the reuse, recovery and minimization of the odor impact of the potential AD. Therefore, transportation cost must be minimized. To minimize the costs of biomass delivery, storage, and transportation, a linear programming method can be used (Cundiff et al., 1997). A sourcing radius of 25 km has consequently been applied by several studies. For England, the stipulation from the Department for Environment, Food and Rural Affairs (DEFRA) is that Energy Crop Scheme (ECS) funding was only available where an end use within 25 km could be demonstrated (Thomas et al., 2013).

Hohn et al., (2014) analyzed the spatial distribution and amount of potential biomass feedstock for bio-methane production and optimal locations, sizes and number of biogas plants in southern Finland in the area of three regional waste management companies. The researchers used maximum transportation distances for raw materials varying from 10 to 40 km, in the study. The lower and upper end were used to study the impact of varying transportation distance on collection area and associated biogas production potential. It was found that a total of 49 biogas plants could be built in three case regions with feedstock available within maximum transportation radius of 10 or 40 km. With maximum of 10 km biomass transportation distance, the production capacity of the planned plants ranges from 2.1 to 8.4 MW. If transportation distance was increased to 40 km, the plant capacities could also increase from 2.3 to 16.8 MW.There have been moves towards a closer integration of GIS data models with transportation planning and modelling. In many cases this involved a re-purposing or re-focussing of tools and models which already existed within GIS (Lucy and Longden, 2009).

2.5.2 Density of Farming and Intensity of Manure Production

Regional clustering of farms are usually formed around economic advantages, such as climate, processors, transportation access and costs, infrastructure such as feed mills, professionals and labour, and proximity to inputs (Hegg, 2008). Teira-Esmatges and Flotats (2003) developed a method consisting of the calculation of the density of nitrogen generation (kg N/ha/year) in squares of increasing surface. When increasing the square surface, the nitrogen generation in areas with low farm density becomes diluted, and only those with enough large farms or many small farms very close to each other remain as areas with remarkable nitrogen generation. These areas always correspond to high livestock density and, therefore, a centralized treatment plant located there will minimize transportation costs.

2.5.3 Biomass Availability within the Region

With the growing interest in exploring renewable energy usage, GIS has proved to be an effective tool to address issues related to biomass availability and biomass logistics (Johnson et al., 2011). Siting bioenergy plants in optimal locations at optimum capacities is a challenging task. Due to high geographical dependence of biomass feedstocks, implementation of spatial information technologies such as remote sensing and GIS in addressing this issue appears to be an appropriate methodology; biomass availability is characterized by year to year variability and spatial non-homogeneity (Kumar and Sultana, 2012). GIS has been used for assessing biomass availability in several studies eg Scarlat et al., (2011) provided a resource-based assessment of availability of biomass resources for energy production in Romania, at NUTS-3 level. The estimation of available biomass includes the residues generated from crop production, pruning of vineyards and orchards, forestry operations and wood processing. The amount of agricultural and forest residues available for bio-energy in Romania was estimated at 228.1 PJ on average, of which 137.1 PJ was from annual crop residues, 17.3 PJ residues from permanent crops and 73.7 PJ/year from forestry residues, firewood and wood processing by-products. The biomass availability shows large annual and spatial variations, between 135.6 and 320.0 PJ, due to the variation in crop production and forestry operations.

2.6 Biogas Digesters

The core of a biogas plant is the digester - an air proof reactor tank, where the decomposition of feedstock takes place, in absence of oxygen, and where biogas is produced. Common characteristics of all digesters, apart from being air proof, are that they have a system of feedstock feed-in as well as systems of biogas and digestate output. In European climates anaerobic digesters have to be insulated and heated. There are a various types of biogas digesters, operating in Europe and around the world. Digesters can be made of concrete, steel, brick or plastic, shaped like silos, troughs, basins or ponds, and they may be placed underground or on the surface. The size of digesters determine the scale of biogas plants and varies from few cubic meters in the case of small household installations to several thousands of cubic meters, like in the case of large commercial plants, often with several digesters. From the point of view of feedstock input and output, there are two basic digester types: batch and continuous.

2.6.1 Batch-Type Digesters

The specific operation of batch digesters is that they are loaded with a portion (batch) of fresh feedstock, which is allowed to digest and then is completely removed. The digester is fed with a new portion and the process is repeated. Batch-type digesters are the simplest to build and are usually used for dry digestion. An example of batch digesters are the so-called "*garage type*" digesters made of concrete, for the treatment of source separated biowaste from households, grass cuttings, solid manure and energy crops. Treatment capacity ranges from 2 000 to 50 000 tonnes per year (see Figure 2.6). The feedstock is noculated with digestate and fed in the digester. Continuous inoculation with bacterial biomass occurs through recirculation of percolation liquid, which is sprayed over the substrate in the digester.

Figure 2.6: Garage-type batch digester, loaded by a loader (BEKON, 2004)

2.6.2 Continuous-type digesters

In a continuous-type digester, feedstocks are constantly fed into the digester. The material moves through the digester either mechanically or by the pressure of the newly feed substrate, pushing out the digested material. Unlike batch-type digesters, continuous digesters produce biogas without interruption for loading new feedstock and unloading the digested effluent. Biogas production is constant and predictable. Continuous digesters can be vertical, horizontal or multiple tank system. Depending on the solution chosen for stirring the substrate, continuous digesters can be completely mixed digesters and plug flow digesters. Completely mixed digesters are typically vertical digesters while plug-flow digesters are horizontal

2.7 Greenhouse Gases Emissions in the Agricultural Sector

Liang et al., (2013) estimated the nitrous oxide and methane emission from livestock of urban agriculture in Beijing from 2007 to 2009, it was noted that the total quantity of GHG emissions from livestock sector in Beijing was 1.67 Tg CO_2e yr^{-1}, of which N_2O-N and CH_4 emissions were 1.04 Gg yr^{-1} (489 Gg CO2e yr^{-1}) and 47.25 Gg yr^{-1} (1181.25 Gg CO2e yr^{-1}), respectively.

Browne et al., (2011) using the Australian National Inventory methodology, whole farm GHG emissions were calculated for different farm types in South Eastern Australia. Fourteen representative farms were examined that included production of Merino fine wool, prime lamb, beef cattle, milk, wheat and canola. The study shows that dairy farms produced the highest emissions/ha (8.4–10.5 t CO_2-eqv/ha), followed by beef (3.9–5.1 t CO_2-eqv/ha), sheep (2.8–4.3 t CO_2-eqv/ha) and grains (0.1–0.2 t CO_2-eqv/ha). When compared on an emissions intensity basis (i.e., t CO_2- eqv/t product), cow/calf farms emitted the most (22.4–22.8 t CO_2-eqv/t carcass weight) followed by wool (18.1–18.7 t CO_2-eqv/t clean fleece), prime lamb (11.4–12.0 t CO_2-eqv/t carcass weight), dairy (8.5–9.4

t CO_2-eqv/t milk fat + protein), steers (6.3–6.7 t CO_2-eqv/t carcass weight) and finally grains (0.04–0.15 t CO_2-eqv/t grain). Christie et al., (2011) examined GHG emissions of 60 Tasmanian dairy farms using the Dairy Greenhouse gas Abatement Strategies (DGAS) calculator, which incorporates International Panel on Climate Change (IPCC) and Australian inventory methodologies, algorithms and emission factors. Total farm GHG emissions of 60 Tasmanian dairy farms, as estimated with DGAS, ranged between 704 and 5839 t CO_2e/annum, with a mean of 2811 t CO_2e/annum.

Methane production from livestock depends on the emission factors of animal management, the quantity of the manure per animal as well as quality of feed consumption are other important factors. However, emission factor selection can be influenced by regional climatic conditions. Suberu et al., (2013) provided a theoretical estimate of methane emissions from both livestock manure in Nigeria and municipal solid waste deposits in some of the country's major cities. Ten-year data obtained from the United Nations Food and Agricultural Organization (FAO) was used to estimate the methane emissions from animal residues using a mathematical approach developed by the Intergovernmental Panel on Climate Change (IPCC). The result of the estimated methane emission from livestock manure in Nigeria based on the IPCC mathematical approach from 2001 to 2010 is shown in Fig. 2.7.

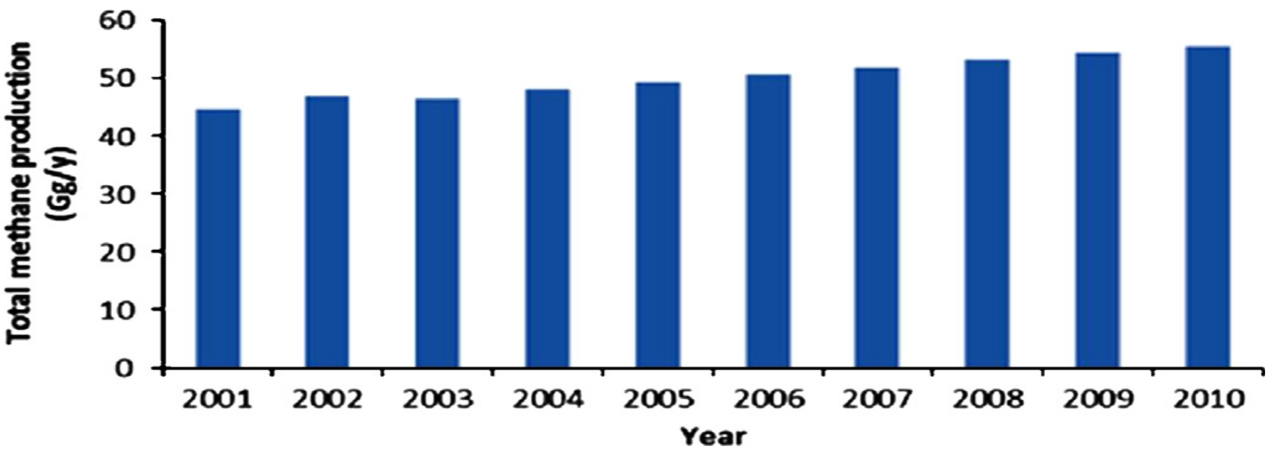

Figure 2.7: Methane production from livestock in Nigeria from 2001 to 2010

Results from this study indicated a large amount and increasing levels of methane emissions from animal residues and solid wastes, from the Figure 2.7 it obvious that there has been continual increase in methane emission in Nigeria.

Suberu et al., (2013) estimated Methane emissions from solid wastes based on the 2011 cities' waste generation and management data from the Renewable Energy Department (RED) of the Federal Ministry of Environment, Abuja (Nigeria). The result of the study is as shown in the Figures 2.8.

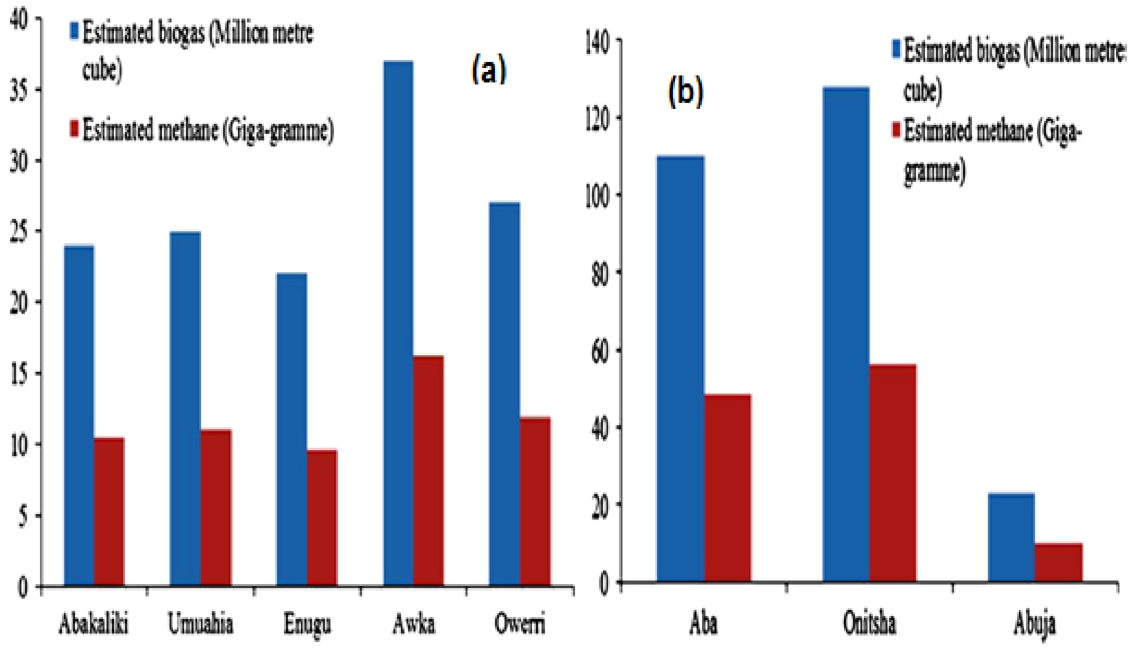

Figure 2.8: (a) Estimated methane emission in Southeastern regional state capitals (b) Estimated methane emission in the selected important cities.

From the result of the study, Onitsha city is shown to be the highest in estimated biogas emission and methane emission in some of the major cities selected in the country, while Awka Town is the highest amongs the state capital territory in the South-Eastern States of Nigeria.

2.7.1 Greenhouse Gases Mitigation

Methane is a potent greenhouse gas whose atmospheric abundance has grown 2.5-fold over three centuries, due in large part to agricultural expansion. The farming of ruminant livestock, which generate and emit methane during digestion (‘enteric fermentation’), is a leading contributor to this growth (Lassey 2007). The livestock sector is one of the largest contributors to greenhouse gases (GHG) emissions globally. It is responsible for 18%–51% of anthropogenic emissions expressed in CO_2-equivalent (Schils et al., 2007; Lassey, 2007). With progressive increase in demand for meat products, intensive livestock husbandry is rapidly expanding. Moreover, livestock farms heavily depend on external inputs (i.e., concentrate feeds, machinery, electricity, fossil-fuel energy sources). Thus animal husbandry emits GHGs into the atmosphere almost at all production stages (Liang et al., 2013). It is important to note that proper manure management is essential for any agricultural operation because improper use of manure can lead to negative impacts on the environment. Effective control of methane and nitrous oxide emission from ruminants can raise ruminants feed utilization, energy conversion rates and productivity (Zhou et al, 2007). Nowadays, the anaerobic digestion is considered as an important option to treat different high-loaded organic wastes due to the necessity of searching for low cost treatments for wastes and at the same time for finding alternatives to reduce the use of fossil fuels and to minimize greenhouse gas emissions. (Buendı´a et al., 2007; Blanco-Canqui and Lal, 2007). It is necessary to evaluate GHG emissions at temporal and spatial scales, to identify problems and trends, and to propose strategies preventing environmental degradation.

On mitigation of greenhouse gases, Curry and Pillay (2012) asserted that where anaerobic digestion technology is applied, food waste would not be sent to landfills reducing transportation costs and greenhouse gas emissions. (Liang et al., 2013) reported that to reduce GHG emissions from the livestock sector, relevant strategies such as improving rearing technologies, breeding, strengthening management and developing large-scale biogas industry should be considered. Theoretically, biogas industry could offset about 80% of GHG emissions from livestock sector, yet there are some barriers, which need to be overcome to enhance cooperation among government agencies, market organizations and livestock enterprises. Beukes et al., (2011) reported that the strategy for New Zealand dairy farming formulates targets for increased national milk production and a reduction in greenhouse gas (GHG) emissions, but acknowledges these two targets conflict because GHG typically increase with increased milk output. Their objective was to determine if both targets could be achieved by implementing combinations of five mitigations. The five mitigations were: (1) improved reproductive performance of the herd resulting in lower replacement rates, (2) increased genetic merit of the cows combined with lower stocking rate and longer lactations, (3) keeping lactating cows on a loafing pad for 12 h/day for 2 months during autumn, (4) growing low protein crops of grains and/or silages of maize, barley and oats on a portion of the farm and feeding this to lactating cows, (5) reducing fertilizer N use and replacing some of this with nitrification inhibitors and the plant growth stimulant gibberellins. No single mitigation strategy achieved both targets of increasing production by 10–15% and reducing GHG emissions by 20%, but when all were simultaneously implemented in the baseline farm, milk production increased by 15–20% to 1200 kg milk fat + protein/ha, and absolute GHG emissions decreased by 15–20% to 0.8 kg CO_2-equivalents (CO_2-e)/kg fat and protein corrected milk, which is equivalent to a decrease from 11.7 to 8.2 kg CO_2-e/kg fat + protein. The synergies of the mitigations resulted in reduced dry matter intake and enteric CH_4 emissions, a reduction in N input and N dilution in feed, and, therefore, reduced urinary N excretion onto pastures, and an increase in feed conversion efficiency (i.e., more feed was used for production and less for maintenance).

2.7.2 GHG Emissions Mitigation in Manure Management

Organic wastes which are potentially valuables as fertilizers or amendments must be considered as resources to be managed adequately, instead of pollutants to be removed. Following this simple concept, manure has to be considered as a by-product of livestock production and when required processed, just for fitting the objective of an optimal management within the context of the farm (Flotats et al., 2009). Greenhouse gas emissions from manure management in the European Union (EU) in 2008 were estimated as 50.26 million tonnes CO_2 equivalent, of which dairy cattle contributed 21% (EEA, 2010). The impact of anaerobic digestion (AD) technology on mitigating greenhouse gas (GHG) emissions from manure management on typical dairy, sow and pig farms in Finland was compared by Kaparaju and Rintala (2011), the results showed that enteric fermentation (CH_4) and manure management (CH_4 and N_2O) accounted for 231.3, 32.3 and 18.3 Mg of CO_2 eq. yr^{-1} on dairy, sow and pig farms, respectively. With the existing farm data and experimental methane yields, an estimated renewable energy of 115.2, 36.3 and 79.5 MWh of heat yr^{-1} and 62.8, 21.8 and 47.7 MWh of electricity yr^{-1} could be generated in a CHP plant on these farms respectively. The total GHG emissions that could be offset on the studied dairy cow, sow and pig farms were 177, 87.7 and 125.6 Mg of CO2 eq. yr^{-1}, respectively. The impact of AD technology on mitigating GHG emissions was mainly through replaced fossil fuel consumption followed by reduced emissions due to reduced fertilizer use and production, and from manure management.

Cuéllar and Webber (2008) observed that there is a double greenhouse gas emission benefit through the use of AD systems. Firstly, methane is captured and eventually converted to heat and carbon dioxide instead of being allowed to escape to the atmosphere as it does in the simple open lagoon storage of manure. Methane's global warming potential is 21 times that of carbon dioxide and thus the conversion of methane to carbon dioxide reduces the global warming potential. Secondly, if the AD biogas plant offsets fossil fuel-based electricity (such as natural gas fired power plants), there is a reduction in fossil fuel-related carbon dioxide emissions. Along with mitigating bio-methane gas emissions, anaerobic digestion of animal manure has the potential to reduce farm-generated odors, improve crop-based nutrient management, and produce local, renewable energy (Labatut et al., 2011). Utilisation of fossil fuels such as lignite, hard coal, crude oil and natural gas converts carbon, stored for millions of years in the Earth's crust, and releases it as carbon dioxide (CO_2) into the atmosphere. An increase of the current CO_2 concentration in the atmosphere causes global warming as carbon dioxide is a greenhouse gas (GHG). The combustion of biogas also releases CO_2. However, the main difference, when compared to fossil fuels, is that the carbon in biogas is taken up taken the atmosphere, by photosynthetic activity of the plants. The carbon cycle of biogas is thus closed within a very short time (between one and several years). Biogas production by AD reduces also emissions of methane (CH_4) and nitrous oxide (N_2O) from storage and utilization of untreated animal manure as fertilizer. The GHG potential of methane is higher than of carbon dioxide by 23 fold and of nitrous oxide by 296 fold. When biogas displaces fossil fuels from energy production and transport, a reduction of emissions of CO_2, CH_4 and N_2O will occur, contributing to mitigation of global warming (Al Seadi et al., 2008).

2.8 Geographic Information System (GIS)

Geographic information system is a system for capturing, storing, checking, integrating, analyzing, and displaying data about the earth that is spatially referenced. It is normally taken to include a spatially referenced database on appropriate applications software. GIS is applicable in many fields. Their application is cross-disciplinary and may be adopted in a variety of fields, such as resource management, logistics, cartography, archaeology, urban planning, environmental impact assessment and many others. Numerous applications of GIS is outlined below: For instance An emergency management agency can plan relief facilities by modeling demand and accessibility; A fire fighting team can predict the spread of a forest fire using terrain and weather data; a biologist can study the impact of construction plans on a watershed; A pipeline company can use GIS to find the least-cost path for a new pipeline; an electric utility can model its circuits to minimize power loss and to plan the placement of new devices; a telecommunication company can determine the terrain to find locations for new cell phone antennae; a hydrologist can monitor water quality to protect public health; a police department could wish to study crime patterns to intelligently deploy its personnel and to monitor the effectiveness of neighborhood watch program; a water resource manager can trace upstream water quality to find the possible sources of a contaminant; a business company can evaluate locations for new retail outlets by considering nearby concentrations of customers; an engineering department can monitor the condition of roads and bridges and produce planning maps for natural disasters; a tax assessor’s office can produce land use maps for appraisers and planners (Booth and Mitchell 2001; Reinhard et al., 2010).

GIS data represent real world objects whose position may be identified via coded maps based on any coordinates systems (e.g. postal codes, longitude, latitude and altitude or relative x, y, z vector grids). They may describe location points (e.g. resources, plants, consumers), regions (e.g. municipal communities, forests, cultivation areas), transmission or connection networks (e.g. roads, railroads, electrical grids) and continuous variables (e.g. altitude, vegetation type, population density). In general, GIS include two types of information sets. Spatial data portray the absolute and relative location of geographic features. Attribute detail illustrate characteristics of the spatial features. These characteristics may be qualitative and/or quantitative. Spatial data generally distinguish between discrete objects (e.g. a house) or continuous fields (e.g. soil fertility, amount of rainfall, elevation). Vector data models are usually adopted to describe discrete features, such as specific point locations and information summarized by area or line/polyline characteristics. Continuous numeric values (e.g. elevation) and continuous categories (e.g. vegetation types) are represented in raster data models (Reinhard et al., 2010).

2.8.1 Applications of GIS in Environmental Engineering

GIS has wide application in environmental engineering, its application includes but not limited to land/facility location suitability analysis, assessment of biomass availability for bio-energy production, prediction of soil erosion, water quality modeling, groundwater quality monitoring etc.

2.8.1.1 GIS-based biomass availability assessment and waste management

Biomass availability is characterized by year to year variability and spatial non-homogeneity. Haddad and Anderson (2008) used geographic information systems technology to identify potential locations in a Midwestern region for collection and storage of corn stover for use as biomass feedstock. Spatial location models were developed to identify potential collection sites along an existing railroad by the researchers. Site suitability analysis was developed based on two main models: agronomic productivity potential and environmental costs, the results suggest that there is a significant subset of potential sites that meet site selection criteria.

Lopez et al., (2008) used a methodology for the design of routes for the ‘‘bin to bin’’ (BTB) collection of paper and cardboard waste (PCB) from small businesses, as well as with the new location and calculation of the number of containers needed in the streets for both commercial and non-commercial use due to the large amount of PCB deposited in them. Their study was carried out in five shopping areas of the city of Legane´s

(Community of Madrid, Spain). One of the characteristics of the area is a high density of population and urban traffic. The tool used is the GIS (GIS-Arc-View). With it they generated PCB points of high population density in commercial streets based on territorial analysis. They placed the special routes and the new container locations within a distance of 60 m of these collection points. The system calculated and optimized six routes according to different urban restrictions. Finally, they provided service to 59% of the shops, which generate almost 82% of the PCB waste, using 160 min per day to collect 1027 kg of high quality PCB. When compared the system with the system in place previously, they concluded that the ‘‘bin to bin’’ (BTB) system improves the quality of the PCB in the containers, avoiding overflow and reducing the percentage of rejected material.

GIS supported methodology was been developed in order to assess the technical and economic potential of biomass exploitation for energy production in Sicily by Beccali et al., (2009). The methodology was based on the use of agricultural, economic, climatic, and infrastructural data in a GIS. Data about land use, transportation facilities, urban cartography, regional territorial planning, terrain digital model, lithology, climatic types, and civil and industrial users were stored in the GIS to define potential areas for gathering the residues coming from the pruning of olive groves, vineyards, and other agricultural crops, and to assess biomass available for energy cultivation. The study shows a significant competitiveness of the finished biomass (pellets), and good potential for a long-term development of this market in Sicily.

Thomas et al., (2013) presented an analysis of the spatial supply and demand relationships for biomass energy potential for England, using Geographical Information System (GIS) mapping techniques. The mapping for England indicates that of the 2,521,996 ha viable for cultivation of Miscanthus, 1,998,435 ha are within 25 km of the identified potential end uses of feedstock, and 2,409,541 ha are within 40 km. Potential generation exceeds the 2020 UK biomass generation target of 259 PJ, whichever radius is applied.

Khachatryan et al., (2009) developed a Geographic Information Systems based model to support cellulosic ethanol plant least-cost location decisions by integrating geographic distribution of biomass in the study area with associated transportation costs. As an initial step of a multi-factor spatial optimization problem, including both feedstock transportation and ethanol distribution cost, the study investigated the influence of feedstock transportation costs on optimal location decisions. To achieve that purpose, the feedstock resources, in this analysis forest biomass and agricultural crop residue, were spatially investigated relative to the road network and potential cellulosic ethanol plant locations in the state of Washington. Study results show that the ethanol plant transportation cost-minimizing location decisions are significantly influenced by the type of the feedstock utilized, and vary depending on the processing plant capacities.

ArcGIS Network Analyst GIS known software was introduced for best routing identification applied in municipal waste collection by Bhambulkar (2011). The proposed application takes into account all the required parameters for the waste collection so that its desktop users to be able to model realistic network conditions and scenarios. In this case, the simulation consists of scenarios of visiting loading spots in the municipality of Nagpur, in order to collect Minicipal Solid Waste that couldn’t be collected by the standard waste collection trucks, due to size and other prohibitive obstacles. The Network Analyst is used to estimate interrelations between the dynamic factors, like network traffic changes (closed roads due to natural or technical causes, for example, fallen trees, car accidents, etc) in the area under study and to produce optimized solutions. The optimal solution is identified by a function that takes into consideration various parameters, for example the shortest distance, road network as well as social and environmental implications.

Satellite imagery covering Akure and its environs was analysed using ArcView GIS 3.2a to develop a user interface for selecting a waste disposal site with special emphasis on geologically suitable conditions by Anifowose et al., (2011). The study demonstrated the potential and efficiency of using GIS in selecting sites for the storage of biodegradable solid wastes. Results show suitable areas where landfill sites can be safely and aesthetically located within the study area, putting urban growth rate into consideration.

In order to decrease collection/hauling costs, route optimization was carried out in Trabzon City located in the northeast side of Turkey by Apaydin and Gonullu (2007), for 39 districts in the city, a shortest path model was used in order to optimize solid waste collection/hauling processes, as minimum cost was aimed. The Route View ProTM software as an optimization tool was used for that purpose. GIS elements such as numerical pathways, demographic distribution, container distribution and solid waste production amount were integrated to the software. To give an idea, thematic container layer has 777 container location points for the entire city. After optimizing routes by the software, the optimized routes were compared with the present routes. Success by the optimization process was around 4-59 % for distance and 14-65 % for time. Consequently, a route optimization process on the street stationary container collection system will contribute a benefit by 24 % in total cost.

2.8.1.2 Application of GIS in land/location suitability analysis

Land suitability analysis involves the search for the best location of one or more facilities to support some desired function, it is the process to determine whether the land resource is suitable for some specific uses and to determine its suitability level. It is an important analytical method for ecological planning. Land suitability refers to the inherent suitability of the land for some specific, persistent uses. Examples range from retail site location to the location of multiple ambulance dispatch points. This land is determined by such characters as hydrology, geography, topography, geology, biology, sociology, etc. Land suitability will have no meanings unless it is relevant to some specific uses, and it is very important for making good use of land and promoting the land's social value (Manlun, 2003, Church et al., 1992).

GIS technology has been applied by various researchers in location suitability analysis. In the context of potential development of collective biogas plants in France, the use of GIS in order to geo-reference the bio-resources and then to locate the optimal sites have been carried out on both national and regional scales but needed to be adapted for local diagnosis. For this purpose Bioteau et al., (2012), did a research project devoted to the development of such methodologies, and then applied it in the "Pays de Fougères", a 1000 km^2 wide rural area located in the North-eastern Brittany in France. Firstly, a bio-resource mapping was drawn. A derived layer, the energy potential grid, is calculated as the sum of the energy potential at any point in the area (100 m resolution per pixel) considering for each substrate a maximum distance proportional to the energetic potential of the substrate. Next, sensitive areas (wetlands, distances from housing) are identified as areas where the development of biogas plants is restricted, resulting in a constraint map. A final suitability map is constructed by combining the constraint map and the energy potential grid, synthesized in the form of a raster GIS file. The network analysis capability of GIS was used, in order to take into account the actual transport route and competitive access to bio-resources. The precise geo-location of farms was successfully obtained through the analysis of aerial photographs and Landsat imagery used in the identification of crop residues.

Uyan (2013) studied the determination of suitable site for solar farms using GIS and AHP in the study area. The final index model was grouped into four categories as "low suitable", "moderate", "suitable" and "best suitable" with an equal interval classification method. The result of the study shows that, 15.38% (928.18km^2) of the study area had low suitability, 14.38% (867.83km^2) had moderate suitability, 15.98% (964.39km^2) was suitable and 13.92% (840.07km^2) was best suitable for solar farms area. 40.34% (2434.52km^2) of the study area is not suitable for solar farm areas.

Höhn et al., (2014) analysed the spatial distribution and amount of potential biomass feedstock for bio-methane production and optimal locations, sizes and number of biogas plants in southern Finland in the area of three regional waste management companies .A GIS based methodology, which also included biomass transport optimisation considering the existing road network and spatially varied biomass sources, was used. Kernel Density maps were calculated to pinpoint areas with high biomass concentration. The results show that the total amount of biomass corresponds to 2.8 TWh of energy of which agro materials account for more than 90%. It was found that a total of 49 biogas plants could be built in three case regions with feedstock available within maximum transportation radius of 10 or 40 km. With maximum of 10 km biomass transportation distance, the production capacity of the planned plants ranges from 2.1 to 8.4 MW. If transportation distance was increased to 40 km, the plant capacities could also increase from 2.3 to 16.8 MW.

Due to constant decrease in farmlands in Algeria, Mendas and Delali (2012) used the development of land suitability maps for agriculture by combining several factors of various nature and of differing importance, the study integrated Multi-Criteria Decision Analysis approaches (MCDA) in a Geographical Information System (GIS) which provides a powerful spatial decision support system and also offers the opportunity to efficiently produce these land suitability maps. The spatial decision support system was developed for establishing the land suitability map for agriculture. A land suitability map in the area of Mleta in Algeria for durum wheat was produced.

Zubaryeva et al., (2012) focused on the assessment of biogas potentials to provide a support for decision-makers and bio-energy industry at a local scale. The study area is one of the three waste management authorities of Lecce province in the Apulia Region of Italy, instituted in 2002. It is composed of 24 municipalities with the area of 589.7 km^2 and a population of 189,105 inhabitants. Zubaryeva et al., (2012) approach exploits the spatial relations among territorial units (i.e., a contiguity analysis), and integrates time series of continuous and discrete data. It was based on the analytic hierarchy process (AHP) combined with GIS based analysis, and permitted to develop a territorial information system in support for biogas planning, perform analysis of feedstock for biogas from different sources potential and produce plausible scenarios for identification of biogas suitable territorial clusters. The result of the study revealed that when it comes to the detailed analysis of the land availability at the local scale, application of multiple environmental and cultural constraints may reduce the physical availability of the area by up to a half. While the resource and infrastructure accessibility would further constrain the examined area, leading to the formation of landscape clusters, which indicate the best suitable areas for AD development. The multi-criteria GIS model suggests that the ADs should be located in the Northern and North-eastern parts of the studied area. These are the areas where the population density is higher and therefore the higher energy demand could be partially addressed**.**

Gbanie et al (2013) presented a methodological framework for identifying municipal landfill sites in urban areas in Sierra Leone using Bo in Southern Sierra Leone as a case in point. The framework involves a multi-criteria GIS approach that blends two aggregation techniques: Weighted Linear Combination and Ordered Weighted Averaging. Key results show that 83.3% of the study area is unsuitable for municipal landfill.

Kumar and Sultana (2012) developed a methodology for determining the suitable locations, optimal sizes and number of biomass-based facilities for a particular region through transport cost optimization which is applied for locating pellet plants in the

Province of Alberta. The methodology also includes computation of local optimal size and cost of pellet production considering road network and spatially varied biomass. Different constraints and environmental factors for siting biomass-based facilities were analyzed to derive a land suitability model. Based on location–allocation model, they suggested that 13 plants could be built in the Province of Alberta with transportation costs in the range of $21–33 per tonne. The locally determined unit costs of pellet plants vary within $108–121 with optimal plant capacities of 150,000–250,000 tonnes per year.

Perpi˜na et al., (2013) presented a complete multi-criteria assessment process in GIS environments for the identification of sites suitable for building biomass plants. To achieve this aim, the principal criteria were defined (factors and constraints), evaluated and weighted in the context of Saaty's analytic hierarchies and divided into three groups: environmental, economic and social. The best alternatives were obtained after applying the two decision rules: weighted linear summation (WLS) and ideal point method. The final stage of the decision problem consisted of a sensitivity analysis of the set of factors and their associated weights using two global methods based on variance, the Soboli and the extended-FAST methods. The model was applied in an area of the European Mediterranean Region (Valencia, Spain) where agriculture and forest are representative land uses. The MCA-GIS analysis concluded that the most suitable areas for siting the biomass plant are located near residential zones. The sensitivity analysis provided insight into the most influent factors on the model for aiding energy planning decisions, such as physiography, crop types, vegetation, potential demand and transport cost.

Shi et al., (2008) presented a case study of using remote sensing and geographical information systems (GIS) to evaluate the feasibility of setting up new biomass power plants and optimizing the locations of plants in Guangdong, China. In their study, the biologically available biomass was estimated from MODIS/Terra remote sensing data. The amount of biomass that is usable for energy production was then derived using a model incorporating factors including vegetation type, ecological retaining, economical competition, and harvest cost. GIS was employed to define the supply area of each candidate site based on transportation distance along roads. The amount of usable biomass within the supply area was calculated and optimal sites were identified accordingly.

Tavares et al., (2011) used spatial multi-criteria evaluation methodology to assess land suitability for a plant siting and applied it to Santiago Island of Cape Verde. They combined the analytical hierarchy process (AHP) to estimate the selected evaluation criteria weights with Geographic Information Systems (GIS) for spatial data analysis. An innovative feature of the method lies in incorporating the environmental impact assessment of the plant operation as a criterion in the decision-making process itself rather than as an a posteriori assessment. A two-scale approach was considered. At a global, scale an initial screening identified inter-municipal zones satisfying the decisive requirements (socio-economic, technical and environmental issues, with weights respectively, of 48%, 41% and 11%). A detailed suitability ranking inside the previously identified zones is then performed at a local scale in two phases and includes environmental assessment of the plant operation. Those zones were ranked by combining the non-environmental feasibility of Phase 1 (with a weight of 75%) with the environmental assessment of the plant operation impact of Phase 2 (with a weight of 25%). The reliability and robustness of the presented methodology as a decision supporting tool was assessed through a sensitivity analysis.

2.9 Suitability Analysis Methodology

There have been many analytical methods since suitability analysis came into being, which primarily Include the method of sieve mapping, landscape unit method, grey tone method (map overlay) and Computer method (GIS). Here the emphasis will be on the GIS method, which can also be divided into three classes: direct overlay, weighted score, and ecological factors combination (Manlun, 2003).

2.9.1 Direct Overlay

The method of direct overlay includes map overlay and equal-weight summation. Map overlay can be traced back to the beginning of 20th century. This method can be successfully applied in land use suitability, which enables urban planning efficiently and comprehensively to allow for the social and environmental factors. The main steps of map overlay can be concluded as: (1) Defining the planning purpose and identifying the factors contributing to the planning. (2) Investigating each factor's situation and distribution (forming ecological purpose), making a classification according to the suitability for some specific land uses, and using some gradual colours to identify each factor's suitability class in a single factor map. (3) Overlaying two or more single factor maps to get a composite map. (4) Analyzing the composite map and finally making the land use planning. In the planning of Staten Island, McHarg and his colleagues applied this method to analyse land use suitability of natural conservation, passive recreation, active recreation, housing development, commerce development and industry development, etc, which has made a great effect. Map overlay is a kind of visual and intuitionistic method. It can integrate environmental factors with social-economic factors to make the suitability analysis. The disadvantage of this method is that it is essentially a kind of equal-weight additive method. Actually each factor's function is different and sometimes the same factor may be considered repeatedly. Another disadvantage is that while the factors increase, it is rather complicated to use the gradual colors to represent different suitability classes and to make the overlay (Manlun, 2003).

The method of equal-weight summation is first to quantify the factor's class, then to make a direct addition and finally to get a composite evaluation value. The formula of equal-weight summation is presented below (the premise of such direct overlay method is that each factor's influence on the specific land use is similar and independent):

$$Vij = \sum_{k=1}^{n} B_{kij} \quad (2.1)$$

Equal weight summation

Where, *i* represents the parcel number or gird number; *j* represents the land use number; *k* represents the number of the ecological factor influencing the *jth* land use; *n* represents the total of the ecological factors; B_{kij} represents the suitability evaluation value of the *kth* ecological factor in the *ith* parcel of the *jth* land use (single factor evaluation value); *Vij* represents the composite evaluation value in the *ith* parcel of the *jth* land use (composite ecological suitability of the *jth* landuse).

2.9.2 Weighted Score

When all kinds of ecological factors' influences on the specific land use are very obvious, it can not make a direct overlay to get the composite suitability. It must take advantage of the method of weighted score. The principle of this method is similar to that of the equal-weight summation. The difference is that it needs to identify each factor's relative importance (weight) in the weighted score. The more influence on the specific land use, the higher weight for the factor. On the basis of scoring each single factor class, it will carry out the weighted summation for the evaluation result of each single factor. Finally the total scores of the corresponding parcels or grids of the specific land use are gotten. Generally a higher score represents the more suitability. The formula of weighted score is showed as follows. Where, W_k is the weight of the *kth* factor for the *jth* land use. Other symbols are the same as the above method of equal-weight summation.

$$V_{ij} = \sum_{k=1}^{n} B_{kij} W_k \quad (2.2)$$

Weighted Score

The method of weighted score overcomes those disadvantages in the method of equal-weight summation. Another important advantage of this method is able to make a girding, classification and quantification in the map, which is suitable for the computer application. This is why this method is so widely applied in the past few years.

2.9.3 Ecological Factors Combination

As mentioned above, direct overlay and weighted score require that each factor should be independent. Actually many factors depend on each other. For example, it is unsuitable to construct an expressway when the slope is over '30%', no matter how the drainage condition is. But according to the weighted score or direct overlay, when the slope is over '30%' and the drainage condition is very good, perhaps it will get the moderate suitability. The method of ecological factors combination acknowledges that different combinations of the dependent factors determine the suitability of the specific land use.

This method can be classified into hierarchical combination and non-hierarchical combination. The method of hierarchical combination involves first to use a set of dependent factors to identify the suitability level, then to regard these dependent factors as new factors and to combine them with other dependent factors to identify the final suitability level. The method of non-hierarchical combination is to combine all the dependent factors to identify the suitability level at the same time. Obviously, this method is suitable for the analysis with a few factors. And it is useful to apply the hierarchical combination in the analysis with large number of factors. Whether the method of hierarchical combination or nonhierarchical combination, first it is necessary for experts to establish a set of complicate and integrated dependent factors and an evaluation standard. This is the most critical and difficult step in applying the method of ecological factors combination in the suitability analysis.

2.10 GIS-base Multi-criteria Decision Analysis (MCDA)

Multi-criteria Decision Analysis (MCDA) has the advantage of blending expert opinion with factual information. This technique evaluates varied criteria, all possible outcome and conflicting objectives that arises from the analysis (Guillermo et al., 1999).

Spatial Multi-Criteria Decision Making (MCDM) is a process that combines and transforms geographical data into a decision (Malczewski, 1999). MCDM, combined with GIS data, is a powerful approach to systematically and comprehensively analyze a problem. The main purpose of the multi-criteria evaluation techniques is to investigate a number of alternatives in the light of multiple criteria and conflicting criteia. GIS-base MCDA is an intelligent system that utilizes and converts spatial and non spatial data into valuable information which in addition to the judgment of the decision maker can be used to make critical decision Approaches to MCDA, which include Analytic Hierarchical Process (AHP), Analytic Network Process, WLC or Simple Additive Method and Fuzzy Logic.

2.10.1 Analytic Hierarchy Process (AHP) and Pair-wise Comparisons

One of the important tasks in the suitability analysis is the integration of different preference criteria by providing weightage factors to the criteria. One approach of incorporating weightage factor in the preference criteria is by employing the Analytic Hierarchy Process (AHP) introduced by Saaty in 1970s (Saaty, 1977). The Analytic Hierarchy Process (AHP) is one of the most used MCDA model, it approaches decision making by arranging the important components of a problem into a hierarchical structure similar to a family tree. In the context of Criteria & Indicator assessment, the AHP method is a useful decision-making tool because it is a good fit with the existing hierarchy of Principles, Criteria, Indicators and Verifiers (Guillermo et al., 1999). The AHP method reduces complex decisions into a series of simple comparisons, called Pairwise Comparisons, between elements of the decision hierarchy. By synthesising the results of these comparisons, AHP helps in arrival at the best decision and provide a clear rationale for the choice made. AHP is a widely used method in MCDM and was introduced by Saaty (Saaty, 2008; Saaty & Vargas, 1991). It is easily implemented as one of the MCDM techniques. AHP is a decision support tool, which can be used to solve complex decision problems. It uses a multilevel hierarchical structure of objectives, criteria, sub criteria and alternatives. AHP is based on three principles: decomposition of the overall goal (suitability), comparative judgment of the criteria, and synthesis of the priorities (Arabinda, 2003; Baniya, 2008). AHP uses a fundamental scale of absolute numbers to express individual preferences or judgment. This scale consists of nine points. In general, nine objects are the most which an individual can simultaneously compare and consistently rank. The score of differential scoring presumes that the row criterion is of equal or greater importance than the column criterion. The reciprocal values (1/3, 1/5, 1/7, 1/9) have been used where the row criterion is less important than the column criterion. This is shown in Figure 2.9:

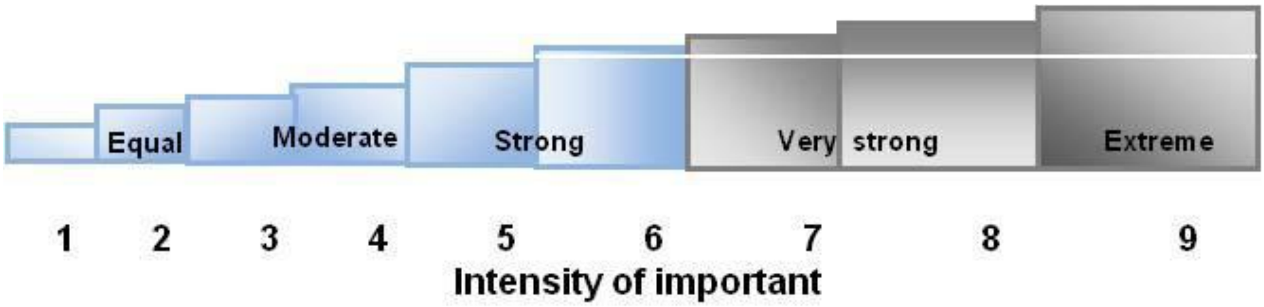

Figure 2.9: Preference scale for pair wise comparison in AHP

Aydin (2009) noted that one of the widely used decision rules is Analytic Hierarchy Process AHP which can be used in two different ways in GIS environment. In the first approach, weights are assigned to each attribute map layer, and then weights are aggregated by using weighted additive combination methods. This method is more practical if large numbers of alternatives are involved. In the second approach, the AHP principle is used to aggregate the priority for all level of hierarchy structure including the level of representing alternatives. In this case, small number of alternatives is needed (Jankowski and Ewart, 1996)

2.10.2 Analytic Hierarchy Process (AHP) Application

Ma et al. (2005) develop an AHP method to model site selection for the production of methane gas from an anaerobic digester of dairy manure. They complement their framework with spatial and non-spatial data and apply it to Tompkins County, New York.

Yahaya et al., 2010 study was aimed at identifying a suitable landfill site for waste disposal in Ibadan North Local Government Area of Ibadan, Nigeria. Geographical Information System (GIS) and Multi-criteria Evaluation (MCE) were applied in order to display and rank candidate sites. The analysis was limited to criteria that were selected and relevant to the area under investigation. The results obtained provide clear areas for landfill sites in the study area and finally arrives at suitable areas. At the end of the analysis, two candidate sites were selected and one was chosen as the best site using super decision software from the AHP component.

In Turkey, solar energy investments have been developed rapidly in recent years. Site selection for solar farms is a critical issue for large investments because of quality of terrain, local weathering factors, proximity to high transmission capacity lines, agricultural facilities and environmental conservation issues. Uyan (2013) used Multi criteria evaluation methods in GIS and AHP in the study area to determine suitable site selection for solar farms.

2.11 Location Modelling

The term Location Analysis refers to the modelling, formulation, and solution of a class of problems that can best be described as siting facilities in some given space (ReVelle and Eiselt 2004). Weber's Least Cost Theory suggests that an industry should be located where it can minimize its costs and therefore maximize its profits (Weber 1929). These costs can be categorized as transportation, labor and agglomeration with transportation being the most important. The facility location problem is common in the realm of GIS, and scientists have been developing and improving location science methods for decades. McHarg, in the late 1960s, proposed the approach of overlaying a series of colored thematic maps, each representing land-based geographic features. These clear acetate sheets were colored from light to dark representing less suitable to more suitable areas in regards to a particular theme. When the sheets were superimposed on top of each other, the composite map revealed darker areas that were more suitable for a particular route or location for a specific function. This basic mapping idea is utilized in GIS today and at the very least it serves as a way to screen out infeasible or undesirable sites. Modern suitability analysis, using a raster data model, allows for the reclassification of the features on each layer to a common suitability scale, and weights can be applied to give preference to particular layers. The composite output map can be adjusted to show, for example, only the top 15 percent or top 1 percent of the areas that are found to be most suitable (Church, 2002).

2.11.1 Classification of Traditional Facility Location Models

Facility location models can be classified according to their objectives, constraints, solutions, and other attributes. Different classifications of facility location models for distribution systems have been proposed in the literature, for example Klose and Drexl, (2004) provided in what follows an extend discussion of the most common criteria that are used to classify the traditional facility location models.

i. **Topological characteristics**. Topological characteristics of the facility and demand sites lead to different location models including continuous location models, discrete network models or mixed-integer programming models, hub connection models, etc. In each of these models, facilities can only be placed at the sites where it is allowed by topographic conditions while distances are calculated using some metric.

ii. **Objectives:** The objective is an important criterion to classify the location models. Covering models aim to minimize the facility quantity while providing coverage to all demand nodes or maximize the coverage provided the facility quantity is pre-specified. *P*-center models have an objective to minimize the maximum distance (or travel time) between the demand nodes and the facilities (Church et al., 1992). They are often used to optimize the locations of facilities in the public sector such as hospitals, post-offices and fire stations. *P*-median models attempt to minimize the sum of distance (or average distance) between the demand nodes and their nearest facilities. Companies in the private sector often use *P*-median models to make facility distribution plans so as to improve their competitive edge.

iii. **Solution methods**: Different solution methods result in different location models such as optimization models and descriptive models. Optimization models use mathematical approaches such as linear programming or integer programming to seek alternative solutions which trade off the most important objectives against one another. Descriptive models, in contrast, use simulation or other approaches to achieve successively enhanced location pattern until a solution with desired degree is achieved. Combined solution methods have also been developed by extending the descriptive models with optimization techniques to address dynamic and interactive location problems (e.g. mobile servers).

iv. **Features of facilities:** Features of facilities also divide location models into different kinds. For instance, facility restrictions can lead to models with or without service capacity; and facility dependencies can result in models that take into account the facility cooperation or neglect it.

v. **Demand patterns**: Location models can also be classified based on the demand patterns. If a model has elastic demand, then the demand in an area will vary (either increase or decrease) with different facility location decisions; while a model with inelastic demand will not vary the demand pattern due to the facility location decisions.

vi. **Supply chain type**: Location models can be further divided by the type of supply chain considered (i.e. single-stage model vs. multi-stage model). Single-stage models focus on service distribution systems with only one stage, whereas multi-stage models consider the flow of service through several hierarchical levels.

vii. **Time Horizon:** Time horizon categorizes location models into static models and dynamic models. Static models optimize the system performance deciding all variables simultaneously for one representative period. In contrast, dynamic models (cost, demand, capacities, etc.) consider different time periods with data variation across these periods, and give solutions for each time period adapting to the different conditions.

viii. **Input parameters:** Another popular way to classify the location models is based on the features of the input parameters to the problems. In deterministic models, the parameters are forecast with specific values and thus the problems are simplified for easy and quick solutions. However, for most real-world problems, the input parameters are unknown and stochastic/probabilistic in nature. Stochastic/probabilistic location models capture the complexity inherent in real-world problems through probability distributions of random variables or considering a set of possible future scenarios for the uncertain parameters.

Location models can also be distinguished based on other attributes such as single- vs. multi-product models, or pull vs. push models.

2.11.2 The Space of Location Decisions

Location scientists often use the space in which facilities are located to distinguish between classes of location problems. Distances in are most often derived from Minkowski distances, which are defined as a family of distances with a single parameter p. In particular, the lp distance between a point (a_i, b_i) and a point (a_j, b_j) with $i \neq j$ is defined as:

$$d^p_{ij} \neq \{[a_i - a_j]^p + [b_i - b_j]^p\}^{1/p} \quad (2..3)$$

A large part of the literature focuses on three special cases: for p=1, we obtain the rectilinear (or rectangular or Manhattan or l_1) distance $d_{ij} = [a_i - a_j]^p + [b_i - b_j]$, the Euclidean (or straight line or l_2) metric with

$$d^2_{ij} = \sqrt{[a_i - a_j]^2 + [b_i - b_j]^2}, \tag{2.4}$$

and the Chebyshev (or ''max'', or '1∞) metric with

$$d^{\infty}_{ij} = \max \{[a_i - a_j]; [b_i - b_j]. \tag{2.5}$$

2.11.3 Facility Location Models

The shape or topography of the set of potential plants yields models in the plane, network location models, and discrete location or mixed-integer programming models, respectively. For each of the subclasses distances are calculated using some metric.

2.11.3.1 Continuous location models

They are characterized by a continuous solution space which states, that each point in the space represents a feasible location. Further, the measurement of distances is carried out by a suitable metric (mainly by l_p-standards). Continuous location models (models in the plane) are characterized through two essential attributes: (a) the solution space is continuous, that is, it is feasible to locate facilities on every point in the plane. (b) Distance is measured with a suitable metric. Typically, the Manhattan or right-angle distance metric, the Euclidean or straight-line distance metric, or the l_p-distance metric is employed. Continuous location models require to calculate coordinates (x, y) Є $R^p \times R^p$ for P facilities. The objective is to minimize the sum of distances between the facilities and *m* given demand points. The subject of the Weber problem is to determine the coordinates (x, y) Є $R^p \times R^p$ of a single facility such that the sum of the (weighted) distances $w_k d_k(x, y)$ to given demand points k Є K located in (a_k ; b_k) is minimized. The corresponding optimization is given below:

$$SWP = \min(x, y) \sum_{j=1}^{p} (w_k\, d_k(x_j, y_j)) \tag{2.6}$$

Where $d_k(x_j, y_j) = \sqrt{[x - a_k]^2 + [x - b_k]^2}$

This Simple Weber Problem has a century-long tradition for the case of $|K|$=3 demand points.

An extended version of the above SWP that requires to locate p, 1 < p < $|K|$ facilities and to allocate demand to the chosen facilities denoted as Multi-source Weber Problem (MWP), is NP-hard. It can be modelled as the non-linear mixed-integer program

$$MWP = min \sum_{k \mathcal{E} K} \sum_{j=1}^{p} (w_k\, d_k(x_j, y_j)) z_{kj} \quad (2.7a)$$

$$\text{S.t } \sum_{j=1}^{p} z_{kj} = 1 \qquad \forall k \; \mathcal{E}\; K, \quad (2.7b)$$

$$z_{kj} \;\mathcal{E}\; \text{B}, \; \forall k \;\mathcal{E}\; K, j = 1, \ldots, p, \quad (2.7c)$$

$$x, y \;\mathcal{E} \mathbb{R}^p \quad (2.7d)$$

Where B = {0,1} and z_{kj} equals 1 if demand point k is assigned to facility j. Exact solution procedures reformulate the model as a set partitioning problem, the LP-relaxation of which can be solved by column generation.

2.11.3.2 Discrete or network location models

In network location models distances are computed as shortest paths in a graph. Nodes represent demand points and potential facility sites correspond to a subset of the nodes and to points on arcs.

The network location model corresponding to the continuous multi-source Weber model is called P-median problem. In the P-median problem p facilities have to be located on a graph such that the sum of distances between the nodes of the graph and the facility located nearest is minimized.

i. ***P*-Median Model:** Another important way to measure the effectiveness of facility location is by evaluating the average (total) distance between the demand points and the facilities. When the average (total) distance decreases, the accessibility and effectiveness of the facilities increases. The *p*-median location model involves the location of a fixed number p of facilities. The objective is to locate the p facilities in such a manner that the total weighted distance of serving all demand is minimised. Weighted distance for a demand point represents the amount of demand multiplied by the distance to the closest facility. For example, if demand is measured in terms of the number of trips that need to be made by users of the facility, then weighted distance represents the total mileage involved in going to the facility. For a fixed level of demand, minimising total weighted distance is equivalent to minimising average distance. This model form can address many different types of application, from locating schools and health clinics to locating road maintenance garages and emergency response vehicles. Because this model captures the essence of locating a set of facilities to serve an area by maximising accessibility, it has become a popular model for application (Church, 2002). In the p-median problem p facilities have to be located on a graph such that the sum of distances between the nodes of the graph and the facility located nearest is minimized. Let K denote the set of nodes, J ⊆ K the set of potential facilities, $w_k d_{kj}$ the weighted distance between nodes k and j, y_j a binary decision variable being equal to 1 if node j is chosen as a facility (0, otherwise), and x_{kj} a binary decision variable reflecting the assignment of demand node k Ɛ K to the potential facility site j. Then

$$PMP = min \sum \sum_{j=J}^{p} (w_k \, d_k) z_{kj} \qquad (2.8a)$$

S.t

$$\sum_{j=1}^{p} z_{kj} = 1 \qquad \forall k \, \mathcal{E} \, K, \qquad (2.8b)$$

$z_{kj} - y_j \leq \forall k \in K, j \in J$ (2.8c)

$\sum_{j=J}^{p} y_j = p$ (2.8d)

$z_{kj}, y_j \in \mathrm{B}, \forall k \in K, \forall j \in J,$ (2.8e)

formally describes the p-median problem. Constraints (2.8b) guarantee that demand is satisfied, inequalities (2.8c) couple the location and the assignment decision, and constraint (2.8d) fixes the number of selected facilities to p.

ii. ***P*-Center Model** In contrast to the *P*-median models which concentrate on optimizing the overall (or average) performance of the system, the *P*-center model attempts to minimize the worst performance of the system and thus addresses situations in which service inequity is more important than average system performance. In location literature, the *P*-center model is also referred to as the minimax model since it minimizes the maximum distance between any demand point and its nearest facility. The *P*-center model considers a demand point is served by its nearest facility and therefore full coverage to all demand points is always achieved. The problem asks for the center of a circle that has the smallest radius to cover all desired destinations. In the last several decades, the *P*-center model and its extensions have been investigated and applied in the context of locating facilities such as EMS centers, hospitals, fire station, and other public facilities. However, unlike the full coverage in the set covering models, which may lead to excessive number of facilities, the full coverage in the *P*-center model requires only a limited number (*P*) of facilities. The aim of p-center problem is to locate p facilities such that the maximum distance is minimized. Unfortunately, for the p-center problem we cannot restrict the set of potential facility sites to the set of nodes because the maximum of concave distance functions is no concave function any more. Fortunately, it suffices to consider a finite set of points on the arcs. These points can be determined as intersection points q for which the weighted distance $w_i d_{iq}$ between q and node i Ɛ K equals the weighted distance $w_k d_{iq}$ between q and another node k Ɛ K. Let J denote the set of intersection points. Then the discrete optimization model

$$PCP = \min r \qquad (2.9a)$$

S.t

$$r - \sum_{j=J}^{p} (w_k\, d_k) z_{kj} \ \geq 0 \ \forall k \ \mathcal{E}\ K \qquad (2.9b)$$

$$\sum_{j=1}^{p} z_{kj} \ = 1 \qquad \forall k \ \mathcal{E}\ K, \qquad (2.9c)$$

$$z_{kj} - y_j \leq 0 \quad \forall k \ \mathcal{E}\ K, j \ \mathcal{E}\ J \quad , \qquad (2.9d)$$

$$\sum_{j=J}^{p} y_j \ = p \qquad (2.9e)$$

$$z_{kj}\, , y_j\, \mathcal{E}\ \mathrm{B},\ \forall k \ \mathcal{E}\ K, \forall j \ \mathcal{E}\ J, \qquad 2.9f)$$

Formally describes the p-center problem which can be transformed into a sequence of covering problems.

iii. **The covering model:** The objective of covering models is to provide “coverage” to demand points. A demand point is considered as covered only if a facility is available to service the demand point within a distance limit. Then the covering model

$$SCP = \min \sum_{j=J}^{p} y_j \qquad (2.10a)$$

$$\text{s.t} \sum_{j\,\mathcal{E} J}^{p} a_{kj}\, y_j \ \geq 1 \qquad \forall k \ \mathcal{E}\ K, \qquad (2.10b)$$

$$y_j\, \mathcal{E}\ \mathrm{B}, \ \ \forall k \ \mathcal{E}\ K \qquad (2.10c)$$

With $a_{kj} = 1$ for $w_k d_{kj}$ < r and $a_{kj} = 0$ for $w_k d_{kj} \geq$ r computes a set of at most p-centers with a radius smaller than r or shows that no such set exists.

The literature on covering problems is divided into two major parts: the location set covering problem (LSCP) and the maximal covering location problem (MCLP). LSCP is an earlier version facility location problem and it aims at locating the least number of facilities that are required to cover all demand points. Since all the demand points need to be covered in LSCP, regardless of their population, remoteness, and demand quantity, the resources required for facilities could be excessive. Recognizing this problem, the MCLP model that does not require full coverage to all demand points was developed. Instead, the model seeks the maximal coverage with a given number of facilities. The MCLP, and different variants of it, have been extensively used to solve various emergency service location problems.

2.11.3.3 Mixed-integer programming models

Starting with a given set of potential facility sites many location problems can be modelled as mixed integer programming models. Apparently, network location models differ only gradually from mixed integer programming models because the former ones can be stated as discrete optimization models. Yet network location models explicitly take the structure of the set of potential facilities and the distance metric into account while mixed-integer programming models just use input parameters without asking where they come from. A rough classification of discrete facility location models can be given as follows: (a) single- vs. Multistage models, (b) uncapacitated vs. capacitated models, (c) multiple- vs. single-sourcing, (d) single- vs. multi-product models, (e) static vs. dynamic models, and, last but not least, (f) models without and with routing options included.

2.12 Identified Gaps in the Literature

Many approaches have been employed in site suitability analysis and location modeling. Most of these approaches heavily rely on mathematics and optimization techniques. Since, site selection is a spatial problem, mathematics and optimization techniques are often inadequate to offer acceptable solution because of their failure to incorporate all relevant aspects of the problem in the overall framework. An alternative framework that is capable of resolving site selection is Geographical Information Systems. After a comprehensive study of the existing literatures, a number of gaps have been observed in literatures. The gaps in the literatures are further detailed below:

i. The optimal locations for bio-refineries depend on a number of other issues that are difficult to quantify and model mathematically (Xie, 2009), some of the researchers determined their best locations as pure mathematical problem (Xiao-Hua, et al., 2014; Florese et al., 2008), this is inadequate, since location problem is a spatial problem. It can be best solved using spatially added tools or programs. Hence this work will integrate GIS with mathematical location models in obtaining the optimal location.

ii. Literature review reveals that few research works carried out on suitability analysis of bio-energy plant omitted the economic aspect of their determined optimal location on the suppliers. Few works that researched on economic viability of the centralized biogas plant, did not consider that of location analysis. Since profitability is the major drive in many ventures, economic availability study which is lacking in previous literatures will be incorporated in the location analysis, hence an integrated approach which is necessary will be the core of this study.

iii. One of the important tasks in the suitability analysis is the integration of different preference criteria by providing weightage factors to the criteria, this area has not been fully explored by many literatures in this field. Few that explored MCA were based on their local preference, since preference criteria are usually localized, this study will appropriate the preference criteria on the conditions of the study area.

iv. The available information in the current literature on combining socio-environmental suitability and economic optimality in local geospatial scale is not adequate. There is a requirement for further research on optimal size and location of biomass-based facilities considering socio-economic factors, hence this study.

v. In addition, majority of work on site suitability analysis available in literatures concluded their research by providing the suitability index of the area under study; this is inadequate, since the most suitable area could be in thousands of kilometers square. There is need to optimize these suitable areas by appropriate location models to obtain specific locations. This work will therefore integrate suitability analysis with location modeling.

Presently there are no scientific works to the best of the author's knowledge available online in Africa as a case study on optimal location of biogas technology plant. Considering the immense need for renewable energy source for Nigeria; the population density of Anambra state which is the second to highest in the country; the necessity to integrate sensitive projects like CBP in urban planning; the climax condition of environmental deterioration and population explosion of the study area. Strategic positioning and integration of environmental variables well suited for the study area will definitely enhance the standard of living in the study area.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

The need for effective management of land in the State to meet competing use cannot be over emphasize considering the fact that the study area is the second most populated dense state in Nigeria. Also most of the urban cities in the state are facing problems of agricultural waste collection, treatment, and utilization due to increasing population and rapid urbanization. Some developed countries have concentration of livestock farms and production; hence collection of agricultural wastes, treatment and utilization is greatly enhanced. The biggest barriers in utilizing agricultural waste in Anambra state is perhaps the dispersion of livestock farms and other agricultural waste generating centres across the state which comprises of many relatively small scale farms that are not capable of having economically viable biogas production. Therefore regional analysis of agricultural wastes resources across the study area with cost assessment of developing centralized biogas power plants considering transport distances, transport costs and size of the power plants is a worthwhile research venture. Since siting of a suitable biogas plant is a geospatial problem, the need for state of art softwares in spatial analysis in evitable; ArcGIS software which is a leading software globally was used in this research. Location modelling which a branch of operation research was strategically integrated with the site suitability model results obtained from GIS analyses and operations for improved decision on the location(s) operations and determination.

3.2 Research Methodology

The research methodology is outlined below:

3.2.1 Data Collection and Sources

The first stage of this study focuses on site suitability analysis of Anambra State of Nigeria using GIS and AHP techniques for biogas siting. Data collections included field surveys, primary and secondary data collection from various organizations and individuals (Figure 3.1). The primary data from the field survey was collected through visit to Agricultural livestock farms and slaughter houses in the study area, to determine the biomass potentials of the various farms and abatoirs. Interviews, onsite observations and structured questionnaires were also used. In addition, a Global Positioning System (GPS) receiver was used in the field survey for the ground truthing to determine the geographical co-ordinate of the farms and abattoir houses for geo-coding in the data analysis. Additional data were also collected from relevant government establishments. Data were collected also from Ministry of Land and Survey, Awka, which include boundary map and administrative land use map. Majority of the demographic and socio-economic figures were based on the population census of 2006 from the National Population Commission. In addition, national and international institutions were contacted for GIS datasets. The GIS-based thematic maps used for the production of the suitability map include political boundary map layer, road network layer, LULC layer, DEM layer, river layer, slope layer, reserved areas layer and biomass potential density layer. The flowchart of the methodology is shown in Figure 3.1.

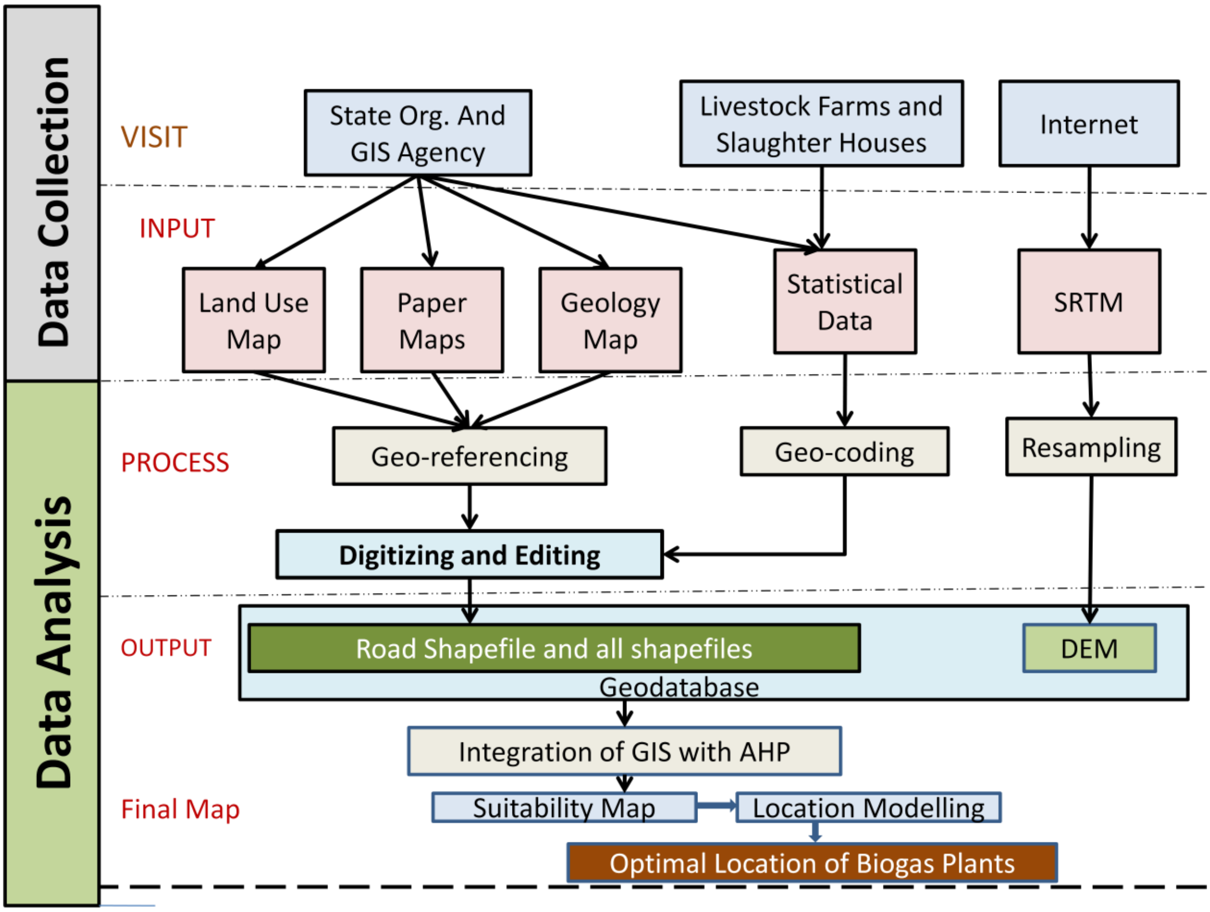

Figure 3.1: Flowchart of Methodology

3.2.2 Data Types and Format

Data collection was the main task and it typically consumes the majority of the available resources. Data collection still remains a time consuming, tedious and expensive process. The data types, format, scale and probable source is shown in Table 3.1:

Table 3.1: Data types and format

List of data	Format/Map scale	Source
Land use map	Landsat-7 ETM + imagery	National Remote Sensing Centre, Jos.
Stream Network	Arcinfo shapefile/digitalized from 1:50,000 scale map	Survey depament, Ministry of Lands, Survey and Town Planning, Awka
Farm Location Maps	Arcinfo shapefile	Field trip, Use of GPS and Department of Veterinary Servics, Ministry of Agric. & Rural Devpt. Awka, Anambra State
Slaughter House Location maps.	Arcinfo shapefile	Field trip, Use of GPS and Department of Veterinary Servics, Ministry of Agric. & Rural Devpt. Awka, Anambra State
DEM	SRTM imagery at 90m resolution of 2000	(http://www.landcover.org)
Road Network	Arcinfo shapefile/digitalized from 1:50,000 scale map	Survey Depament, Ministry of Lands, Survey and Town Planning, Awka
Population Data 2007	Census figure	National Population Commission

Landsat-7 ETM+ image of 2000 with spatial resolution of 30m was acquired. GPS was used to acquire ground control points for geo-referencing and ground truth sampling for the livestock farms and slaughter houses.

3.2.3 Data Processing and Data Analysis

The study was undertaken with pre-processed and corrected Landsat-7 ETM+ image and was geographically registered before being used for the analysis. The data imagery was analyzed at the National Centre for Remote Sensing, Jos, Nigeria. A sub-map of the image was done for the study area, from which a composite image was generated from the Landsat-7 ETM+ image and then classified to extract the different land uses of the study area using maximum likelihood classification algorithm which is a supervised classification algorithm provided by ARCGIS 10 software. Image classification refers to the task of extracting information classes from a multiband raster image. The resulting raster from image classification can be used to create thematic maps. Supervised classification was used in image classification in this study. The Image Classification toolbar in ArcGIS was used in classification of a multiband raster. With the assistance of the Image Classification toolbar, training samples were created to represent the classes to be extracted. A signature file from the training samples was created, which is then used by the Spatial Analyst Multivariate Classification Tools to classify the image. To create training samples, polygons tool was selected from the list of drawing tools on the Image Classification toolbar. Areas that belong to a known class were identified and enclosed with the polygon tool. The new class created in Training Sample Manager with a default name, value, and colors were changed to the desired class name, value, and color. The above procedures were repeated to create a few more training samples to represent the rest of the classes on the image. When the sample training dataset was ready, a signature file required when using the geo-processing tool "Maximum Likelihood Classification" to classify an image was created and Maximum Likelihood Classification tool selected. The result was Landuse and landcover map of Anambra state shown in Figure 4.26.

The thematic maps were prepared and edited, overlaid and visualized on the basis of the suitability analysis for CBP using ArcGIS 10 software of ESRI. The application of GIS for overlaying thematic layers to establish land databases requires that all the layer maps need to be converted into a common coordinate system. This involved a stepwise arrangement and organisation of acquired data in a manner that will be appropriate for analysis. Major GIS spatial operations that were performed to achieve the set of objective for this project were buffering, overlay, query etc.

3.2.4 Softwares for Data Management

ArcGIS 10 software was used to perform the majority of the GIS operations eg buffering, overlay, query, polygon to raster conversion and raster to polygon conversion, digitalizing, georeferencing etc, it was also used to analyze all the factors represented by GIS thematic layers and to produce the biogas plant suitability map. ArcGIS 10 software was used to sub-map and form composite image from Landsat TM image and then classified to extract the different land uses of the study area. ArcGIS software was used for MCA (weighting, rating) based on the AHP method. Lat Long converter software was used for conversion of the geographical co-ordinate points from Decimal Minutes Seconds obtained from the GPS device to Decimal Degrees to aid further calculations; Lat Long converter software was used in computation of origin destination cost matrix used in the location and allocation modelling. Microsoft Excel solver was used in solving the set covering and location and allocation model. Microsoft Excel was used for spreadsheet calculations, while Microsoft Word was used for the write up of this thesis setting.

3.3 GIS Mapping of Biogas Production Potential

To identify areas with high biogas potential which will eventually represent suitable areas for bio-energy siting considering transportation cost and raw material availability. The biogas production potential was analyzed using livestock waste generation capacity of the study area.

3.3.1 Livestock Waste Generation Capacity

Manure quantity and characteristics are influenced by the species, age, diet and health of the birds and by farm management practices. Estimates of the manure excreted by 1000 birds per day (based on average daily live weights during the birds' production cycle) are approximately 120 kg for layer chickens, 80 kg for meat chickens, 200 to 350 kg for turkeys (grower females and grower heavy males, respectively), and 150 kg for ducks (Williams, et al., 1999). Extrapolations were calculated to give general estimates for the manure generated with the corresponding number of birds in various farm given operations. The details of the number of farms according to the number of Local Government in Anambra State is given in the Appendix. Out of twenty one local government areas in Anambra State, only Anambra West was exempted in the poultry statistics because of its swampy terrain, making it difficult for poultry production. There are about 2000 poultry farms in the state with about 1,844,557 total numbers of poultry in Anambra State (Anambra State Veterinary Department, 2015). The data of various livestock farms capacity of the various L.G.A of the state is shown in Appendix A.2 to Appendix A.21. The data was converted according to Williams, et al., (1999) to produce GIS-based dataset shown in Figure 4.13 and 4.14.

3.4 Spatial Statistics of Livestock Waste

Spatial statistics helps in measuring spatial processes, spatial distributions, and spatial relationships. With these statistics, the study was able to determine if the features are random, clustered, or evenly dispersed across the study area. Also spatial statistics helps in making decisions with higher level of confidence.

3.4.1 Spatial autocorrelation analyses

Moran's I is a commonly used indicator of spatial autocorrelation. In this study, global Moran's I (Moran 1950) was used as the first measure of spatial autocorrelation. Its values range from −1 to 1. The value "1" means perfect positive spatial autocorrelation (high values or low values cluster together), while "−1" suggests perfect negative spatial autocorrelation (a checkerboard pattern), and "0" implies perfect spatial randomness (Tu and, 2008).

Global Moran I: This is the first approach in spatial autocorrection, global calculations identifies the overall patterns or trends in the data. These types of statistics are very effective when there is a lot of complex messy data, and the interested is in understanding broad, overall trends. They work by comparing feature locations and/or attributes to a theoretical random distribution in order to determine statistically significant clustering or dispersion. The global Moral I is given by the mathematical model below (eq. 3.1):

$$I = \sum_{i}^{n}\sum_{j}^{n} W_{ij}\,(X_i - \dot{X})/(S^2 \sum_{i}^{n}\sum_{j}^{n} W_{ij}) \qquad 3.1$$

Where the numerator is the covariance term with i and j (two areal units), x is the data value in each unit, $\dot{X}$ the overall value of x, and W_{ij} is the proximity of location between point i and j. By calculating the product of the unit's differences from *x*, the extent to which they vary together is determined. The product is positive, if both x_i and x_j lie on the same side (above or below) of the mean. It is negative, if the sides they are positioned are different, and the value depends on the difference from the overall value to the unit's values. These covariance terms are multiplied with W_{ij} which switches each possible covariance on or off depending on

$$s^2 = \frac{1}{n}\sum_{i}^{n}(X_i - \dot{X})^2 \qquad 3.2$$

Local Moran I: The other type of statistics tools we have for analyzing patterns are categorized as Local Calculations. These calculations identify the extent and locations of clustering. They answer the question, where do we have spatial clustering? Local Moran's I index (Levine, 2004) can be expressed as:

$$(x+a)^n = \frac{z_i - \hat{z}}{o^2} \sum_{j=0, j \neq i}^{n} \left[W_{ij} \; (z_j - \hat{z}) \right] \qquad 3.3$$

Where $\hat{z}$ is the mean value of z with the sample number of n; z_j is the value of the variable at location i; z_j is the value at other locations (where $j \neq i$) o^2 is the variance of z; and W_{ij} is a distance weighting between z_i and z_j , which can be defined as the inverse of the distance. The weight W_{ij} can also be determined using a distance band: samples within a distance band are given the same weight, while those outside the distance band are given the weight of 0.

3.4.2 Hot Spot Spatial Statistic Analysis

One of the tools in the Mapping Clusters toolset is called the Hot Spot Analysis Getis Ord Gi* statistic, and it can be used to delineate clusters of features with values significantly higher or lower than the overall study areas mean or average value. This tool identifies clustering in both the high and the low attribute values. A standardized Z score is calculated for each feature. A high Z score results when a feature has a high value and it is surrounded by other features with high values. This is a hot spot. Similarly, a low Z score results when we have features with low values surrounded by other features with low values. This is a cold spot. Getis-ord local statistic is given as

$$G = \frac{\sum_{j=1}^{n} w_{ij} x_j - \dot{X} \sum_{j=1}^{n} w_{ij}}{s \sqrt{\frac{\left[n \sum_{j=1}^{n} w^2{}_{ij} - (\sum_{j=1}^{n} w_{ij})^2 \right]}{n-1}}} \qquad 3.4$$

$$\dot{X} = \frac{\sum_{j=1}^{n} x_j}{n} \qquad 3.5$$

$$s = \sqrt{\frac{\sum_{j=1}^{n} x^2{}_j}{n}} - (\dot{X})^2 \qquad 3.6$$

The result of the hot spot and cold spot analysis is shown in Figure 4.16.

3.5 Suitability Analysis Method

There have been many analytical methods since suitability analysis came into being. The three major ones using GIS are direct overlay, weighted score and ecological factors combination. The weighted score and hierarchical combination were used in the site suitability analysis for this study.

3.5.1 Weighted Linear Combination Method

In the data analysis, the suitable sites in terms of environmental and socio-economic factors were evaluated using Weight Linear Combination (WLC) methods. The main criteria and sub – criteria score ranking was assigned by experts in the field with related experience, using literatures. Site suitability was calculated using the ARC/INFO vector module and the following weighted linear combination:

$$S_i = \sum W_i X_i \qquad 3.7$$

Where Wi is the weighted score of the factor, Xi is the suitability rank of the factor, S is the suitability value for each factor and i is factor i.

The calculated suitability values were classified into areas of most suitable, highly suitable, moderately suitable, less suitable and non-suitable within the Arc info GIS software. Consequent selected suitable areas with values of most/highly suitable in terms of environment and socio-economic factors were used as sites for location modelling. This method can be processed using any GIS system having overlay capabilities that allow the evaluation criterion map layers to be aggregated to determine the composite map layer.

3.5.2 Analytical Hierarchy Process (AHP)

The analytical hierarchy process (AHP) method, developed by Saaty (1977), is a mathematical method for analyzing complex decisions with multiple criteria. The multicriteria decision uses hierarchical structures to represent a decision problem, and then develops priorities for the alternatives based on the decision maker's judgments throughout the system. There are four crucial steps to produce site suitability map for bio-energy plant and these are: (1) finding suitable factors to be used in the analysis, (2) assigning factor priority, weight and class weight (rating) to the parameters involved, (3) generating land suitability map of suitability analysis, and (4) determining potential areas for bio-energy plant. Figure 3.2 shows the environmental, social and economic factors considered in overlay analysis for the production of the final suitability map. For economic factors, road was given a weightage of 85% and electric transmission line 15% to produce economic suitability map. The Slope layer, Hillview layer and Elevation layers were overlay at 30%, 40% and 40% weight respectively using weighted Overlay tool to produce the LULC. The economic and spatial density maps were overlay at 50% weight to obtain the economic/ spatial density suitability map, similarly the land use suitability map and economic/spatial density suitability map were overlay at 50% weight to obtain the final suitability map

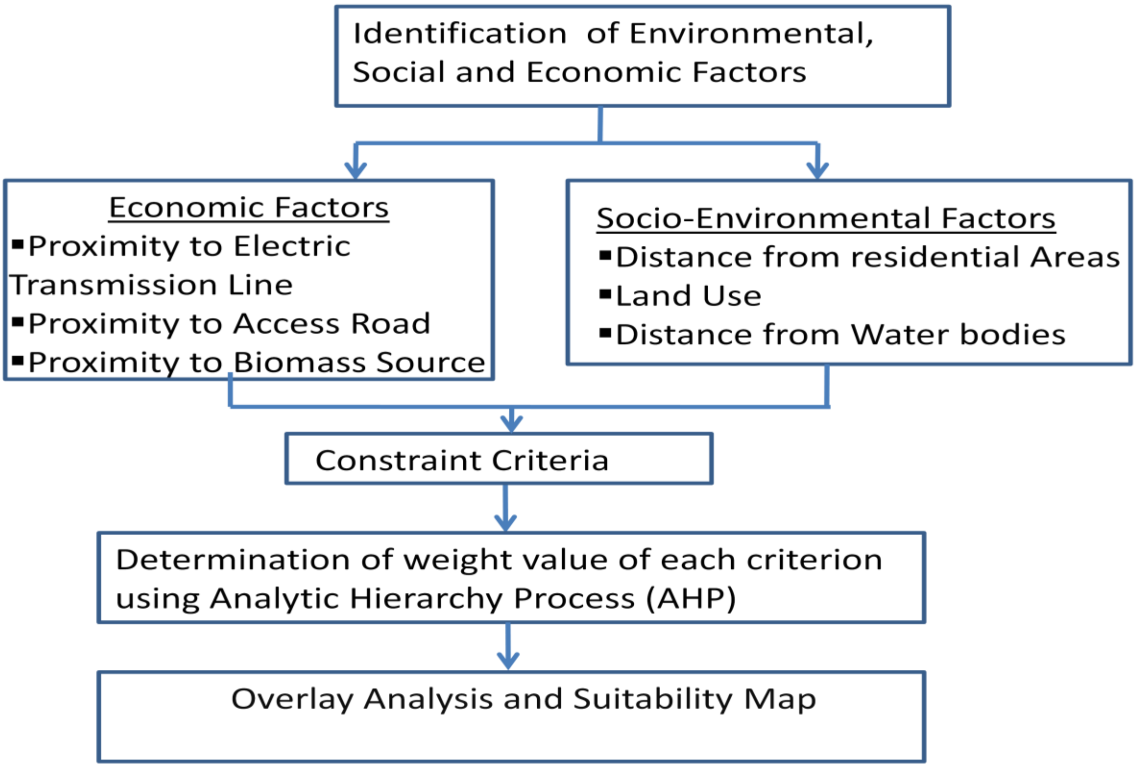

Figure 3.2: Schematic diagram for modeling suitable Bio-energy Plant sites using Hierarchical Model

3.6 Optimality of Location from the Site Suitability Analysis

From the suitability model obtained from the thematic layers and AHP analysis, the appropriate site among many sites was reduce to most and highly suitable site. The goal of location modeling is to optimize the available sites considering investment cost, which is one of the critical factors in siting of facility. The profitability analysis was used to select the best site from the three major regions that were classified as the best sites which are located in Onitsha, Njikoka and Dunukofia L.G.A of Anambra State.

3.6.1 Economic Analysis

Profitability analysis implies that at some point in the operations, total revenue is above total cost. Profitability analysis can be especially useful in location analysis when the costs of each location is known. The economic principle applied in this study is based on the theory that profit maximazation can be only be achieved by cost minization. This implies that access to road, biomass source, transmission line and other economic factors should be minimised to increase profitability. This study applies cost benefit analysis in comparing location alternatives on the basis of quantitative factors (ie transportation cost, quantity of manure available etc) that can be expressed in terms of total cost.

Basic steps in the profitability analysis:

1. Determination of the variable and fixed costs.
2. Plotting the total cost lines for all the alternatives on a single graph.
3. Identify the approximate ranges for sites with the lowest total cost.

The total cost for siting central biogas plant is divided into investment cost (fixed cost) and variable cost. Fixed cost comprises of land, property taxes, insurance, equipment, and building while the variable cost include labor, materials, transportation costs, and variable overhead.

3.6.2 Investment or Capital Cost

Capital costs for the construction of this type of AD plants was assumed to be a function of the plant nominal capacity, according to a moderate scale economy as shown in Figure 3.3

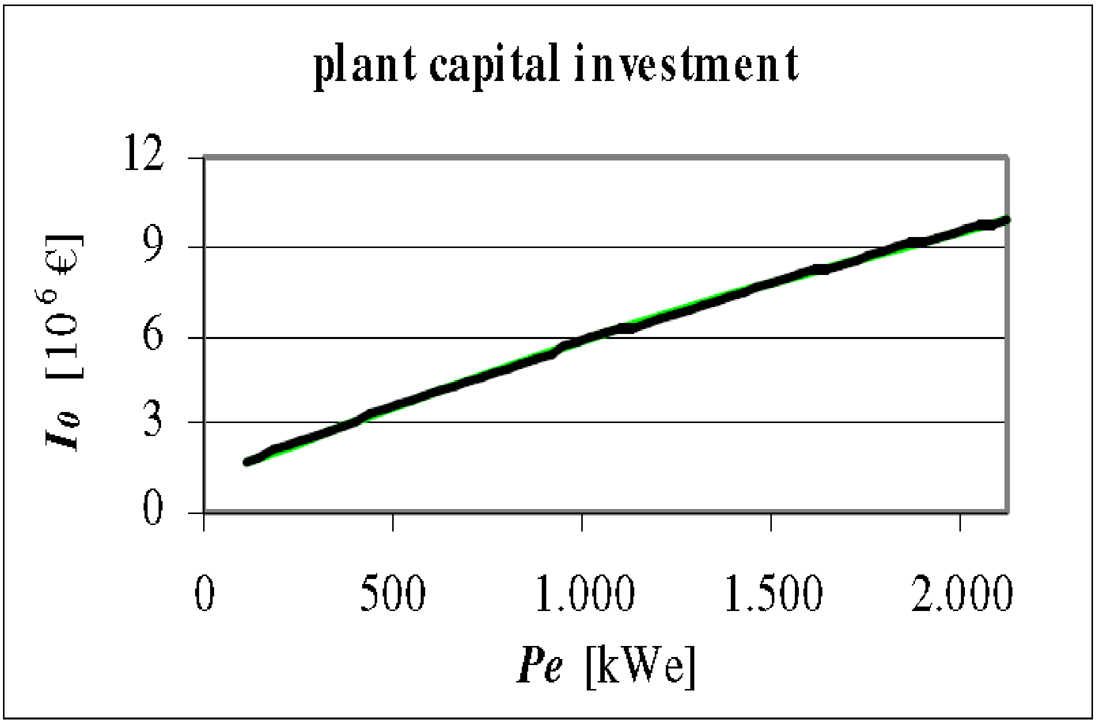

Figure 3.3: Capital investment (I_o) as a function of AD plant nominal capacity.
Source: (Florese et al., 2008)

The nominal capacity was estimated based on Pantaleo et al., (2013) the gross electrical power Pe (kWe) of a biogas plant, can be expressed as a function of the input biomass according to the formula:

$$P_e = [(Q_p \times TS_p \times VS_p \times BY_p \times BA_p) + (Q_c \times TS_c \times VS_c \times BY_c \times BA_c)]\frac{CH_4 \times LHV \times \eta_e}{H} \quad 3.8$$

Where Q_p (t/yr) and Q_c (t/yr) are respectively the annual poultry manure and annual cattle manure consumption of the biogas power plant, TS (%), VS (%), BY (N m^3/t) and BA (%) are respectively the total solids percentage, volatile solids percentage, biogas yield of the volatile percentage and biogas availability of the biomass; CH_4 (%) is the percentage of natural gas in the biogas and LHV (kW h/Nm^3) is the low heating value of natural gas; η_e is the electric efficiency of the power plant and H the annual operating hours (h/yr). The values of the parameters in the above equation are shown in Table 3.2 below:

Table 3.2: Average Biogas composition values

S/N	Onitsha	Njikoka	Dunukofia
Q_p [(c)] (Ton)	57,412.95	63,914.07	54,982.76
Q_c [(c)] (Ton)	6,914.6	6,914.6	6,914.6
TS_p [(b)] (%)	20	20	20
TS_c [(b)] (%)	8.5	8.5	8.5
VS_p [(b)] (%)	80	80	80
VS_c [(b)] (%)	80	80	80
BY_p [(b)] (%)	4.75	4.75	4.75
BY_c [(b)] (%)	0.25	0.25	0.25
BA_p [(b)] (%)	70	70	70
Heating Value [(b)] MJ/Nm³	25.2	25.2	25.2
Electric efficiency [(a)]	0.44	0.44	0.44
Annual Operation Hour [(a)] (hours/yr)	7468	7468	7468

Source: [(b)]Al Seadi et al., (2008);[(a)] Florese et al., (2008); [(c)]Author's research

Q_p was estimated by summing up all the livestock waste generation point within a distance of 40km to each of the three locations. Höhn et al., (2014) reported that a maximum transportation distances for raw materials vary from 10 to 40 km. In the present study the upper end was used to estimate the collection area and associated biogas production potential. Distance above 40km was excluded in the available waste because of economic considerations. The nominal capacity for Onitsha was estimated to be 3661.35 (kWe), while the nominal capacity for Njikoka and Dunukofia L.G.A is about 3969.46 (kWe) and 3546.18 (kWe) respectively. The investment costs for a biogas unit include all expenses for the erection of the plant e.g.: the land, excavation-work, construction of the digester and gasholder (wages and material), the piping system, the gas utilisation system, the substrate storage system and other buildings. Capital cost of a project does not always vary linearly with plant capacity. The cost of a specific item depends on size or scale and can usually be correlated by the approximate relationship. Equation 3.9 below proposed by Marouli and Maroulis, (2005) and Figure 3.3 above were used to approximate the investment cost of the biogas plant.

$$\frac{C_1}{C_2} = (\frac{Q_1}{Q_2})^n \qquad 3.9$$

Where C1 = cost of the item at size or scale Q1; C2 = cost of the reference item at the size or scale Q2. n = scale exponent or cost capacity factor.

Amigun and Blottniz (2010) determined capital cost relationship for small–large scale biogas systems and reported that the value of n for small and large scale biogas plant is 1.21 and 0.8 respectively. The value of n=0.8 was used in the estimation of the investment cost of the biogas plant.

3.6.3 Variable Cost

The variable cost consists majorly of transportation cost, operational cost and maintenance cost. The transportation cost was estimated using equation 3.10 below (Florese et al., 2008)

$$T_c = \sum_{i=1}^{N} \sum_s [(V_{tc} * d_{ij} + F_{tc}) a_{ij} * x_{ij}] \qquad 3.10$$

*Where a_{ij} is the b*iomass available in the *i*-th demand point, *s*=1 for poultry manure and *s*=2 paunch manure; x_{ij} is the fraction of biomass in the *i*-th livestock site or abattoir centre conferred to the *j*th plant. The value of x_{ij} was taken to be 1, since all the waste in each demand points should be treated. The transportation costs (T_c) considered the cost of manure transportation cost to the plant only without including digestate round-trip transportation costs, this is based on the fact that majority of livestock farms and abattoir centres do not really need the digestate for farming, the cost of digestate transportation will be incurred by farmers who need the digestate for farming needs. The transportation cost comprises of both fixed costs (F_{tc}) representing loading and unloading operations, and variable costs (V_{tc}) which is a function of distance as shown in Figure 3.4 (adapted from Ghafoori *et al.*, 2007). Dij is the Euclidean distance (in km) between the demand points and the suitable points. The value of d_{ij} was estimated based on upper distance of 40km, the Euclidean distance was multiplied with the factor 1.4 so as to determine the actual distance (Leduc et al., 2010).

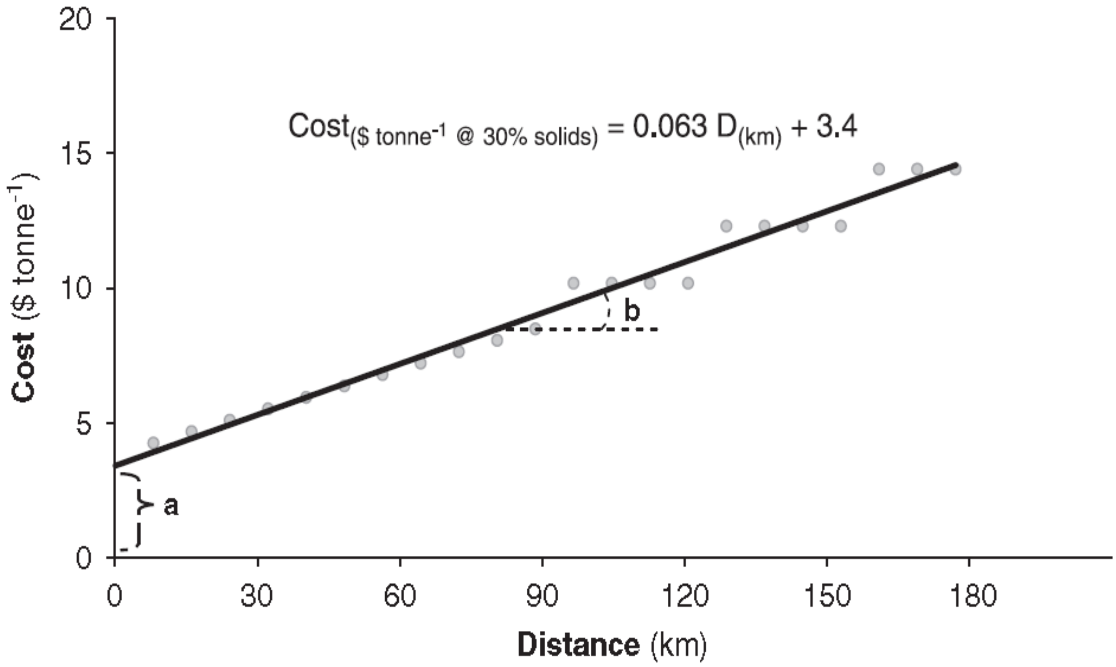

Figure 3.4: Cost of transporting manure by truck: ‘‘a’’ is the distance fixed cost, and the slope ‘‘b’’ is the distance variable cost.

Plant Operational Cost: the operational cost for biogas plant consists of personnel (labour) costs and overheads; cost of consumable like lime and active carbon, for the removal of odours and other noxious gases; pretreatment of feedstock cost etc. Sotirios et al., (2010) proposed that 3-5% of the total investment cost should be used for the operational and maintenance cost. 2% of the investment cost was used as the operational cost.

Plant Maintenance Cost: Plant maintenance costs (P_{main}) were calculated as a fraction of gross energy output E_o. Florese et al., (2008), proposed the gross energy output to be given by:

$$E_o = \frac{1}{3.6} * (1 - f_{el}) * {}^{\eta}{}_{el} * LHV_{biogas} *\textstyle\sum_i^N \sum_s a_i * f_{b,} * b_s) x_{ij} \qquad 3.11$$

x_{ij} are the fractions of biomass in the i-th biowaste site conferred to the jth plant; f_b is Organic fraction in the s-th biomass; b_s is the Biogas yield for biomass s; LHV Biogas low heating value; f_{el} is the electrical auto-consumption fraction; η_{el} is the electrical efficiency of the biogas plant.

The above equation was multiplied by 3% to obtain the plant maintenance value.

3.7 Location Optimization Model Development

Location model for bio-energy plant development is treated in two parts. One is for single bio-energy facility and the other is for multiple plant energy facilities.

3.7.1 Modelling Single Plant Bio-energy Problem

To determine the best location from the site suitability analysis, we use capacitated plant location model (CPLM) which has two parts. CPLM is most applicable in multiple facility allocation. The first part deals with the construction and operational cost which is fixed cost. The second part deals with the variable cost, which consists mainly of cost of transporting the goods from the supply point to the processing point. The CPLM has been described as the best location model for biogas production plant optimization (Delzeit, 2008). The CPLM is given as:

$$Min. \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} X_{ij} \qquad 3.12$$

Subject to:

$\sum_{i=1}^{n} x_{ij} = D_i$ for j = 1 … m

$$\sum_{i=1}^{m} x_{ij} = k_i y_i \quad \text{for i = 1 … n}$$

$y_i \; \mathcal{E} \; \{0,1\} \; for \; i = 1..n; \; x_{ij} \geq 0$

Where n= Number of potential plant location capacity, m = Number of demand points, D_j= Annual demands of wastes to process, K_i = potential plant capacity, f_i= Annualized fixed cost of biogas plant, C_{ij} = Cost incurred in waste transportation from demand point to the processing point, y_i= 1 if the plant j is open, 0 otherwise, x_{ij}= Quantity shipped from demand point i to processing plant j.

The above general equation was modified for bio-energy plant location, for single plant location, the construction cost and the annual operation cost does not vary significantly, therefore the fixed cost part of the equation was expunged. Since transportation cost is the major cost in variable cost, the variable cost component of equation is modified as follows:

$$\sum_{j=1}^{m} \sum_{i=1}^{n} P_{ij} \, d_{ij} \qquad 3.13$$

Where P_{ij} represent the quantity of bio-waste conveyed from waste generating site to processing site and d_{ij} represent the distance from biowaste source i to the chosen processing plant j. d_{ij} represent the cost function. Equation 3.13 above is similar to load distance location model.

3.7.2 Modelling Multiple Facility locations

It is extremely difficult economic-wise to have a full coverage in facility location modelling due to dispersiveness of supply/demand points. Hence, set covering location model was used in this study to determine minmum suitable locations that will enhance maximum coverage.

3.7.2.1 Set covering problem

The objective of covering models is to provide “coverage” to demand points. A demand point is considered as covered only if a facility is available to service the demand point within a distance limit.

Problem Definition

Having a set of n elements: P = (1,2,3...n) and set of m elements P: S = (S_1, S_2, S_3, ...S_n), the goal of set covering problem is to choose the minmum number of these elements m subsets such that all elements in P are covered.

Then the set covering model is given as:

$$SCP = \min \sum_{1=1}^{p} C_i X_i \quad (3.14)$$

$$\text{s.t} \sum_{j}^{p} a_{ij} X_i \geq 1 \qquad \forall i \quad (3.14a)$$

$$x_i \, \mathcal{E} \, \mathrm{B}, \forall i \quad (3.14b)$$

Type equation here.

Problem Forumulation

The set covering problem was applied to Anambra agricultural waste generating centres the map of the study area showing the various poultry and paunch waste generating centres in the State is shown in Figure 4.13 and Figure 4.14. Some sites were selected as potential location for bio-energy processing plant; the site selection was based on suitability analysis considering majorily land use criteria. The power of GIS is determining the hotspot sites and land suitability model were used in selecting areas that will give a good coverage for all demand points. The most suitable, highly suitable and moderately suitable were selected as potential sites, site collection radius of 3 and 10km were used as the maximum distance of transportation for economic reasons. The model was forumulated by considering a total of nine (9) collection radius where because of overlapping of the various collection radius minmum potential sites is to be selected in such in way that will minimize distance and will enhance maximal covering of centres. Since each radius of collection has it own potential biomass quantity, the goal of set covering modelling is to locate a minimum number of potential processing centres from 9 overlapping centres in general. Two radials connecting each other constitutes a union set, if a poultry poultry centre can transport its waste from radius say a to b which is within a threshold of 10km distance, by adopting set concept, the linking of the radius to each other is such that opening bio-energy processing centre in radius a can satisfy a given number of poultry waste generating centres within it neigbhoood. The aim here is to find the minmum number of poultry centres that will cover majority of the poultry waste generating centres for 9 subset indexed on i = 1, 2, 3...9.

The various collection radial were labelled 1 to 10. Table 3.5 shows the subsets, covers and the quantity of waste generated within the collection radius used in formulation of the set cover location model problem.

Table 3.3: Subset and covers used for the set covering location model

S/N	Subset	Covers	Qty of waste within radius of collection (Kg)
1	1 (Onitsha)	1,2,7	12749373.35
2	2 (Orafite)	1,2,4	6086222
3	3 (Awka)	3,7,8	10592004.35
4	4 (Ihiala)	2,4	1752182.5
5	5 (Ajali)	5,6	1729370
6	6 (Akpo)	5,6,8	3851279
7	7 (Abagana)	1,3,7,8,9	12976115
8	8 (Adazi-ani)	6,7,8	11063529.6
9	9 (Aguleri)	7,9	3429076.45

Decision Variable

X= 1, if subset i is selected and 0 otherwise. i = 1, 2, 3...n. For this application: x = 1, if a bio-energy processing potential site is opened/selected and 0 otherwise i = 1, 2, 3...n.

Parameter

A_i = 1, if bioenergy centre opened in location i can cover location j, and 0 otherwise

Constraint

Every biowaste source in proximity to selected processing sites must be served (or covered) by at least one bio-energy processing centre.

Objective Function

$$\text{Min. } 13x_1 + 6x_2 + 11x_3 + \ldots 18x_9 \quad (3.15)$$

Subject to

$x_1 + x_2 + x_7 \geq 1$ (Onitsha)

$x_1 + x_2 + x_4 \geq 1$ (Orafite)

$x_3 + x_7 + x_8 \geq 1$ (Awka)

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$x_7 + x_9 \geq 1$ (Aguleri)

$x_i \in (1.0)\ \forall i$

The total biomass in tonnes in each subset was used as cost function in the formulation of the objective function. The set cover data used for the formulation of the constraints and objective function table is shown in Figure 4.32 and appendix Table B.23.

3.7.2.2 Location Allocation Problem Modelling

The variant of fixed charged facility location problem (FCFLP) suited for bio-energy plant location optimization is given as:

$$Min. \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} P_i d_{ij} \qquad 3.16$$

Problem Decription

Based on available statistics on agricultural waste generation from animal houses in the state, there exist different waste generating centres in each LGA. There is need to estimate best sites for allocation of theses wastes, these locations are refer to processing sites, while the waste generating sites are referred to supply points. Assuming that a given processing site can process a given amount of waste from a radius of approximate 10km; this represent the capacity of bio-energy plant opening in j location. Each bio-energy processing centre can accommodate and process bio-wastes with facilities at fixed operating cost. The goal is to determine which bio-energy centre to open as well as the best allocation of wastes sources to the opened bio-energy processing centres. Min 4000 for instance in equation 3.17 was estimated using equation 3.8 and 3.9 above.

The specific objective function for the problem is

$$Min\ 4000 \times y_1 + 380 \times y_2 + 120 \times y_3 + 33x_{11} + 34x_{12} + 48x_{13} + ... + 12x_{38} + 16x_{39} + 19x_{310} \qquad 3.17$$

Supply constraints

$$x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} + x_{18} + x_{19} + x_{110} \leq 1752183$$

$$x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} + x_{27} + x_{28} + x_{29} + x_{210} \leq 5580649$$

$$x_{31} + x_{32} + x_{33} + x_{34} + x_{35} + x_{36} + x_{37} + x_{38} + x_{29} + x_{310} \leq 57101414$$

Demand Constraints

$$x_{11} + x_{21} + x_{31} = 12749373.35$$

$$x_{12} + x_{22} + x_{32} = 6086222$$

$x_{13} + x_{23} + x_{33} = 10592004.35$

.

.

$x_{101} + x_{102} + x_{103} = 205093.5^*$

3.8 Profitability Analysis of Centralized Biogas Plant

A situation where either the government, interested companies, NGOs and organization owns the centralized biogas plant and situation where farmer's co-operative society decides to finance and operate the biogas plant has long been sought for. The profitability analysis of centralized biogas plant was carried out in this study, this is based on Puksec and Duic (2012) centralized biogas plant assessment methodology. Nigerian Electricity Regulatory Commission seeks to encourage investment in renewable energy for power generation to achieve 10% of the total energy mix; hence Feed-in Tariff (FIT) structure which is renewable technology based has been established. A proposed FIT presented by Acting Director of Electrical Inspectorate services Department is shown in Table 3.4 for various types of renewable energy.

Table 3.4: General Assumptions of determination of FIT in Nigeria

S/N	DESCRIPTION	UNIT	ASSUMPTIONS			
			WIND	SOLAR	SMHP	BIOMASS
1	Installed Capacity	MW	10	5	10	5
2	Capital Cost	US$/kW	2,525	5,545	3,500	4,000
3	O & M Cost (Fixed)	NGN/MW/yr	2,900,000	9,570,000	5,655,000	8,370,000
4	O & M Cost (Var)	NGN/MW	232	87	775	
5	Capital factor	%	38	33	60	68
6	Auxiliary Requirement	%	1	1	1	10
7	Economic Life	years	25	25	25	25
8	Construction Period	years	3	3	3	3

A general assumption for 5MW biomass installed capacity for electricity generation is shown above. The economic life of such renewable energy is estimated at 25 years. Table 3.5 below shows the increasing FIT applicable to these renewable energy sources.

Table 3.5: Renewal Energy Feed-in-Tariff Structure of Nigeria

Renewable Energy Technology	2012	2013	2014	2015	2016
SMHP	23,561	25,433	27,456	29643	32,006
Wind Power	24,543	26,512	28,641	30,943	33433
Solar Power	67,917	73,300	79,116	85,401	92192
Biomass	27,426	29,623	32,000	34,572	37,357

Source: Nigeria Federal Ministry of Power (2013)

The Table above should increase in FIT structure, indicating the interest of the government to investiong in renewable energy generation. Also from the Table 3.5 above, FIT for biomass energy source seems to be the highest. Considering the fact that there is available biomass in the study region, electricity generation using biomass renewal energy source could be a highly profitable venture in the study area. In this situation if farmers need to take over all of the investment as well as operating costs of the plant. If farmers are taking over the risk of success then the most important parameter would be the profitability of the plant and the possible payback period. The biogas profitability index is a given in eq. 3.18 below:

$$B_{pi} = \frac{FIT\left(\frac{B * LHV * \eta_{el}}{1 + \mathrm{Rel}} A\right)}{(I_o + C_{o\&M})} \qquad 3.18$$

where B_{pi}, biogas plant profitability index. FIT, feed in tariff (₦/kWh); B, yearly biogas production (m^3/h); LHV, energy value of biogas (kWh/m^3); CHP efficiency; A, availability h/year) and $R_{el/heat}$, CHP electrical energy/heat ratio.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Thematic Maps for GIS Analysis

Thematic maps were prepared, edited, overlaid and visualized on the basis of the suitability analysis for bio-energy sites using ArcGIS 10 software of ESRI. The application of GIS for overlaying thematic layers to establish land databases requires that all the layer maps need to be converted into a common coordinate system. The thematic maps used and their various function is detailed below.

4.1.1 GIS Study Area Administrative Map

For assessing suitable site for installation of bio-energy plant, there is need for administrative data i.e. maps with administrative details. Administrative shapefile of the study area is shown in Figure 4.1, the 21 local government areas were digitalized and saved as shapefile in ArcGIS. The shapefile shows the local government areas with their administrative headquarters.

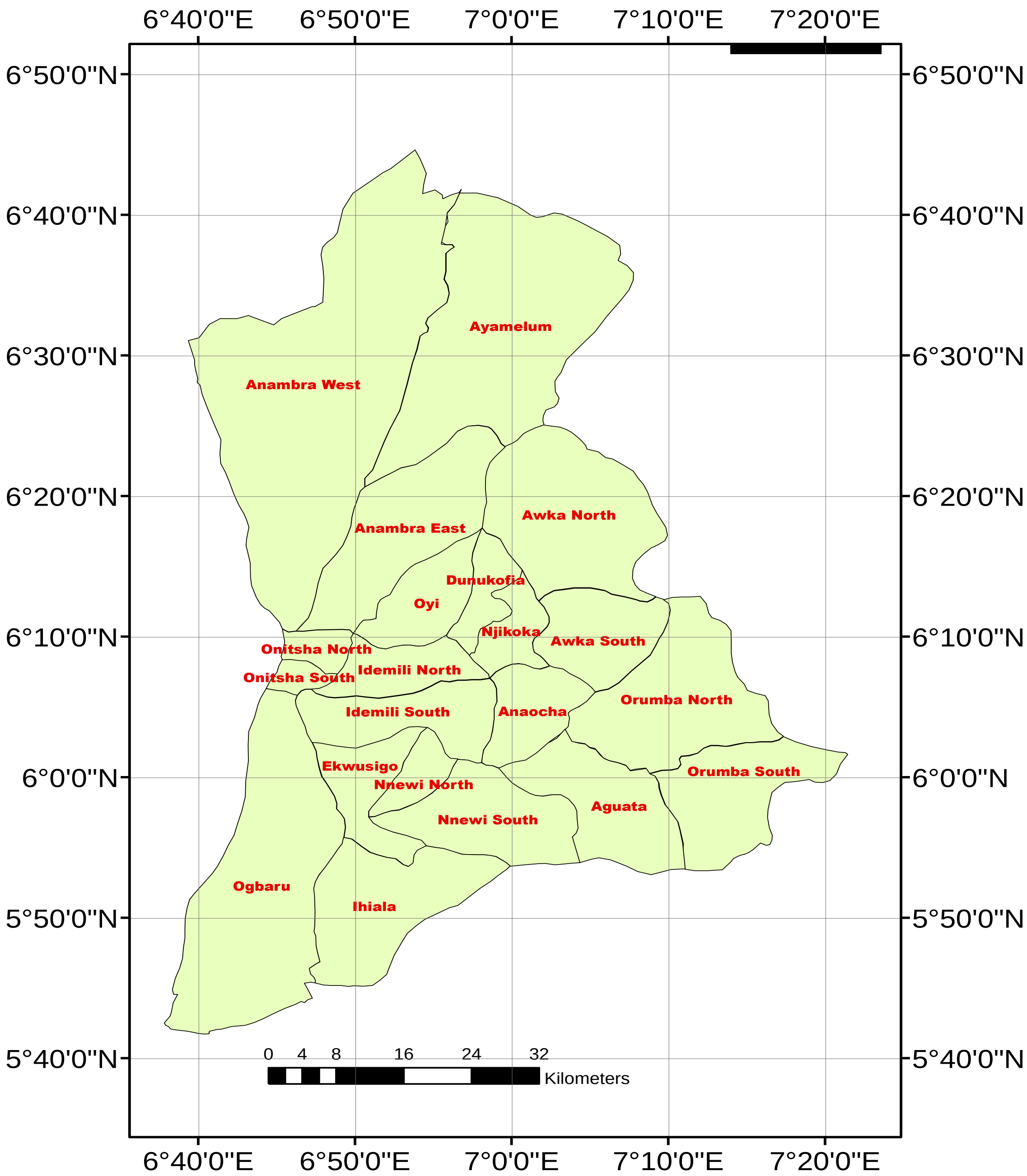

Figure 4.1: Shapefile of Anambra Adminstrative Map

4.1.2 Road Network Thematic Layer

The major road network was digitalized and prepared to ensure that transportation cost is minimized. The thematic layer indicating the road network was represented by polylines. Figure 4.2 shows that the major roads crossing through various L.G.As of the study area. The Figure shows that Anambra West and Ogbaru L.G.A has the least road network, indicating that for proximity of siting biogas plant to road networks, these areas would be least suitable. A lot of road network is seen in the central region of the state.

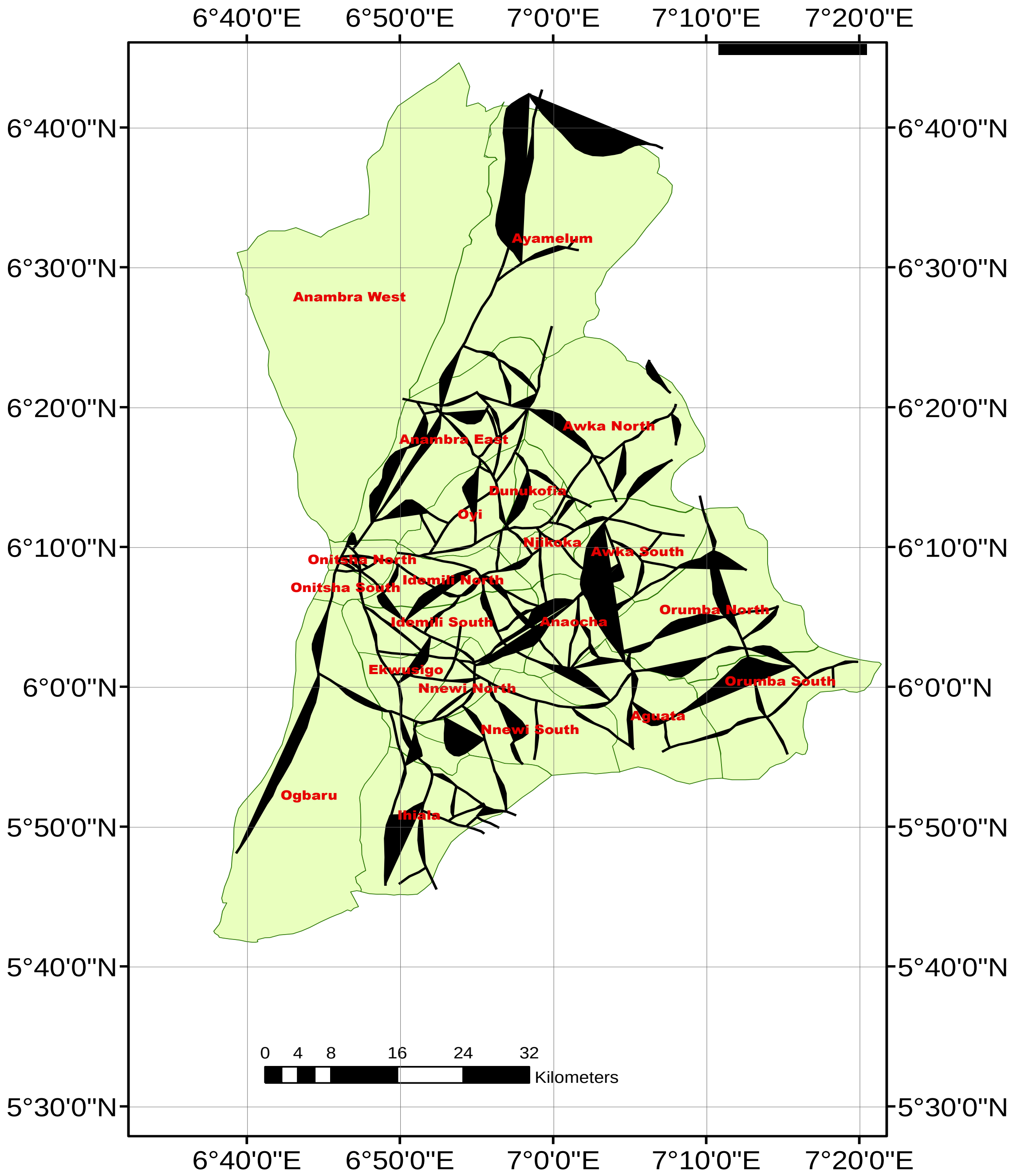

Figure 4.2: Shapefile of Major Roads in Anambra State

4.1.3 River Thematic Map

River shapefile was also digitalized and used for GIS analysis; Figure 4.3 shows the river shapefile. River Niger cuts across the state boundary towards the west. Majority of the river network is seen in Anambra West. Tributary rivers from Ojoto and Ukpo as shown in the figure cut across several towns to discharge in the river Niger.

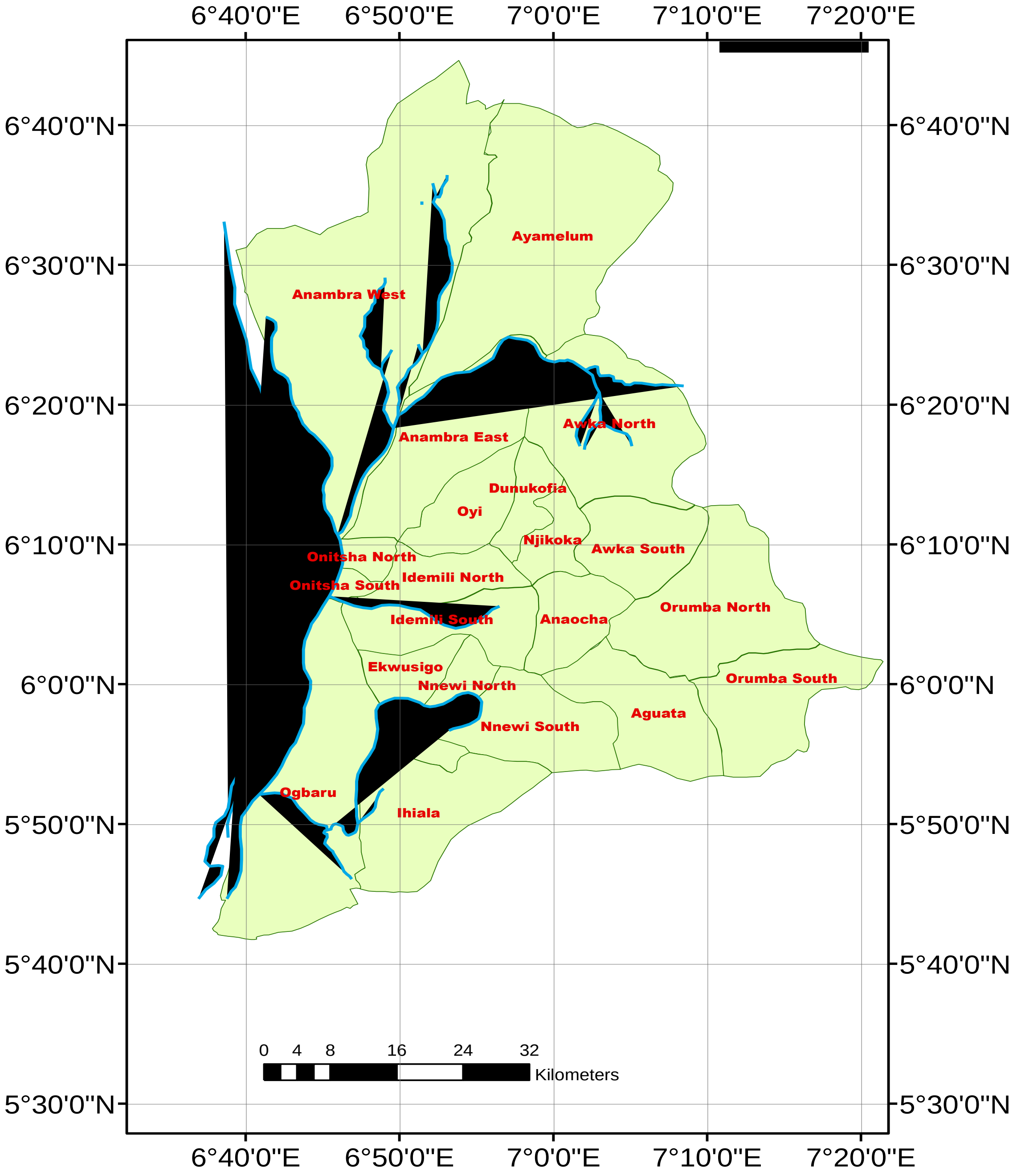

Figure 4.3: River shapefile of Anambra State

4.1.4 Electric Transmission Line Thematic Layer

Electricity is generated at a power station (coal, natural gas, nuclear plants, wind turbines, hydro, and solar power), stepped up to a high voltage for long distance transport over transmission lines, and then stepped down again at a substation. The electric utility companies' transmission and distribution system links power plants to customers through high power transmission line service, the shapefile of electric line distribution of Anambra State of Nigeria is shown in Figure 4.4 below.

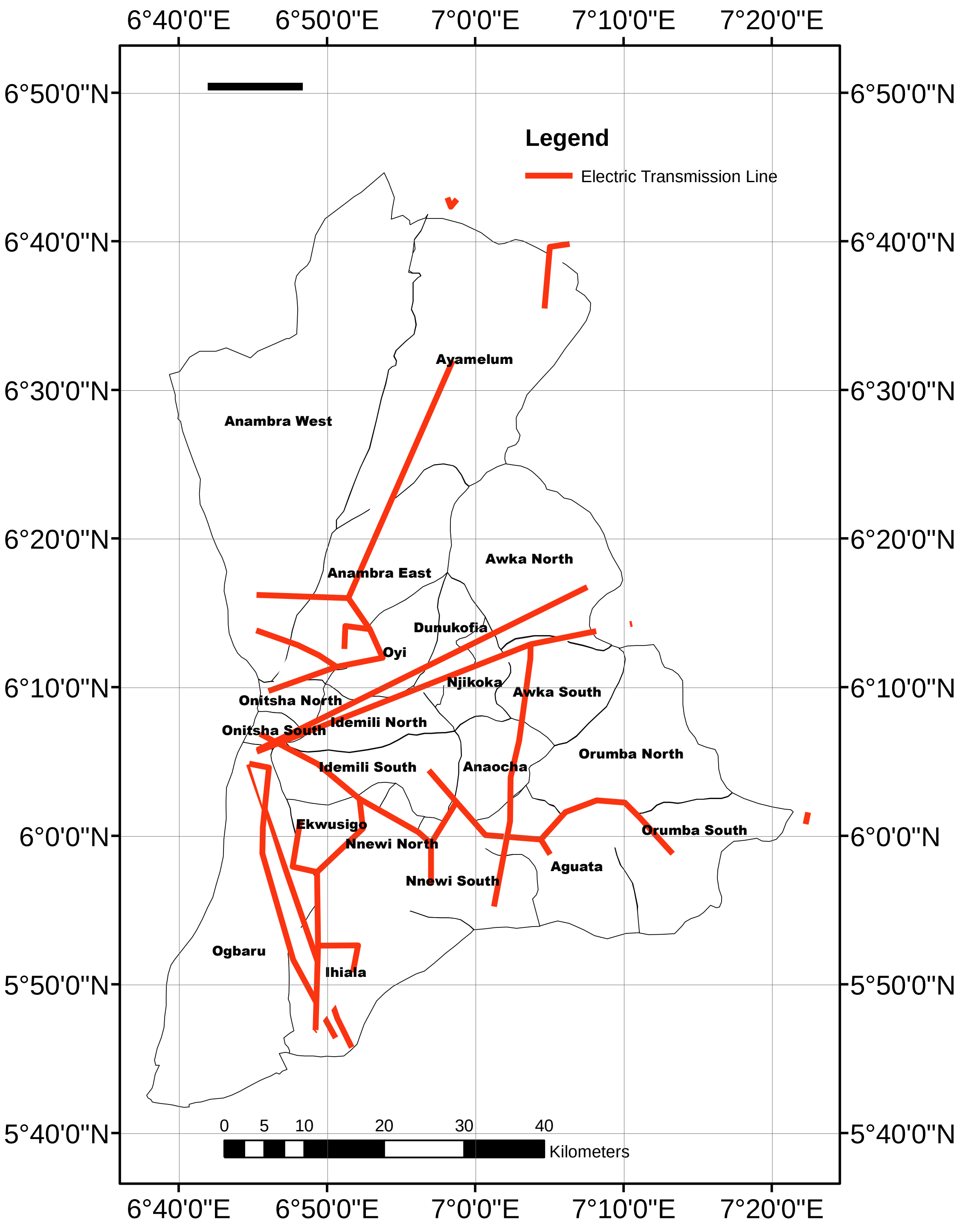

Figure 4.4: Shapefile of Power Plant and Transmission lines in parts of Nigeria

The Figure shows two electric transmission lines that runs through Onitsha South through various LGAs to Awka North and South, these lines terminated in Enugu State. All the 21 LGAs were adequately covered by these electric transmission lines. The electric transmission line provides the layer that ensures that sites for bio-energy installation are located in proximity to power lines, this will reduce energy losses in transmission process and operation.

4.2 Image Processing and Analysis

All the raster-based data were analyzed using appropriate GIS analytic tools such as ArcGIS application software, the results of the raster processing and analysis yielded several polygonized GIS layers, these are explained below:

4.2.1 Landsat Image Classification

Remote Sensing techniques through mapping from satellite imageries are being used today in solving the topographic needs of developing countries. Remote sensing and Geographic Information Systems have proved to be reliable and accurate tools for explicit measurement, mapping and analysis of spatial information. Remote sensing aids in synoptic observations of large areas. In providing multi-temporal and multi-spectral data that can be used to quantify the type, amount and location of land use and land cover. Satellite remote sensing has advantage of being effective, cheap and timely tool for monitoring changes in land use change. The analytical and integrative capability of Geographic information systems in providing explicit spatial information has given GIS an edge over all other analytical tools (Lowry, 2006). The Landsat-7 ETM + used for the study was obtained from National Centre for Remote Sensing Jos, it covers the entire South East. In order to define the area of interest since the spatial extent of the satellite images were greater than the study area; the imagery were sub mapped to a smaller area using the clip tool in Arcgis, bounding study area was extracted using Anambra shapefile. The satellite imagery was used to classify the land cover. The satellite imagery is shown on Figure 4.5 below. The Landsat-7ETM+ raster file was classified and reclassified to obtain Anambra Land cover raster file.

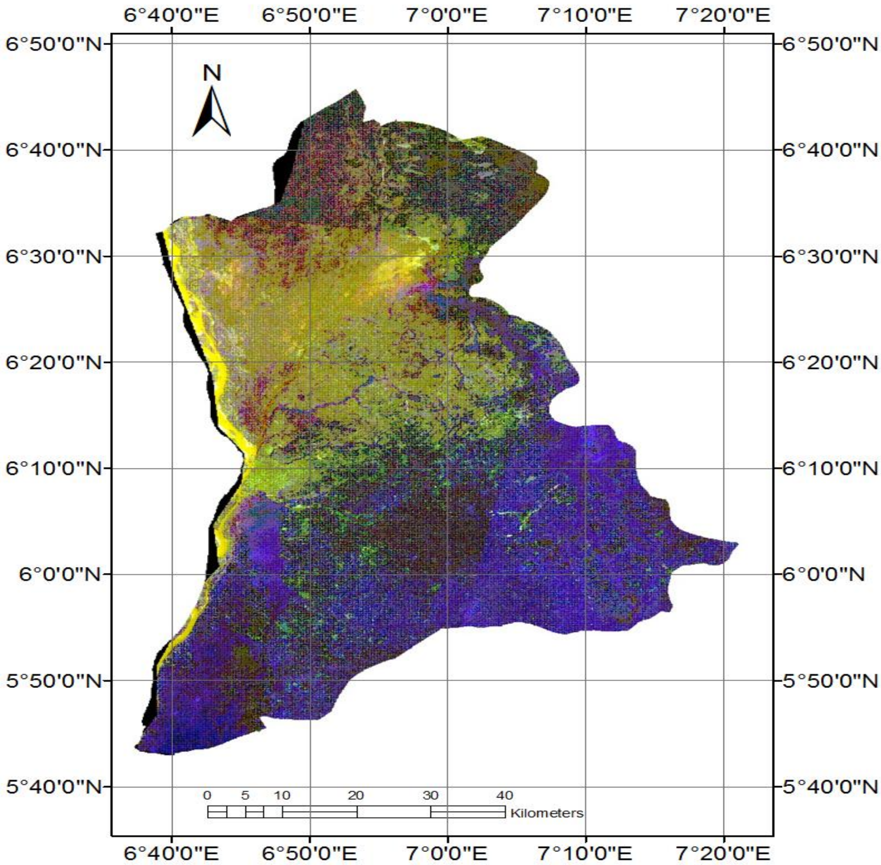

Figure 4.5: Landsat Imagery of Anambra State (False Colour Composite)

Source: National Remote Servcing Centre Jos.

Image classification operation was carried out in this study which is the process by which pixels which has similar spectral characteristics and which are consequently assumed to belong to the same are identified and assigned a unique colour. In classification procedure, spectral pattern of pixel are used as numerical bases for categorization of scene features. These classifications are based on the assumption that feature vectors of different object classes or groups cluster together in the feature spaces. This means that every classification procedure involves separating individual cluster and identifying what these cluster represent in reality. The images were polygonized into different classes of land use and land cover in

ArcGIS environment. Based on prior knowledge of landuse of some geographical co-ordinates points, six classes were categorized. They are agriculture areas, barren/open land, densed forest, sand, urban land, and water body. The classified landuse map is shown in Figure 4.6.

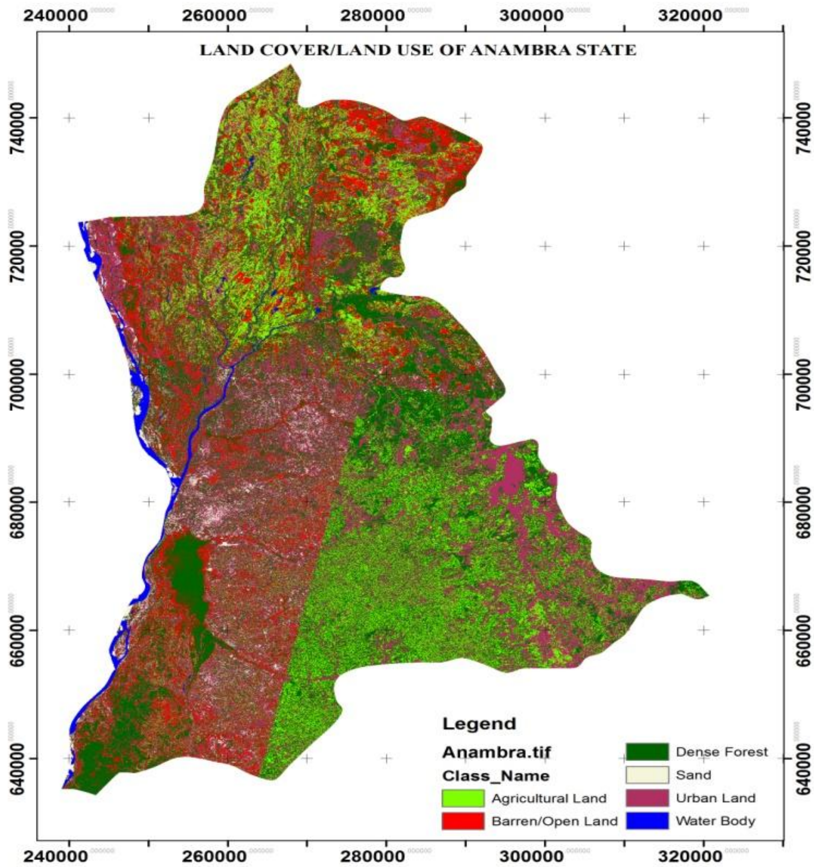

Figure 4.6: Land Use/Land Cover Classification of Anambra State

Assessment of classification accuracy was carried out using the scatter plot analysis in statistical toolbar in ArcGIS 10. All the training data were highlighted to compare the scatter plot of the six classes to each other. The classes were examined to detect any form of overlap (these are classes having different pixel value). This shown in Figure 4.7, the statistic for the training data was also used to assess the accuracy of the classification. The statistic are usually organised for each training area. The covariance statistics evaluates the correlation between the values of different bands and were adequate for the study.

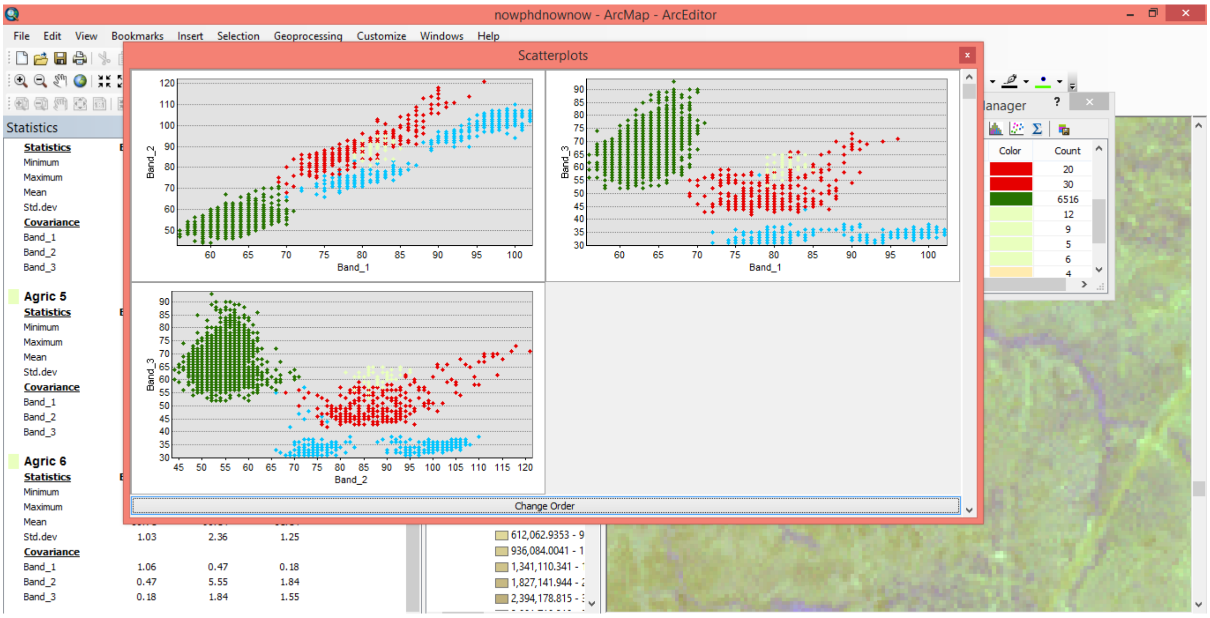

Figure 4.7: Scatter plot of image classification in ArcGIS

The areas covered by each class of the LULC shows that urban land occupies 36.52% which represent 506896km^2 of landmass of the overall LULC while the least class is the sand class followed by water body, these feature classes occupies landmass of 13080km^2 and 14000km^2 respectively. The overall classification accuracy determined is 83%. The Table of LULC classification of Anambra State, area occupied in km^2 and percentage occupies by the various classes is shown in Table 4.1.

Table 4.1: Area occupation of various LULC classes

Class	Area(km)	Percentage (%)
WATER BODY	14000	1.00
SAND	13080	0.94
DENSE FOREST	257999	18.59
URBAN LAND	506896	36.52
AGRICULTURAL LAND	356430	25.68
BARREN/OPEN LAND	239400	17.25
TOTAL	1387805	100

4.2.2 Data Analysis from Shuttle Radar Topography Mission (SRTM)

The downloaded SRTM Image was in Latitude, Longitude coordinate frame of WGS 84 ellipsoid. The calculate tool in raster properties was used to resample the SRTM data in ArcGIS. The downloaded SRTM Image was clipped for Anambra Administrative area. The SRTM imagery is shown in Figure 4.8. The SRTM Imagery was the source of elevation points for this study. The downloaded SRTM was used to produce contour of the study area. The elevation information shows that the elevation of the study area ranges from 0 to 385 feet.

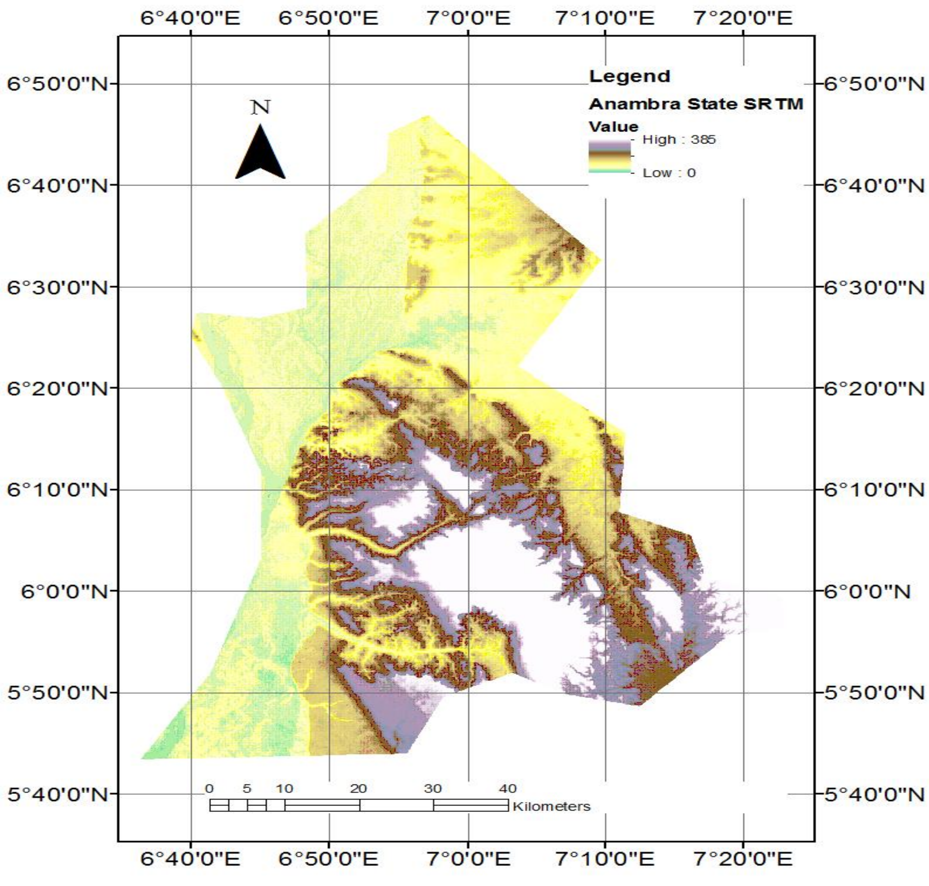

Figure 4.8: Anambra SRTM

Hillshade View

A hillshade is a grayscale 3D model of the surface, with the sun's relative position taken into account for shading the image. This function uses the latitude and azimuth properties to specify the sun's position. The inputs for this function are the following: Input DEM, Azimuth, Altitude and Z Factor. A grayscale color ramp is used to display a hillshaded elevation model. The properties altitude and azimuth together indicate the sun's relative position that will be used for creating any 3D model (hillshade or shaded relief). Altitude is the sun's angle of elevation above the horizon and ranges from 0 to 90 degrees. A value of 0 degrees indicates that the sun is on the horizon—that is, on the same horizontal plane as the frame of reference. A value of 90 degrees indicates that the sun is directly overhead. Azimuth is the sun's relative position along the horizon (in degrees) The default is 45 degrees.. This position is indicated by the angle of the sun measured clockwise from due north. An azimuth of 0 degrees indicates north, east is 90 degrees, south is 180 degrees, and west is 270 degrees, The default azimuth is 315º (NW). Z Factor is used as the scaling factor to convert the elevation values. The scaling factor is used for two purposes: first, to convert the elevation units (such as meters or feet) to the horizontal coordinate units of the dataset, which may be feet, meters, and second, to add vertical exaggeration for visual effect. The hillshade example below has an azimuth of 315º and an altitude of 45º.Since Bio-energy plant is dependent on the heat energy source, the best site for location of bioenergy plant should be on a site with illumination for heating the biogas plant.

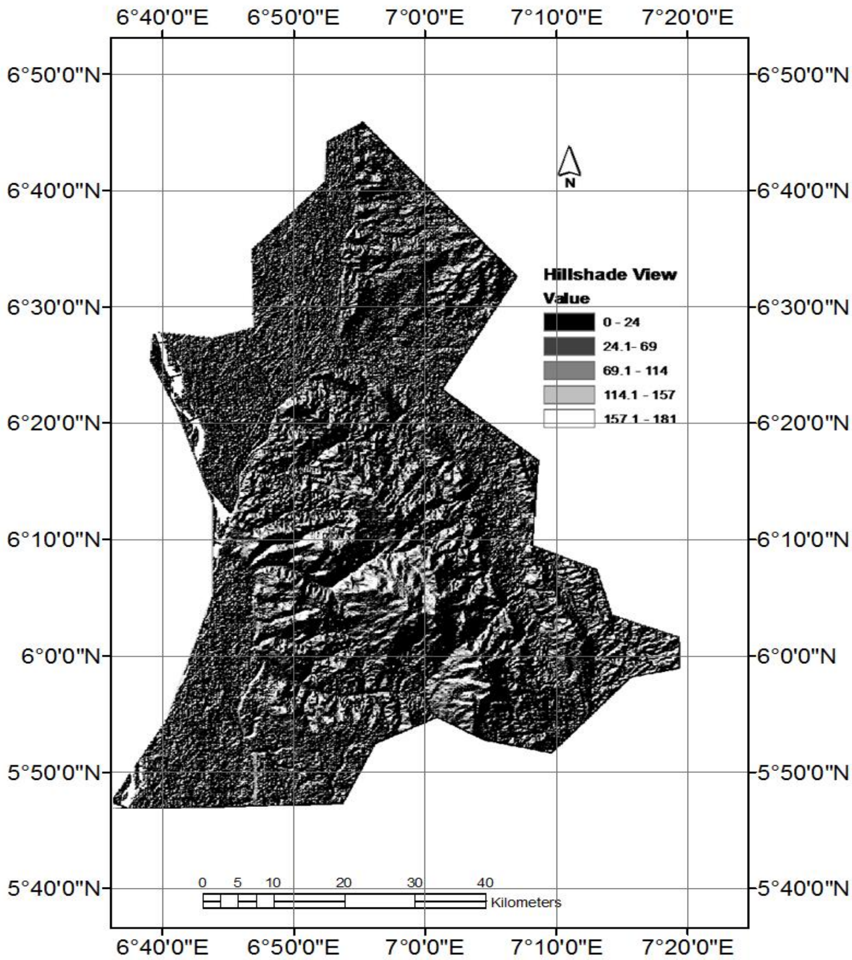

Figure 4.9: Hillshade view of the study area

Slope Consideration

Suitable areas for ADS are evaluated to avoid close proximity to land features and uses that may be sensitive to the characteristics of utility-scale power production and waste streams, including surface water, wetlands, forests, public lands, highly sloped lands, and developed residential areas, with acceptable slopes of 14^o or fewer is suggested by Ma etal. (2005). Slope was derived from the digital elevation model of the study area. The slope of the study area was obtained by spatial analysis using the slope function in spatial analyst tool in ArcGIS 10. The Slope command takes an input surface raster and calculates an output raster containing the slope at each cell. The steeper slopes are shaded red on the output slope raster (see Figure 4.10).The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. The output slope raster can be calculated as percent slope or degree of slope. The output slope raster can be calculated in two types of units, degrees or percent (percent rise).The slope of the study area ranges from 0 to 89% degree. The slope is shown in Figure 4.10:

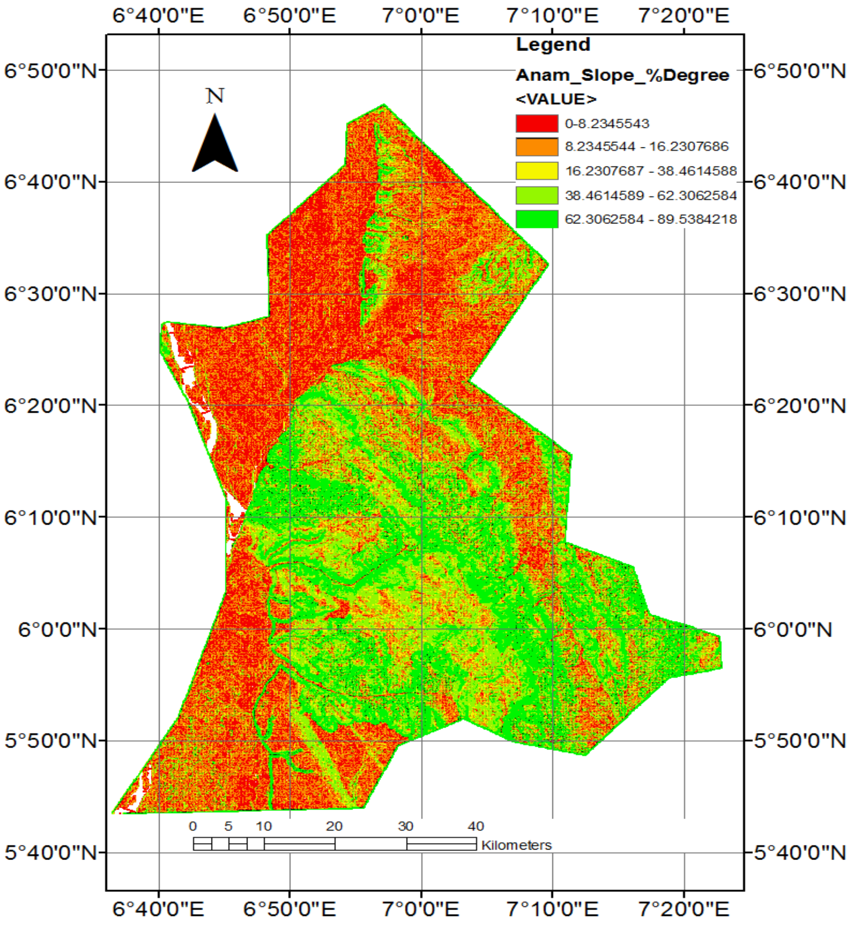

Figure 4.10: Slope of the study area

The slope obtained in GIS operation was divided into 5 intervals to the enable classification into suitability analysis and subsequent GIS overlay for the overall site suitability analysis. The raster dataset use for land suitability analysis considering the slope is shown in Figure 4.11.

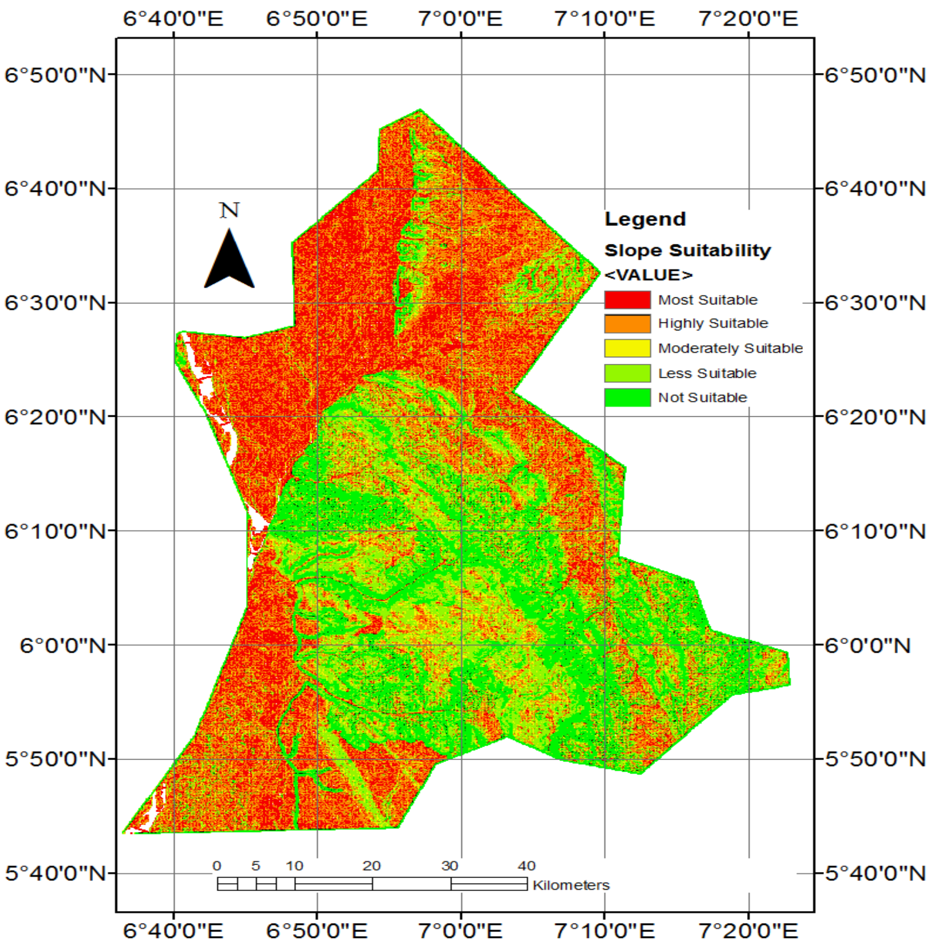

Figure 4.11: Suitability Analysis for Slope

4.3 GIS Mapping of Biogas Production Sites

One of the biggest barriers in utilizing biogas potential in several regions is the dispersion of livestock farms across the region and the availability of biomass capable of having economically viable biogas production. There is need for a methodology for regional analysis of biogas potential of Anambra state with cost assessment, the figure below shows the major towns and villages in Anambra state

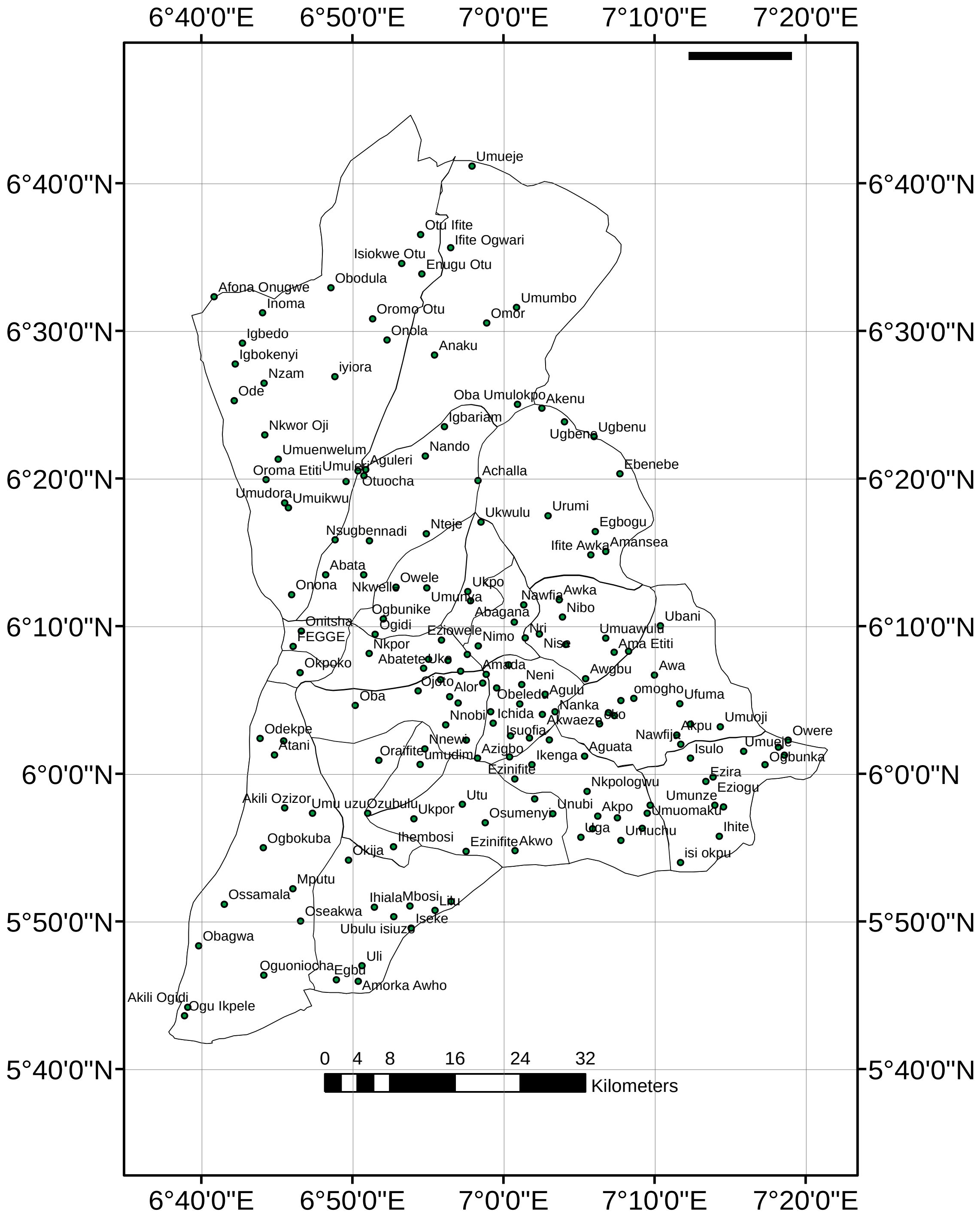

Figure 4.12: Shapefile of major towns and villages in Anambra State

Figure 4.12 shows clustering of towns and villages in the central part of the State while the Northern region (Anambra West and Ayamelum L.G.A) indicates slight dispersion of towns and villages. Similarly, the South-West regions of the State (Ogbaru and Ihiala L.G.A) show minor dispersion of towns and villages.

4.3.1 Poultry Producing Areas

One of the basics for regional analysis of biogas potential density in the study area is on the poultry production potential and density, Figure 4.13 shows only poultry production towns and villages in the State. From the figure below, Anambra West has no poultry production site; this has been attributed to the swarmy nature of the terrain.

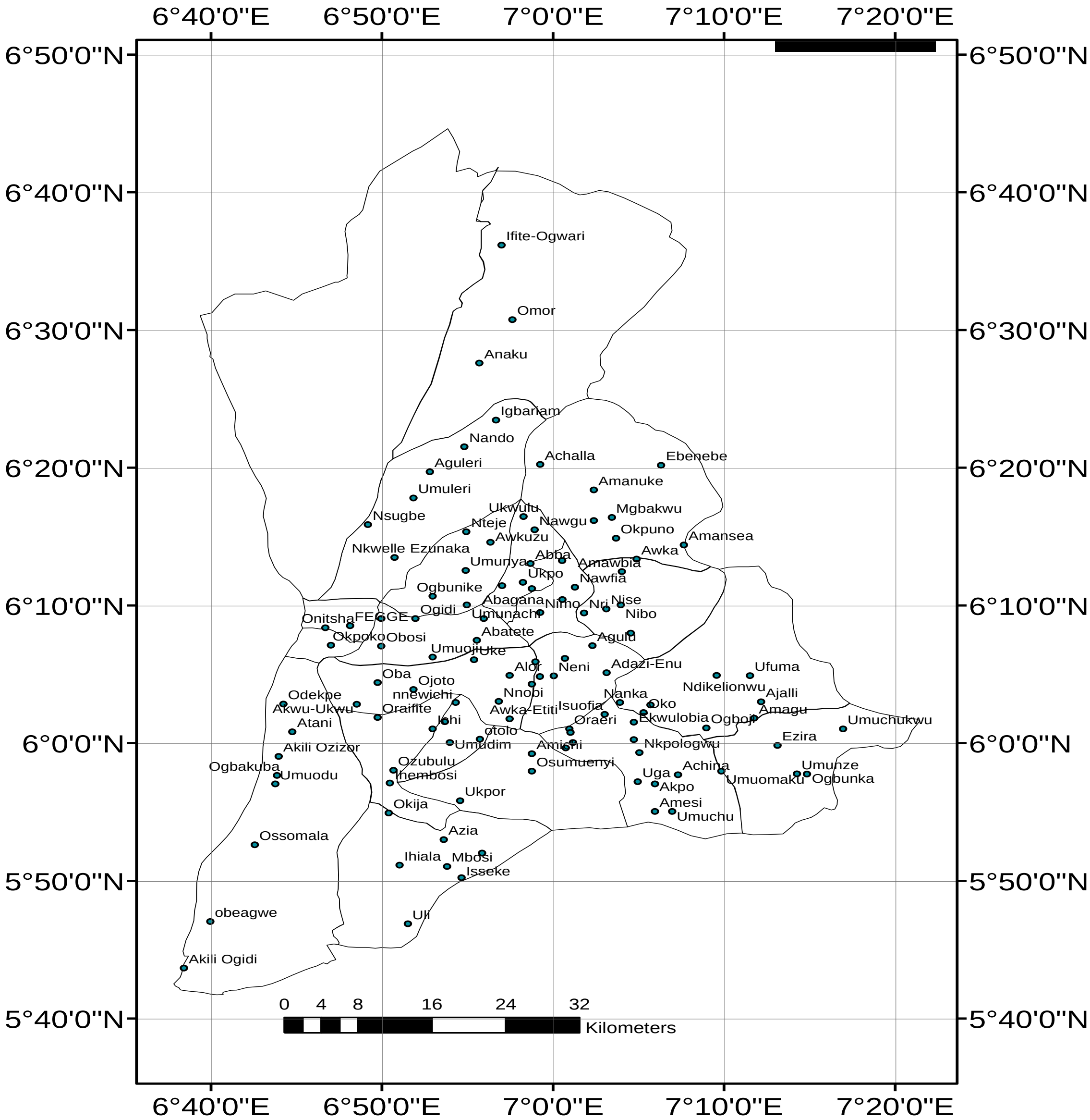

Figure 4.13: Shapefile of poultry birds producing areas of Anambra State

Hence, such region is eliminated in the study area for siting biogas plant. Ayamelum L.G.A has only three poultry production sites, which include Anaku, Omor and Ifite-Ogwari.

Several poultry production site in a Local government indicates higher biomass - availability/accessibility and consequently sites suitable for location of bio-energy plants.

4.3.2 Abattoir Waste Producing Site

Another basis for regional analysis of biogas potential density in the study area is on the abattoir waste production from slaughtered cattle, goats, pigs and sheep in all the abattoir centres in the State. Treating abattoir wastes with anaerobic digestion technology can reduce environmental pollution, odor and poor esthetic conditions of municipal abattoirs in the state. (Preliminary investigation shows that poor esthetic conditions (uncompleted abattoir houses) and odor production constitutes a major nuisance in most abattoirs in the state. In addition, energy produced during the biogas digestion could be use in various operations in meat processing in the abattoir. The energy source from biogas represents clean energy, this would be better to the current practices of burning wood in meat processing in most abattoirs in the state. Biomass wastes generated during the slaughter of these animals includes blood, wastewater, ruminal content etc. Figure 4.14 shows only the towns and villages in the State that has abattoir centres. From the Figure, Anambra West, Ayamelum, and Anambra East L.G.A has no abattoir centre, Ogbaru, Orumba South and Anaocha L.G.A each has one slaughterhouse located in Iyiowa-Odekpe, Umunze and Agulu respectively. There were a good number of abattoirs in Nnewi North and South, Awka North and South and in Onitsha North and South L.G.A. The concentration of abattoirs in these areas is probably connected to the high population density of these areas. Since meat demand logically increases with increase in population. Areas with high concentration of poultry production and clustering of abattoir centres are best sites when considering proximity of waste sources as major criteria for bio-energy plant location.

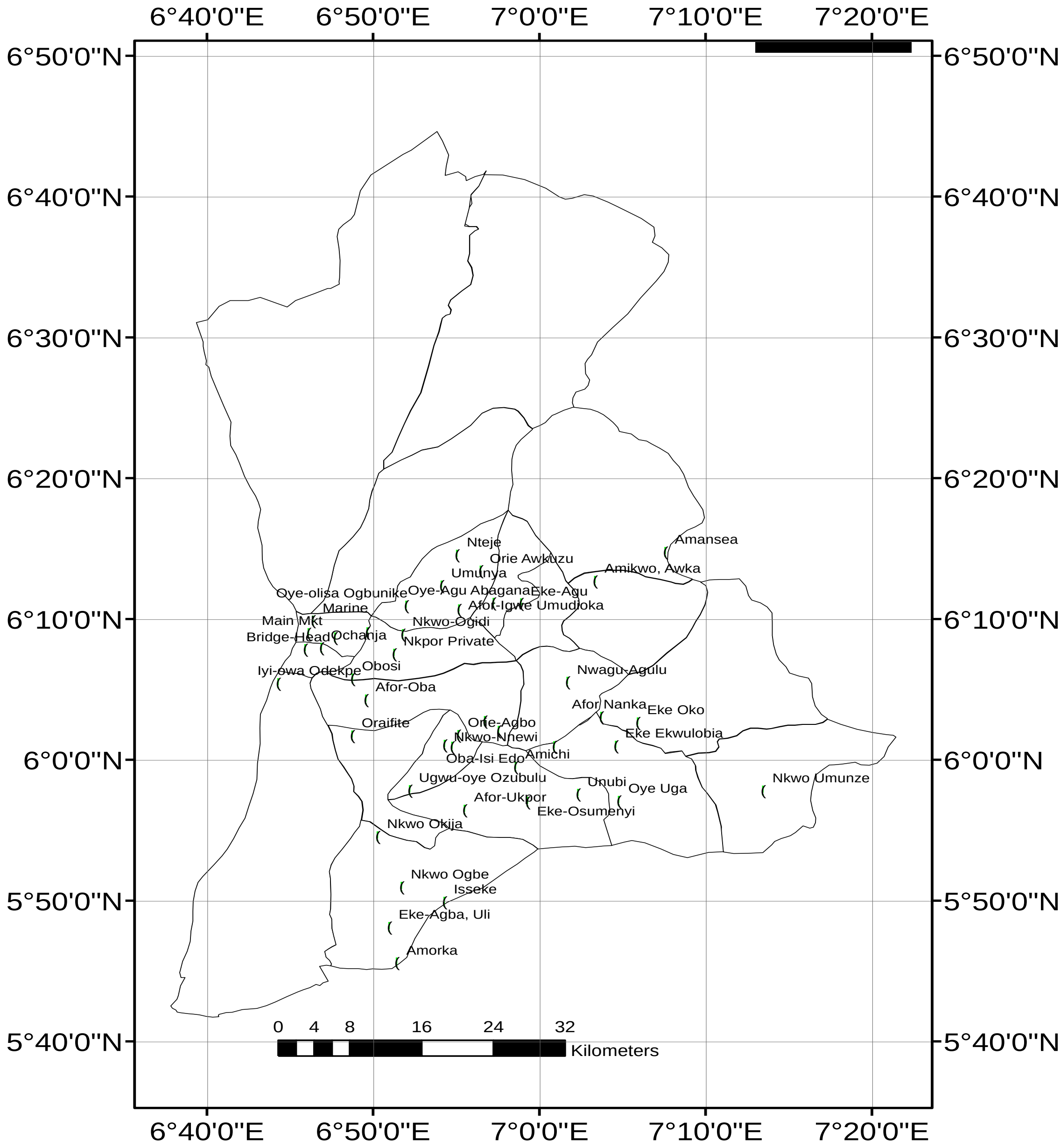

Figure 4.14: Abattoir Waste Generating Sites

4.4 Spatial Statistics of Biomass Availability

The Spatial Statistics is a method of analyzing spatial distributions, patterns, processes, and relationships. While there may be similarities between spatial and non-spatial (traditional) statistics in terms of concepts and objectives, spatial statistics are unique in that they were developed specifically for use with geographic data. Unlike traditional non-spatial statistical methods, they incorporate space (proximity, area, connectivity, and/or other spatial relationships) directly into their mathematics.

4.4.1 Spatial density analysis of biomass availability

Density analysis of biomass availability takes known quantities of agricultural wastes obtained from field survey and spreads them across the landscape based on the quantity that is measured at each location and the spatial relationship of the locations of the measured quantities.

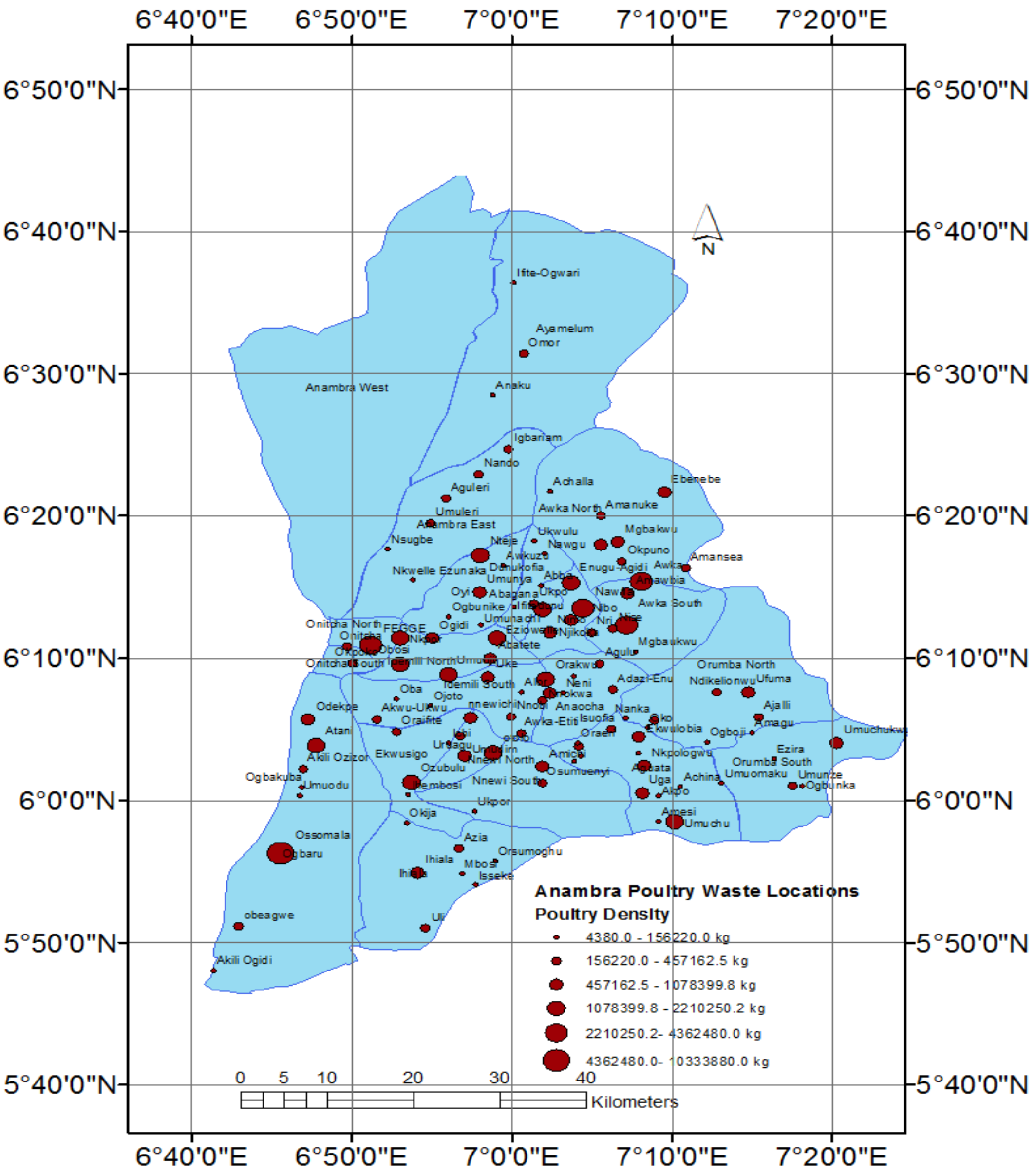

Figure 4.15: Poultry Production Spatial Density Map of the Study Area

Figure 4.15 shows the point density map of poultry production sites across the study area obtained from point density tool in spatial density toolbox in ArcGIS. From Figure 4.15, the Ogbaru town has the highest point density which is above 4,362,480kg of poultry droppings annually. This is followed by Umuchu, Onitsha, Nise, Nibo and Amawbia, with point density that ranges from 2210250 to 4362480kg. The point density map ranges of other poultry production sites with their various ranges are as shown in Figure 4.15.

4.4.2 Spatial distribution analysis of biomass locations

Hot spot analysis uses vectors to identify the locations of statistically significant hot spot and cold spot of poultry production sites. The analysis is focused on determining if high or low biomass resource centre are clustered. Spatial statistic toolset was used to analyze the dataset. A high Z score and small P value for a feature indicates a significant hot spot. A low negative Z score and small P value indicates a significant cold spot. The higher (or lower) the Z score, the more intense the clustering. A Z score near zero means no spatial clustering. The spatial clustering of poultry production sites is shown on Figure 4.16:

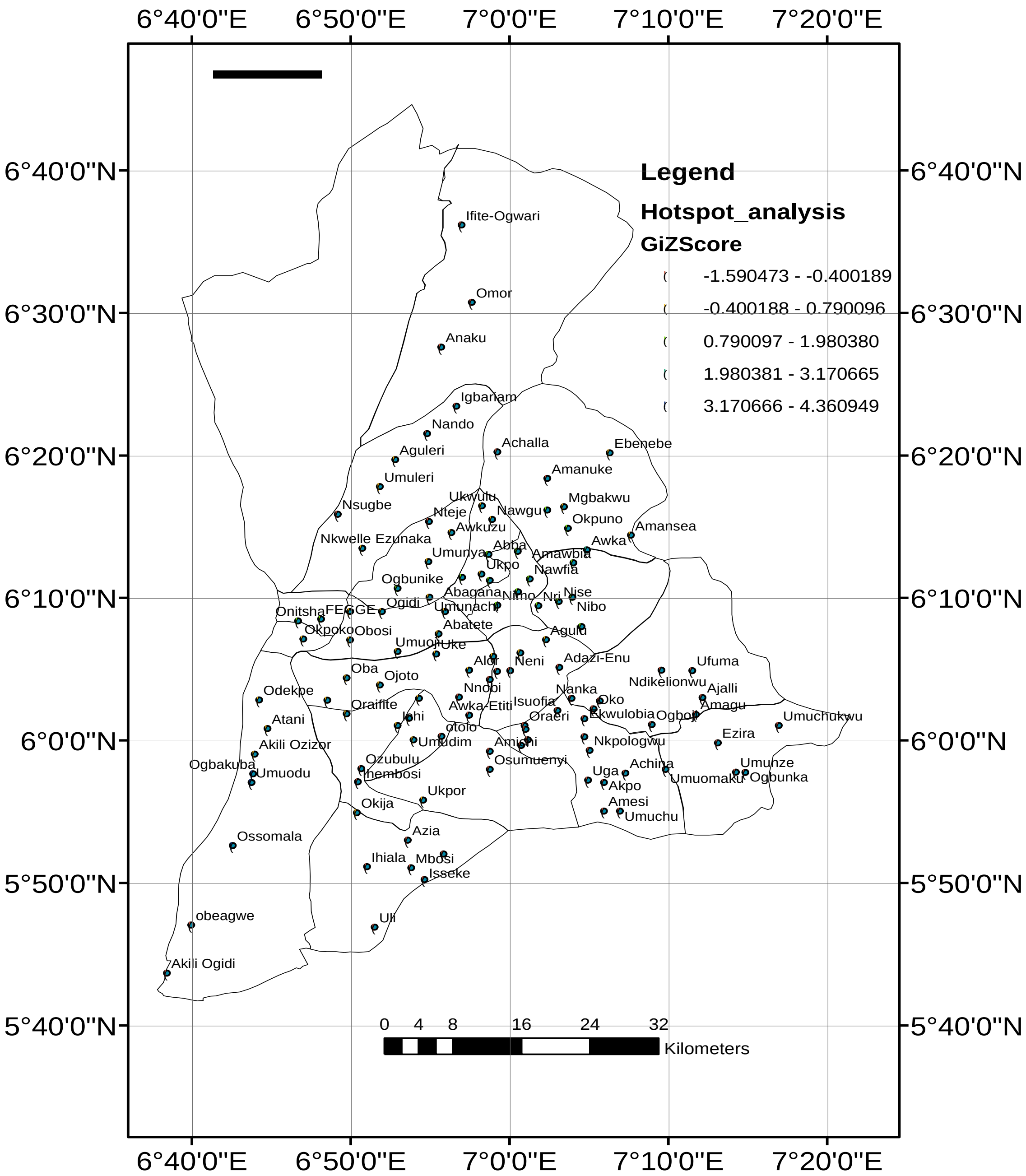

Figure 4.16: Hotspot Analysis of poultry production sites

The box “generate report” was selected in the Getis-Ord General G statistic, this produced a report which is shown below:

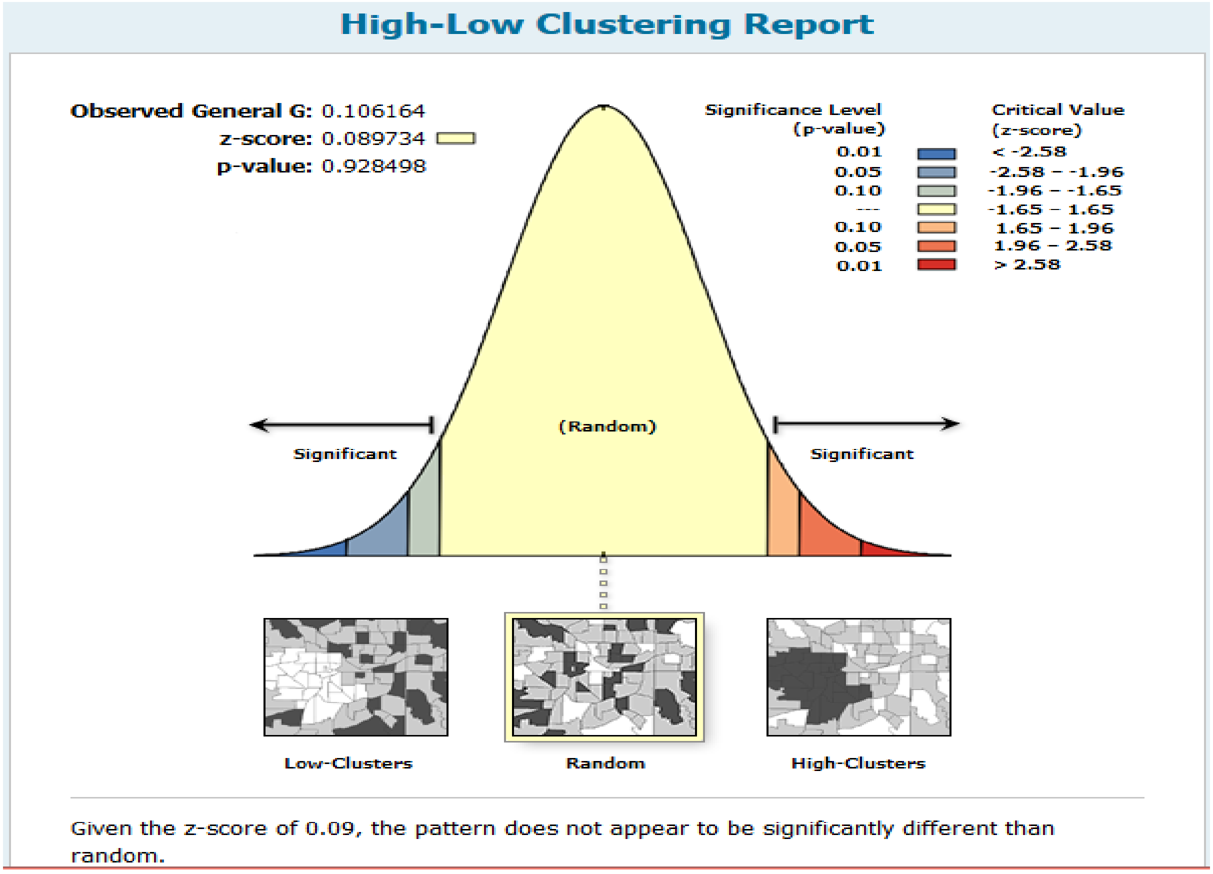

Figure 4.17: High-Low clustering report

The observed General G is 0.106164, while the z score is 0.089734. The p-value is 0.928498 as shown on Figure 4.17. The value of z lies between -1.65 to 1.65, the pattern therefore does not appear to be significantly different than random.

Table 4.2: High-low clustering statistical values

General G Summary	Values
Observed General G:	0.106164
Expected General G:	0.104247
Variance:	0.000457
z-score:	0.089734
p-value:	0.928498

Spatial autocorrelation test was further undertaken to see if the general pattern of features is clustered or dispersed (as opposed to clustering specifically of high or low values) as done for the data above, Univariate Moran's I is a global statistic that tells you whether there is clustering or dispersion, but it does not inform you of the location of a cluster. Moran's index of 0.018522 and z score of 0.96 indicates that there is no cluster of similar values. Since it is positive, there is an overall pattern of clustering of biomass centre. It is also quite far from 1, indicating the values are slightly clustered.

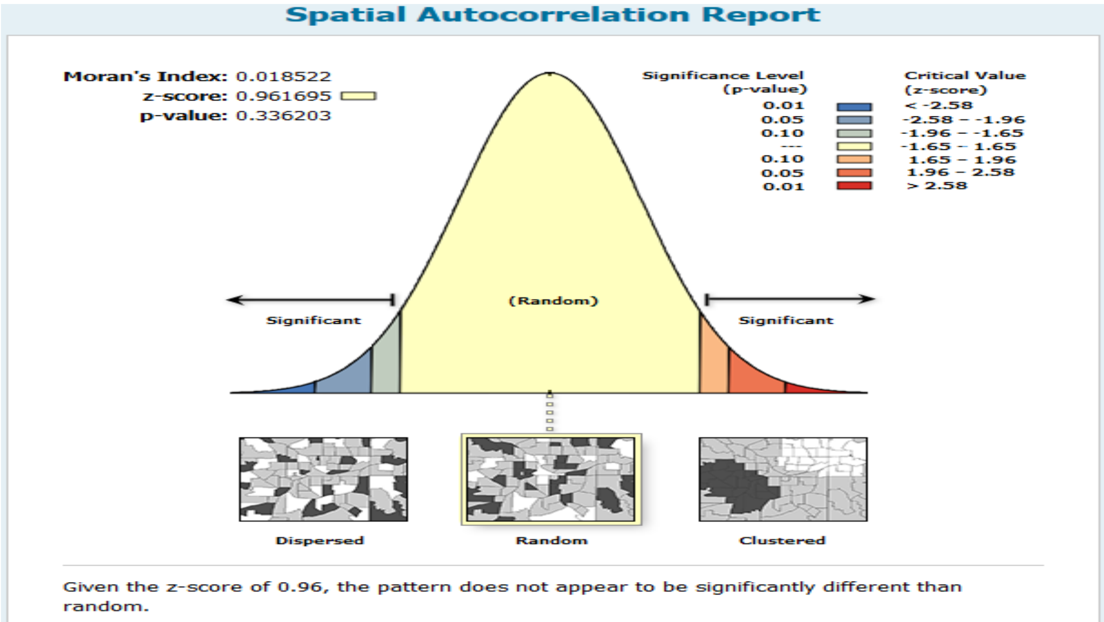

Figure 4.18: Spatial Autocorrelation Report

The auto-correction table report is presented below:

Table 4.3: Autocorrelation Index

General G Summary	Values
Moran's Index:	0.018522
Expected Index:	-0.009009
Variance:	0.000820
z-score:	0.961695
p-value:	0.336203

4.4.3 Spatial Density of biomass resource

The spatial density map of paunch waste generated across the state is shown in Figure 4.19. The map shows that Onitsha North has the highest spatial density; this could be attributed to the population density of the area and clustering of slaughterhouses in the area. This is followed by Idemili North, Idemili South and Oyi L.G. A. Their spatial density ranges from

2780-9356kg/km^2, indicating that these areas have appreciable slaughterhouses and consequently high abattoir waste. Njikoka, Awka South, Ekwusigo and Ihiala L.G.A has slightly lower spatial density of wastes ranging from 1105-1150kg/km^2 in comparison to Nnewi North, Orumba North and South with estimated spatial density of wastes that ranges from 1511-2779kg/km^3.

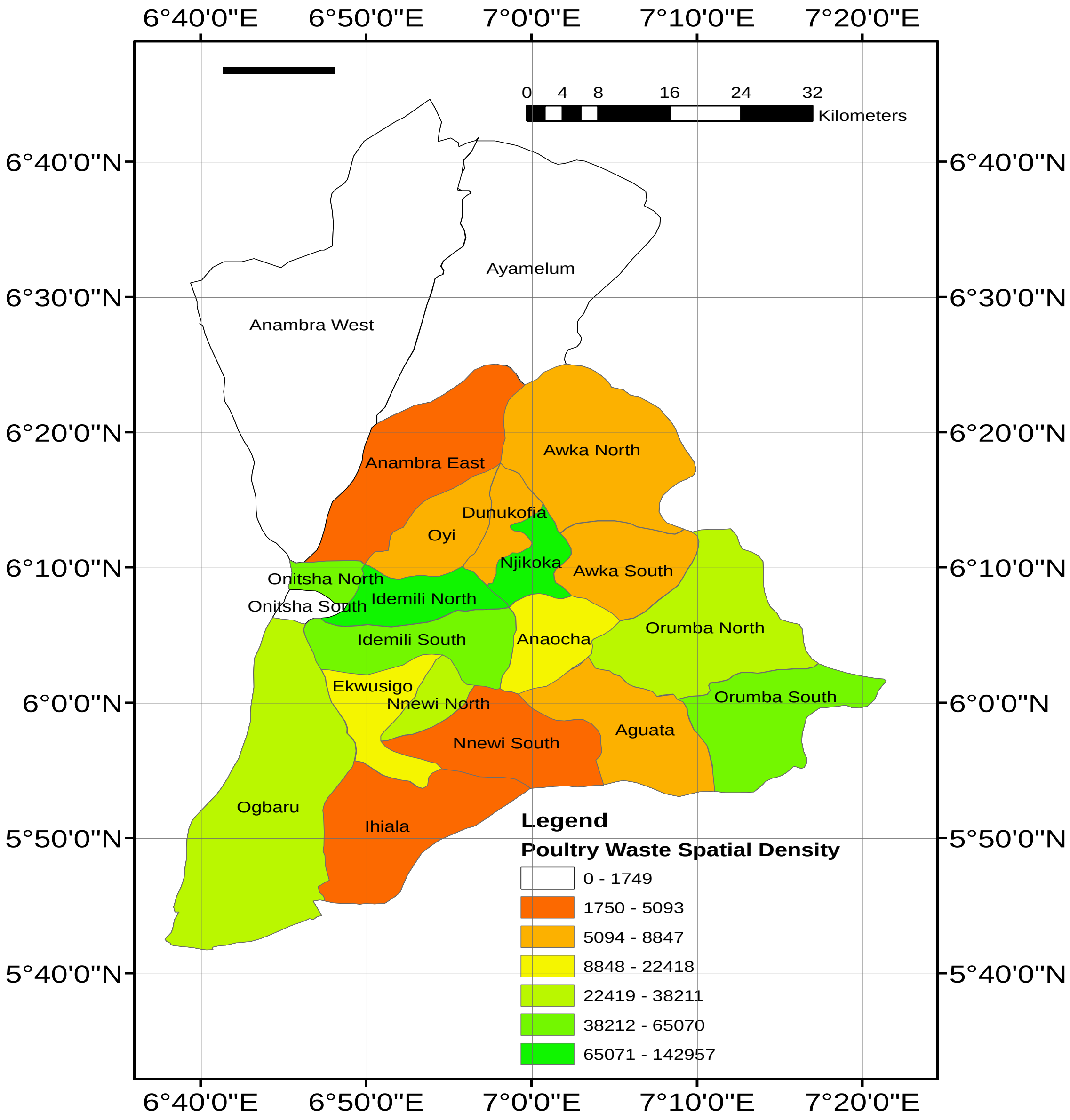

Figure 4.19: Spatial density map of Poultry waste capacity

Dunukofia and Anaocha L.G.As have spatial density ranging from 791-1104kg/km^2 while Nnewi South, Aguata and Awka South had spatial density ranging 50-790kg/km^2 , though these L.G.As have a good number of abattoirs, the landmass probably attributed to it low spatial density value. Ogbaru, Onitsha South, Anambra East and West L.G.As have the lowest spatial density values of abattoir wastes majorly due to the absence of slaughterhouses in these areas or as a result of high landmass. Another major source of agricultural waste in the study area is abattoir wastes. There are wastes generated in the form of paunch manure, blood, animal droppings etc Figure 4.20 shows the spatial density of abattoir wastes generated in the study area.

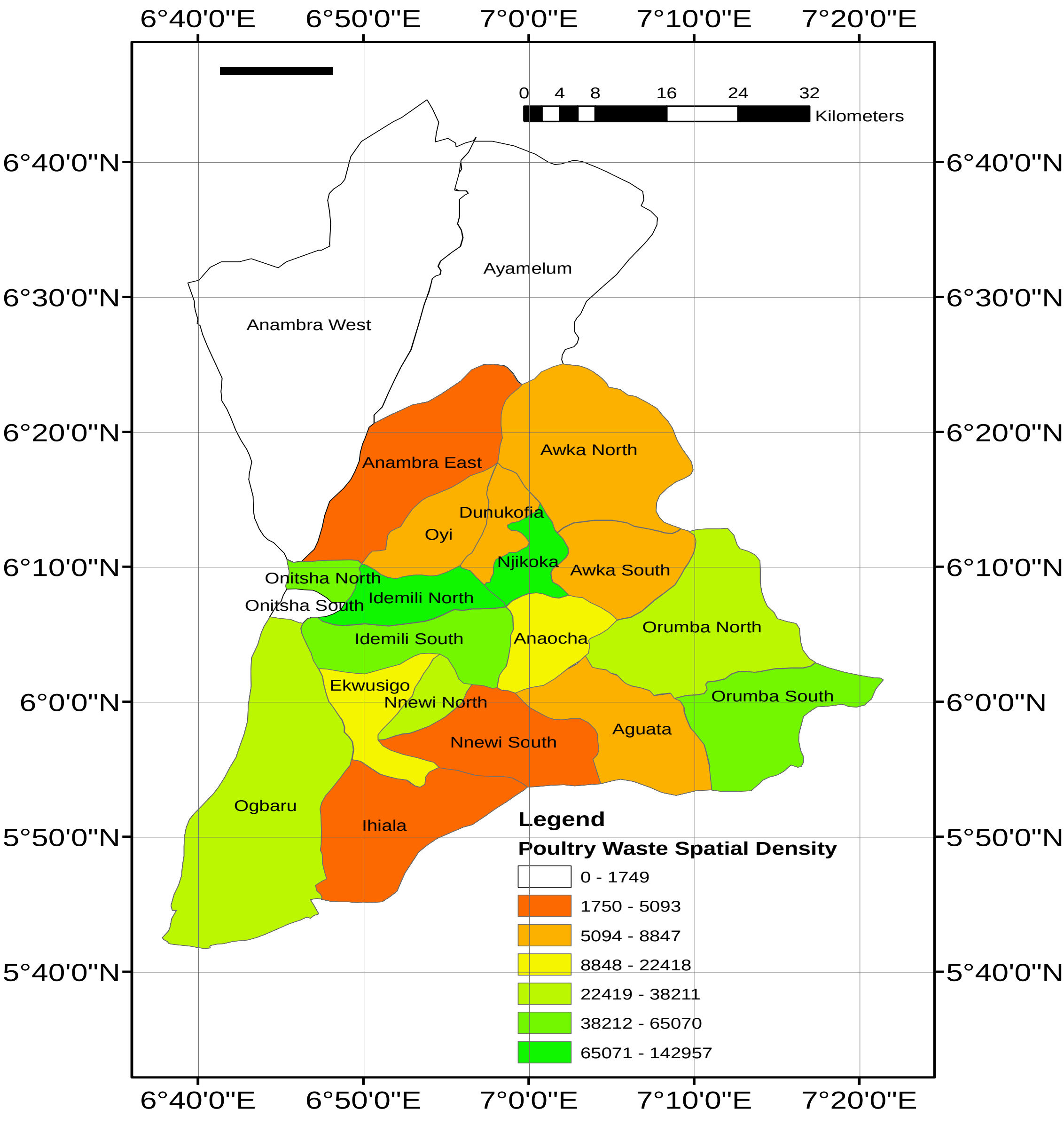

Figure 4.20: Abattoir Spatial density map of the study area

From the Figure 4.20, Onitsha North is shown to have the highest spatial density of generated waste. This could be attributed to the human population density of the area and the small land mass of the area. Oyi, Idemili North and South L.G.A are observed to be slightly lower than Onitsha, and is seen to have between 2780-9356kg/km of spatial density of abattoir wastes. Other Local government as indicated have varying spatial density with the minimum been Anambra West and East, Ayamelum and Ogbaru L.G.A. This could also be attributed to their high land mass, and lack of abattoir centres in these areas. Emphasis is laid here on the major sources of agricultural waste generation which includes poultry and abattoir wastes.

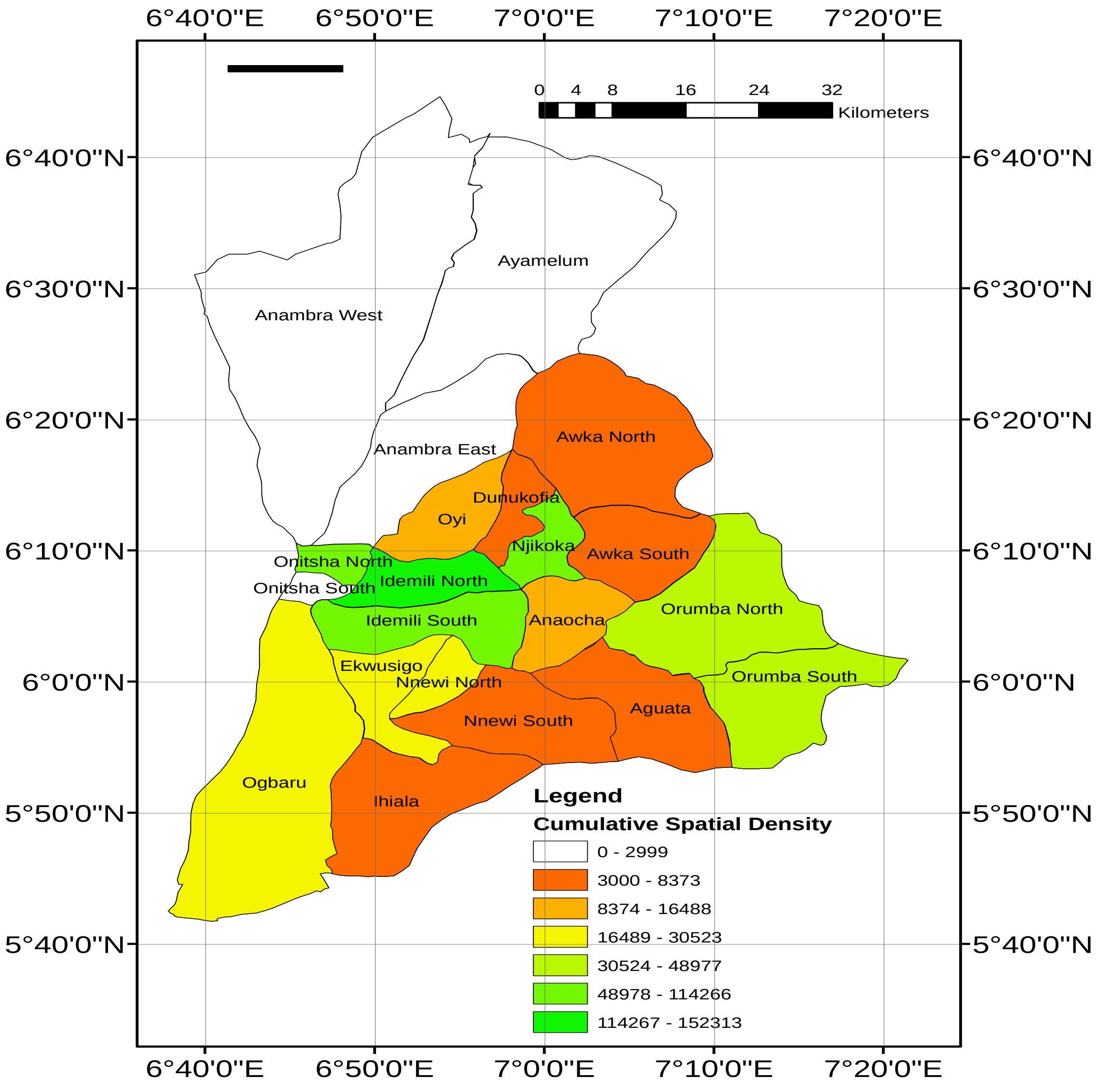

Figure 4.21: Cumulative Spatial density map of livestock and Abattoir waste generation

The cumulative wastes generated from both source is as shown on Figure 4.20. The spatial density map signifies that there is a clustering of high spatial density of areas for the cumulative wastes around Idemili North and South, Njikoka and Onitsha North. This centralization or clustering of these high wastes generation areas has a positive economic advantage in the form of minimization of transportation cost.

4.5 Spatial Modelling of Bio-energy Location

Spatial modelling involves applying one or more of three categories of GIS function to some spatial data. This includes geometric modelling functions. Generating buffers is a type of geometric modelling analysis, and as one of the spatial models was used in this study in modelling bio-energy site. Buffer is a type of GIS analysis of finding what is near a feature. One way to find what is near a feature is by creating a buffer around the feature. GIS Site suitability analysis could identify suitable site within a given distance of a proposed bio-energy site by buffering the economic dependent features. The buffer could be used with other layers of data to show which sites would be near the bio-energy centre. Figure 4.22 shows the buffering of road in the study area. It is proposed that for economic reasons the bio-energy centre should be located preferably within 100 meters of the road network. The farther it is, the less economic viable the site is. A buffer of 100 meters, 1 kilometers, 3 kilometers and 5 kilometers were created. This is similar to a study conducted by Yuttitham et al. (2003) where transportation distance were graduated and weighted according to proximity to road network.

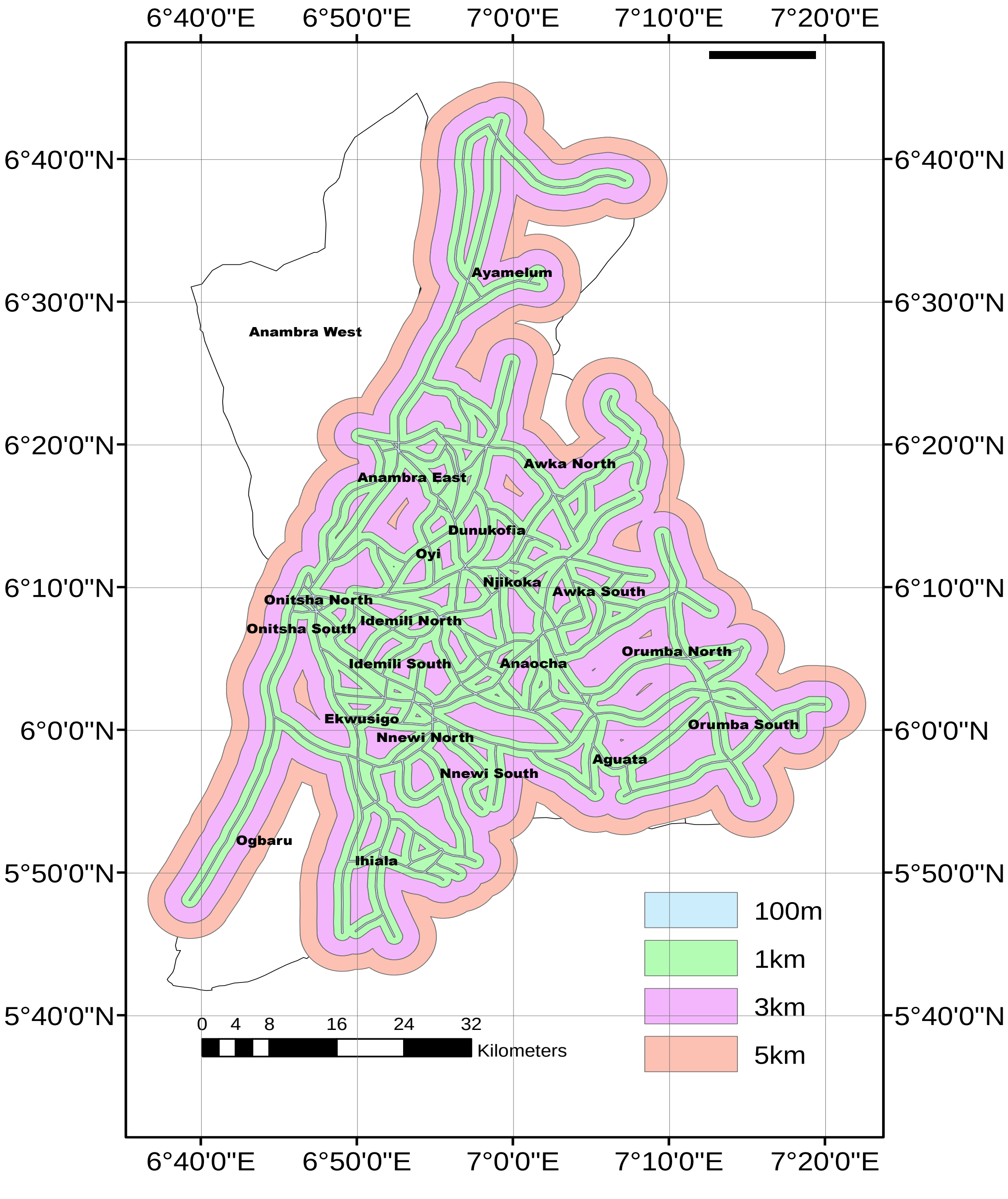

Figure 4.22: Multiple Ring Buffered Road of the study area

Another economic index in bio-energy siting is distance to electric transmission line, transmission Losses can be reduced by siting bio-energy facilities close to transmission lines. Kumar and Sultana, 2012 and Uyan (2013) considered distance to transmission line in their study, while Wang et al., (2013) define land suitability for ADS development on the same basis and resulted in the identification of clusters of suitable areas near three-phase transmission lines in Addison County. A buffer of 1, 3, 5 and 10 kilometers were created in this study (see Figure 4.23). The buffer of 1km of the electric transmission line (Onitsha North to Enugu transmission line) traversed Onitsha North, Oyi, Dunukofia, Njikoka, Awka North and South L.G.As while the transmission line from Onitsha South to Owerri crisscross Idemili, Egwusigo, Nnewi North and Ihiala L.G.As. However, despite the maximum buffer of 10km Ayemelum and Orumba South L.G.As were both exempted in the overlapping of the buffers. These areas are worst zones in siting bio-energy plants in proximity to electric transmission lines.

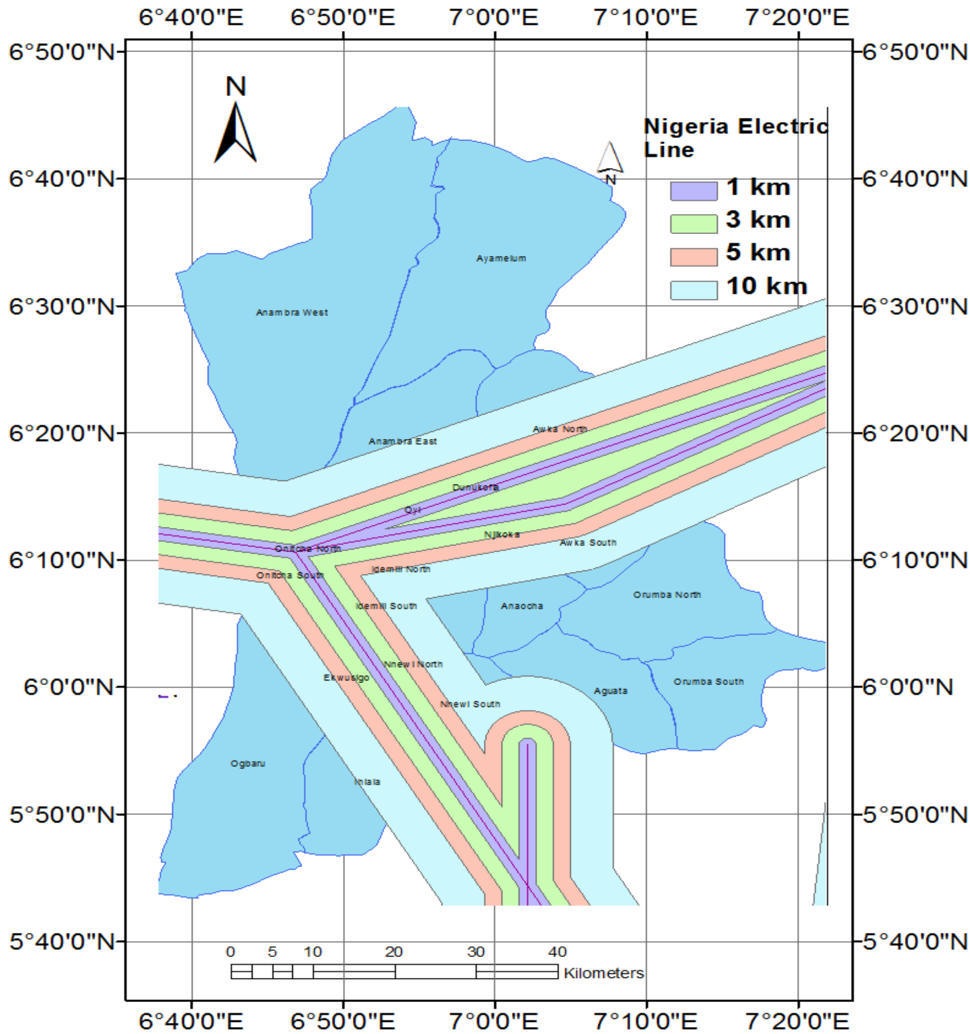

Figure 4.23: Multiple Ring Buffered Transmission Line of the study area.

A fundamental difference between GIS-based and non-GIS models is that datasets in GIS models, such as geographic distribution of biomass, highway networks and processing plant location in the study area can be layered and geographically integrated. The multi-layer datasets allow spatial manipulation of that integrated information, such as extraction of biomass availability information within different driving distances from biorefinery locations in the study area. There is need to develop a method capable of integrating biomass availability, energy demand, biogas production, in a realistic dynamic geographical model, such that conclusions can be drawn on mainly the sustainability, and additionally on the efficiency, flexibility and economy of biogas production in the study area. The importance of transportation costs, region-specific road infrastructure, and the nature of commodities transported usually have major influence on the economy of bio-energy siting. The study area was buffered to ensure that transportation cost is minimized in the cause of supply the bio-energy plants with agricultural wastes. Since poultry waste production is the major source of waste for bio-energy production in the study area, the driving distance of 5km, 10km, 15km and 20km was used. Lopez et al, (2008) in a study for the feasibility of biogas plant production installation in Sonderborg reported that a driving distance over 14 km brings in the need for farm separation before transporting slurry to the biogas plant. However, in this study, most of the farms in this study area were situated within 5km radius according to the distance analysis done using the map, As a result of spatial clustering of the farms, there was overlapping of the bio-energy supply sites, this could also be attribute to the high population density of the study area. Figure 4.24 shows the buffering of the bio-waste sources and the overlap especially in the central part of the study area.

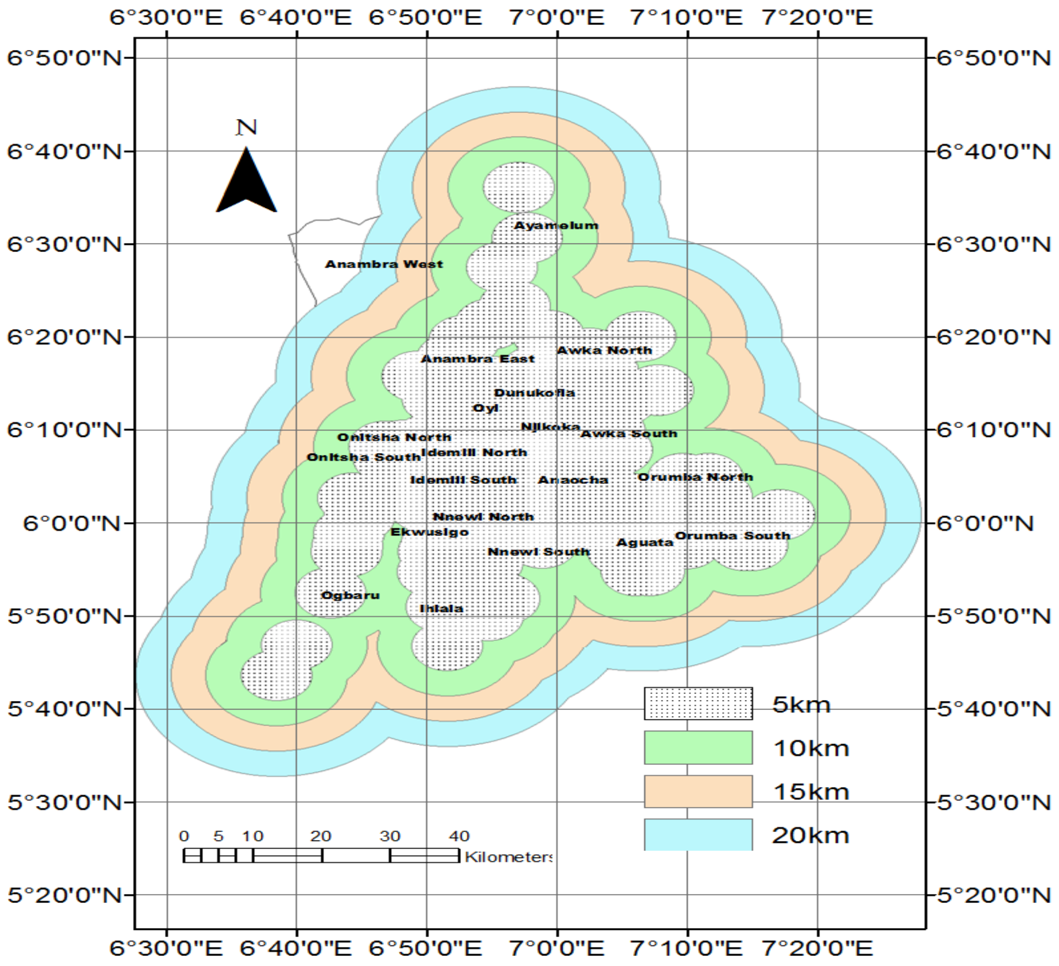

Figure 4.24: Spatial buffering of livestock production sites

A constraint map was developed for the GIS analysis, the constraint map criteria is shown in Table 4.4

Table 4.4: Criteria for constrain map

Constraints	Specifications
Rural and urban areas	A distance of 1 km from residential and urban areas
Park and recreational areas	Sites falling within these areas and a buffer of 500 m are avoided
Rivers, lakes and other waterbodies	Sites within buffer zone of 200 m are avoided
Wetlands	Wetland areas and a buffer zone of 200 m are avoided
Environmentally sensitive areas (flood plains, conservation areas, habitat sites)	Sites falling within such areas and a buffer zone of 500 m are avoided
Roads	Sites falling within a buffer of 30 m are avoided
Transmission line	Sites falling within a buffer of 100 m are avoided
Power plant and substation	Sites falling within a buffer of 100 m are avoided
Land surface gradient	Areas with slopes larger than 15% are avoided

4.6 Suitability Analysis

Suitability analysis involves the search for the best location of one or more facilities to support some desired function, it is the process to determine whether the land resource is suitable for a particular purpose. It is an important analytical method for ecological planning. Several factors were considered in the suitability analysis which include economic considerations, the spatial density, Land use and cover etc

4.6.1 Economic Suitability Analysis

The two economic factors considered are proximity to road and proximity to electric transmission line. Since proximity to road is considered to incur more cost as a result of being a continuous variable cost, more weight was given to this factor (85%) while proximity to electric transmission line as a fixed cost was given a weighted value of 15%, this is comparable to the work of Kumar and Sultana (2003), where road network was given the value of 3 and transmission line the value of 9 in pair-wise comparison matrix and weights of preference factors in AHP. The figure below shows that areas within the 100m and 1km buffer of road network was indicated as most and highly suitable sites respectively. 3km of the road network was indicated generally as moderate suitable sites while 5km distance from the road network was generally classified as less suitable except in Ayemelum L.G.A and parts of Anambra West, Anambra East, Ogbaru and Ihiala L.G.As. The GIS analysis portrays that location of sites 5km away from major roads in the state would be generally classified as unsuitable. The most suitable sites should be 100m to 3km of the road network in all the parts of the State.

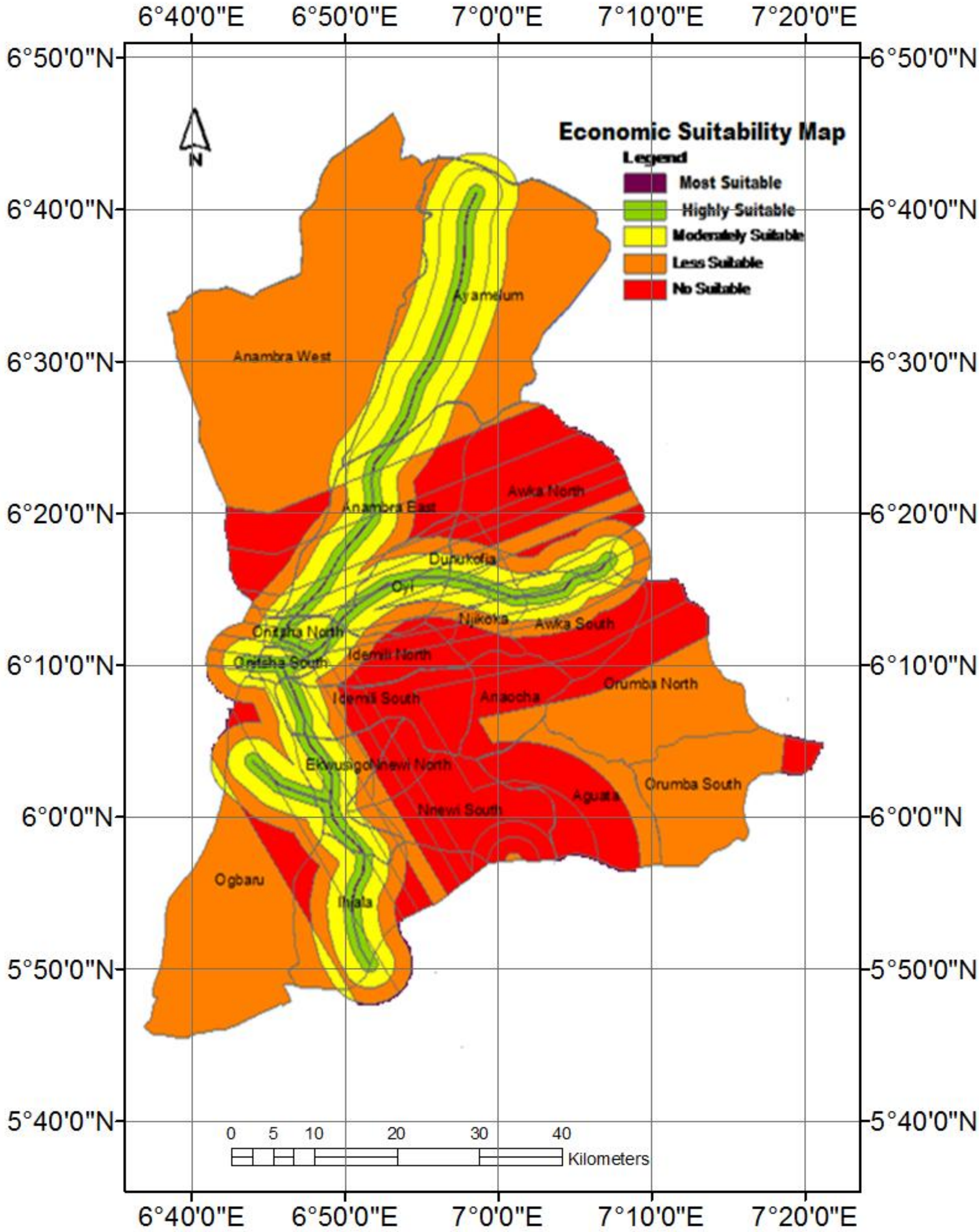

Figure 4.25: Economic Suitability Map

4.6.2 Economic and Spatial Density Suitability Analysis

From the combination of the economic and spatial density factor in determination of suitable sites for location bio-energy plant, the most suitable areas include Onitsha North and Njikoka L.G.A (see Figure 4.26). The highly suitable locations are within Onitsha North and South, Njikoka, Idemili, Egwuiso L.G.A. The moderately suitable sites are located at the extreme of

Onitsha North and parts of Onitsha South; 100m along Anambra East and Ayamelum L.G.A major road; also along the expressway connecting Oyi, Dunukofia, Awka North and South L.G.A; along Onitsha to Owerri major road are found other moderately suitable sites which are Idemili South, Ogbaru, Egwusigo, Nnewi North and Ihiala L.G.A; other sites classified as moderately suitable are Orumba North and South, and Idemili North. Other areas according to the Figure were classified as either Less Suitable or Not Suitable.

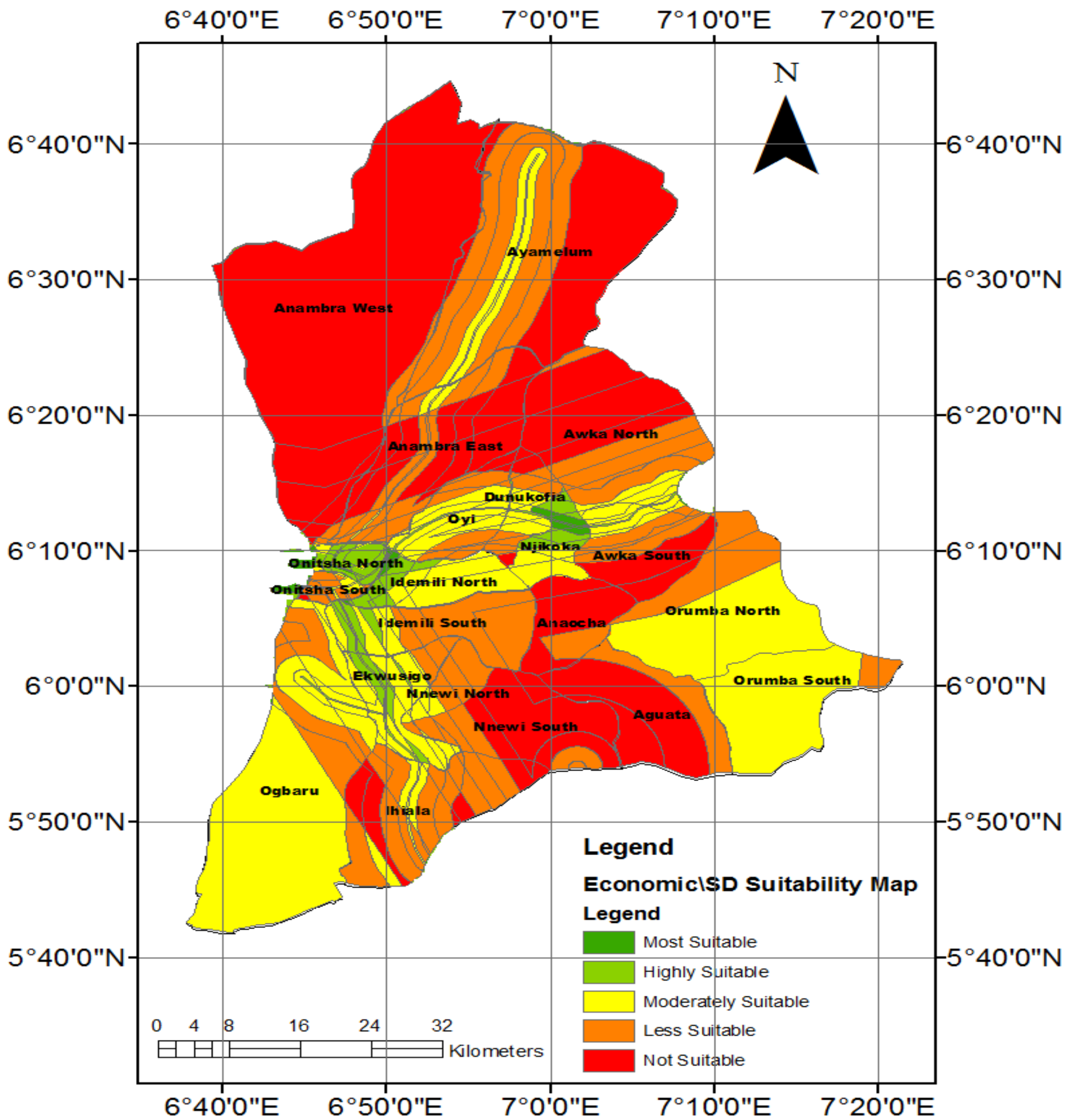

Figure 4.26: Economic and Spatial Density Suitability Map

4.6.3 Land Use Suitability Map

The land use suitability map was obtained by excluding unwanted areas identified as constrain map. These are areas prone to flooding, areas that are close to residential areas and water bodies etc. The Slope layer, Hillview layer and Elevation layers were overlay at 30%, 40% and 40% weight respectively using weighted Overlay tool. The weighted overlay tool in ArcGIS overlays several rasters using a common measurement scale and weights each according to its importance. The resultant dataset is the Land Use suitability map shown in Figure 4.27. The LULC suitability analysis showns is graduated from the Most Suitable to the Less Suitable.

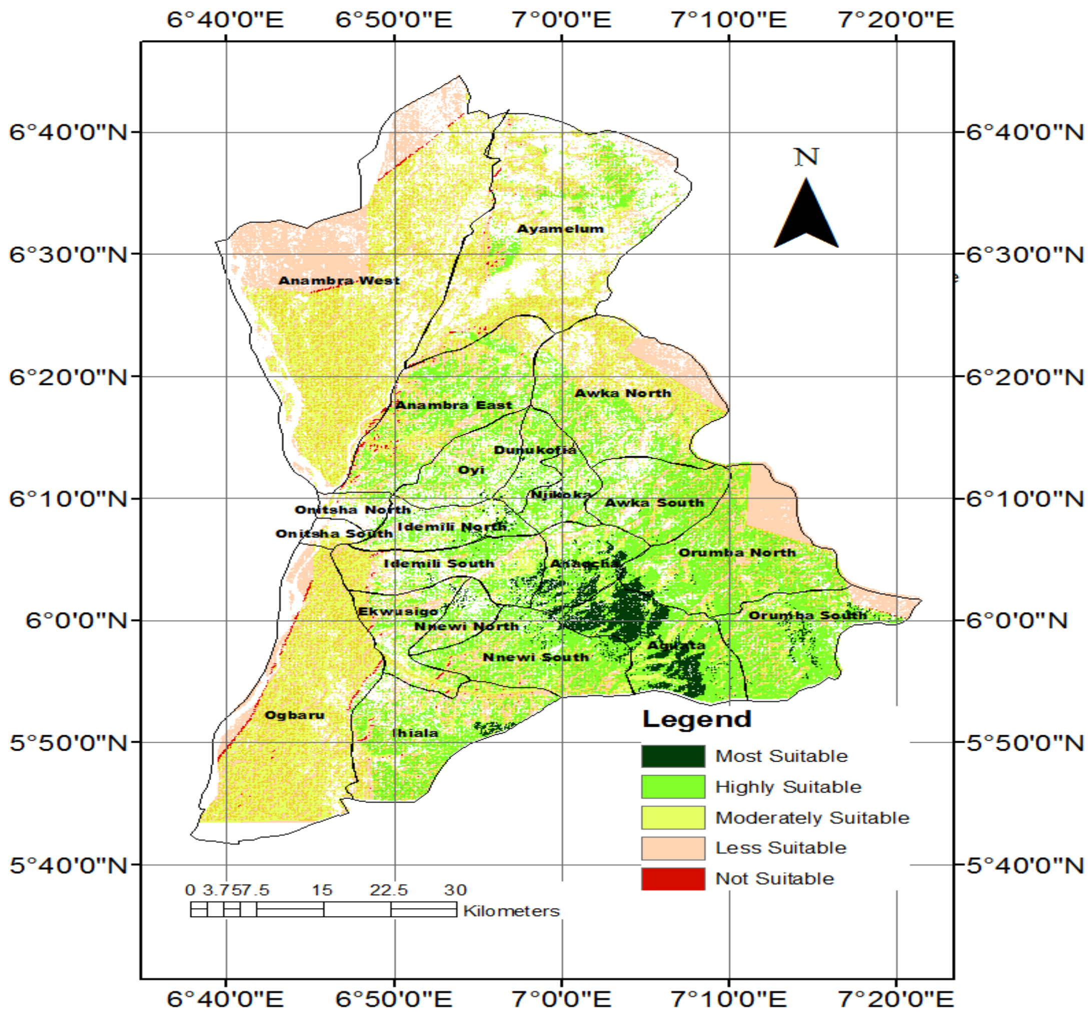

Figure 4.27: Land Cover and Land Use suitability map

The suitability map suggests that the most suitable areas are located mainly in Aguata, Aniocha, Orumba South and North, Nnewi South and North L.G.A. Ogbaru region was majorly classified as moderately suitable area because of it low elevation which makes the area unsuitable for siting bio-energy plants considering the emergency of flood.

4.6.4 Final Suitability Map

The most suitable and the highly suitable areas were extracted from the land use suitability map and overlayed with economic and spatial density suitability map to obtain the final suitability map. This is shown on Figure 4.28.

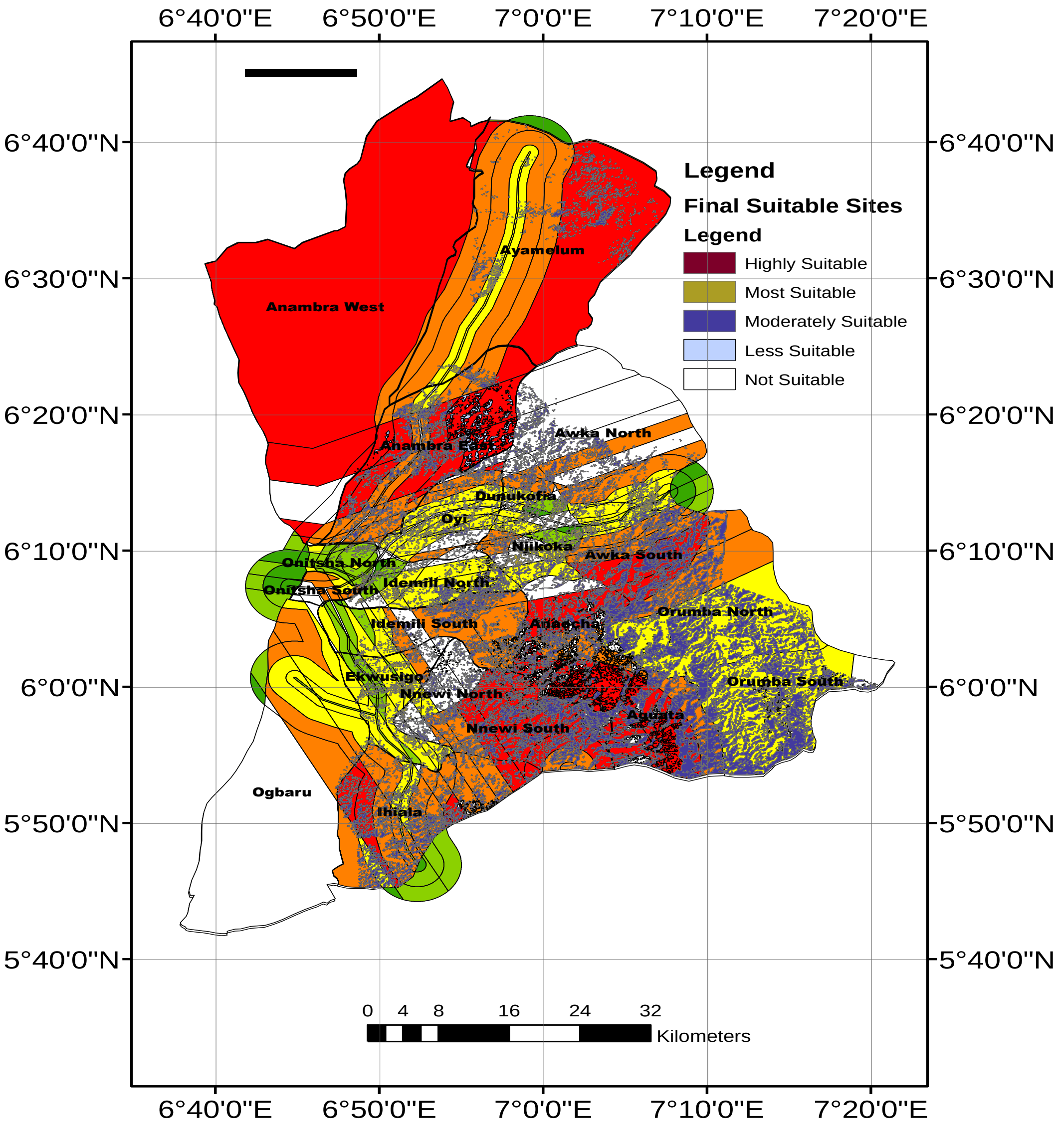

Figure 4.28: Final Suitability Map of the Study Area

The final suitability map shown above indicates patches of sites designated as most suitable and highly suitable sites. About 186 polygons were identified as the most suitable considering land use suitability index. The most suitable land use polygons that intersected with the most suitable economic and spatial density suitable polygons were identified and designated as the most suitable sites for bio-energy siting. The most suitable sites identified were located in Njikoka, Onitsha North and Dunukofia L.G.A. The Figure 4.29 shows polygons of most suitable sites overlaying with high index economic suitable sites in Njikoka L.G.A

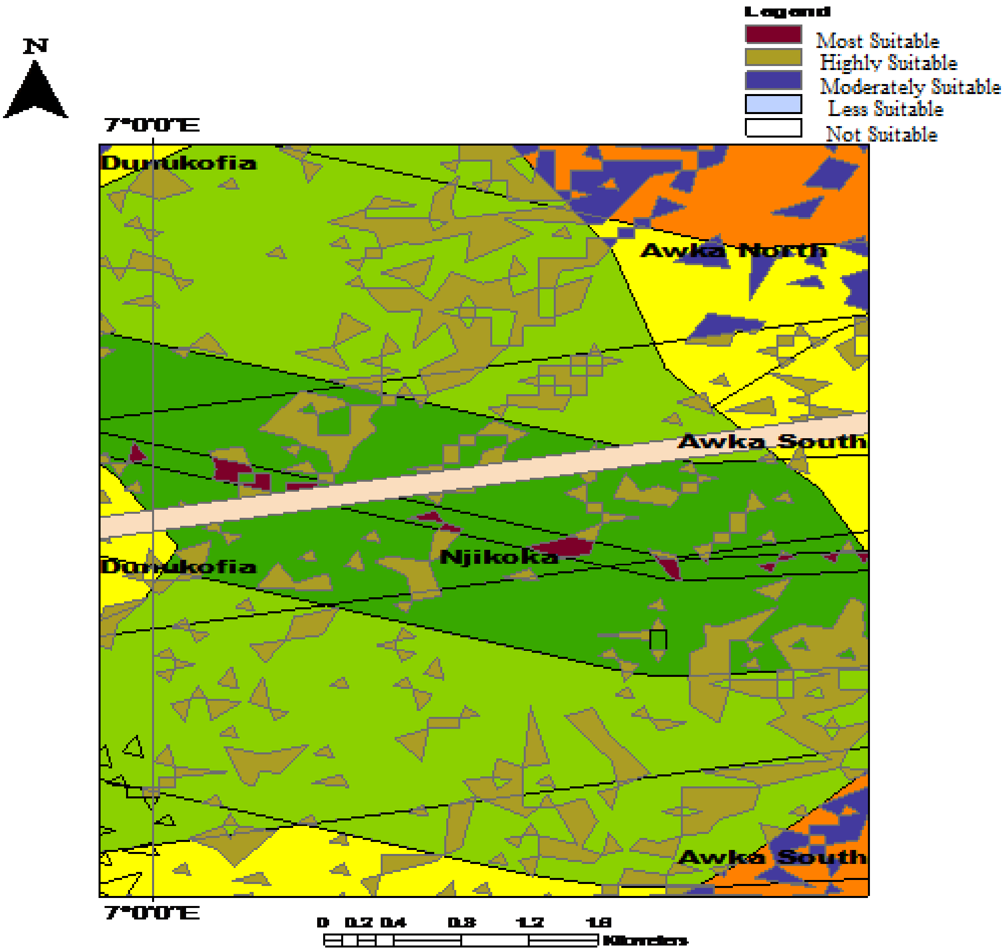

Figure 4.29: Suitable sites in Njikoka L.G.A

Most suitable sites were identified in Njikoka L.G.A, the Figure above shows a number of suitable polygon sites, these sites were intersected by a major road from Onitsha to Awka. The Figure also shows the buffered electric transmission line across the major road, displaying that the proximity of major road and electric transmission line was achieved in the site selection through GIS analysis.

Other highly suitable sites shown on the high indexed economic suitability sites could also be harnessed for siting bio-energy plant should the available most suitable sites be insufficient. Apart from suitable sites obtained from Njikoka L.G.A, polygons of most suitable sites were also identified in Onitsha region. This is shown in Figure 4.30:

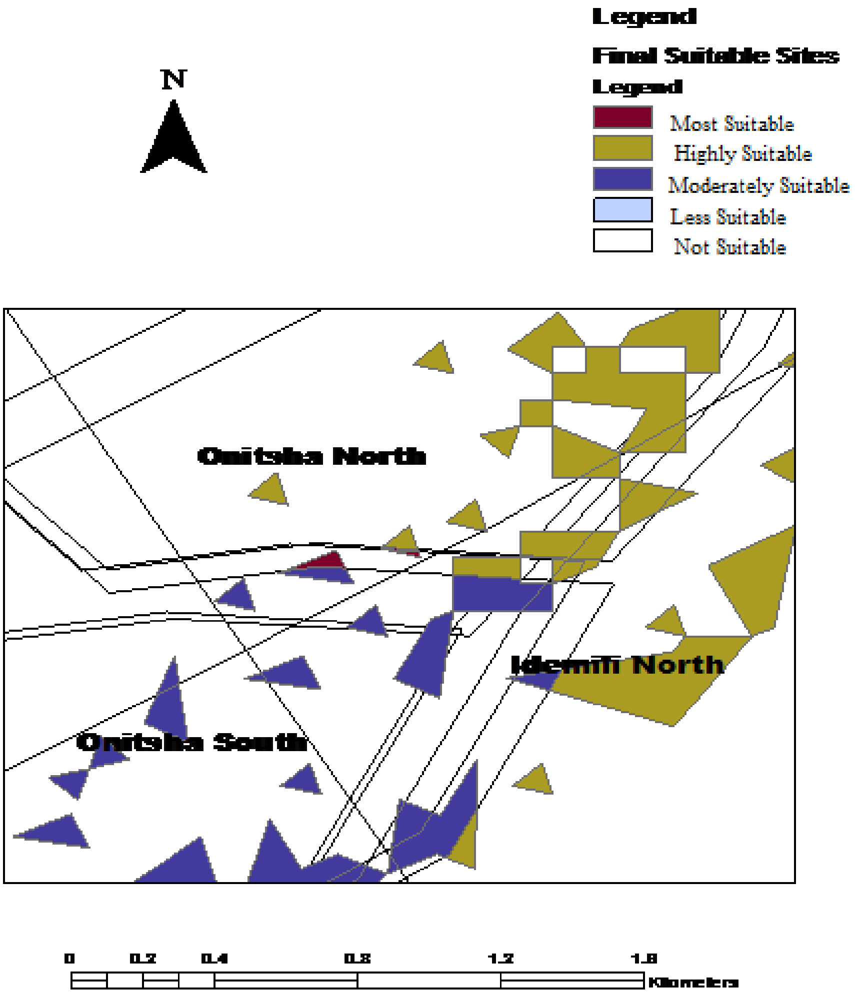

Figure 4.30: Suitable sites in Onitsha North L.G.A

Unlike Njikoka L.G.A that is characterized with multiple suitable polygons, most suitable sites in Onitsha North are shown to be primarily of two sites which are close to each. These sites are also close to electric transimission line and the major road network. Three suitable sites were identified in Dunukofia L.G.A. These sites were scattered across the L.G.A. One of the suitable sites is as shown in Figure 4.31:

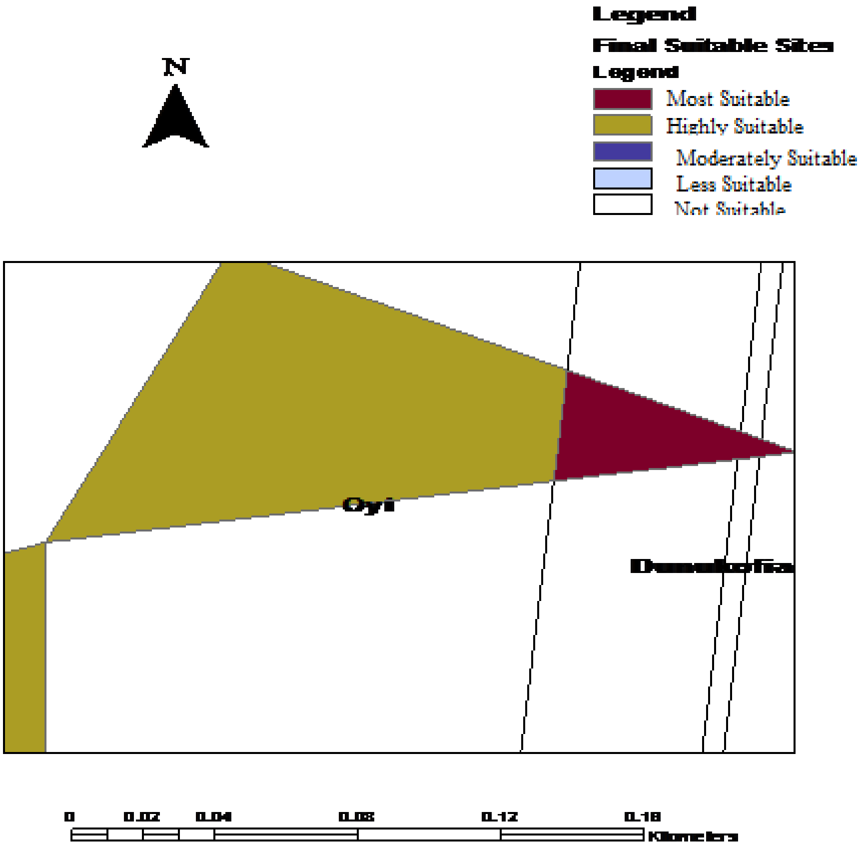

Figure 4.31: Suitable sites in Dunukofia L.G.A

The co-ordinate points of these most suitable sites were obtained and recorded in Table 4.4 below:

Table 4.4: Co-ordinate points of most suitable sites in the study area

	Towns	X	Y
1	Onitsha North	6.81	6.128
2		6.813	6.125
3	Njikoka	6.999	6.206
4		7.004	6.204
5		7.014	6.201
6		7.022	6.198
7	Dunukofia	6.958	6.235
8		6.957	6.222
9		6.954	6.211

4.7 Location Optimization

Optimization of location for both single facility scenario and multiple facility scenarios using location model was achieved. The result of the optimization analysis is presented under single and multiple facility location modeling.

4.7.1 Single Facility Location Modelling

The modified capacitated location model shown in equation 3.13 was used to evaluate the three most suitable locations viz- Onitsha, Njikoka and Dunukofia L.G.As. The result of the analysis is presented in the Appendix Table B.21. The result of the model computation shows that when the distance of travel includes addition of waste sources that are above 40km to the central waste processing site, the cumulative distance is 2873.26km, 2504.51km and 2698.23km for Onitsha, Njikoka and Dunukofia respectively. However, for distance less than 40km (which is the recommended maximum distance of travel for animal waste processing because of economic reasons) the cumulative distances are 2219.948km, 2070.08km and 2049.64km respectively for Onitsha, Njikoka and Dunukofia respectively. This indicates that Dunukofia has the least travel distance and would serve as a central point for single facility location in the study area. Also considering the cumulative distance and the quantity of waste conveyed for above 40km and less than 40km, the result of the study indicates Dunukofia is the best location for facility location having the least waste load distance value amongst the three most suitable locations.

4.7.2 Multiple Facility Location Modelling

The set covering location model was used to determine the minimum suitable locations that will enhance maximum coverage. The power of GIS which enhances visualization of spatial data was used to obtain collection centres. The hotspot sites and land suitability model were used in selecting areas that will give a good coverage for all demand points. The most suitable, highly suitable and moderately suitable were selected as potential sites, site collection radius of 3 and 10km were used as the maximum distance of transportation for economic reasons. Figure 4.32 shows the various collections radial obtained using the above procedure. About ten collections radial were obtained, which are shown in Figure 4.32:

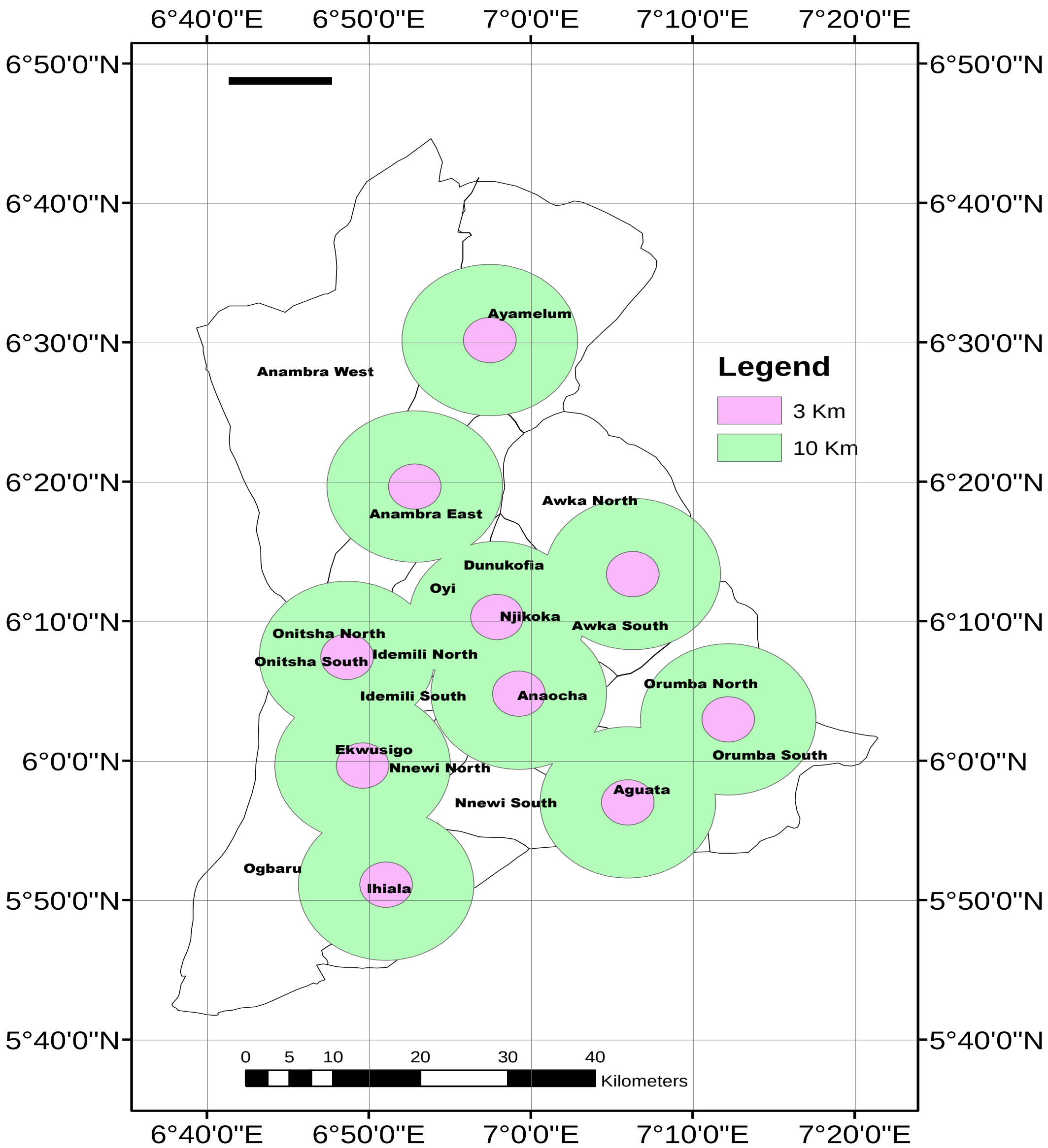

Figure 4.32: 3-10 km distance drive coverage for optimum location of bio-energy centres

The central locations of the collection radius are Onitsha, Orafite, Awka, Ihiala, Ajali, Akpo, Abagana, Adazi-ani, Aguleri and Omor. The selection was done in such a way as to cover the entire waste generating centres. The set location covering model as explained in section 3.7.2.1 was used to determine the minimum location points and locations to be opened, the result is as shown in Table 4.5.

Table 4.5: The result of sites selection using the set cover location model

Objective Coefficient	13	6	11	2	2	1	13	1	4	
	*1	*2	*3	*4	*5	*6	*7	*8	*9	Optimal objective value
Decision Variable	0	0	0	1	1	0	1	0	0	17
Constraints	*1	*2	*3	*4	*5	*6	*7	*8	*9	
1	1	1	0	0	0	0	1	1	0	
2	1	1	0	1	0	0	0	0	0	
3	0	0	1	0	0	0	1	8	0	
4	0	1	0	1	0	0	0	0	0	
5	0	0	0	0	1	1	0	0	0	
6	0	0	0	0	1	1	0	1	9	
7	1	0	1	0	0	0	1	1	1	
8	0	0	0	0	0	1	1	1	0	
9	0	0	0	0	0	0	1	0	1	

`Computations

	*1	*2	*3	*4	*5	*6	*7	*8	*9	LHS	RHS
1	0	0	0	0	0	0	1	0	0	1	1
2	0	0	0	1	0	0	0	0	0	1	1
3	0	0	0	0	0	0	1	0	0	1	1
4	0	0	0	1	0	0	0	0	0	1	1
5	0	0	0	0	1	0	0	0	0	1	1
6	0	0	0	0	1	0	0	0	0	1	1
7	0	0	0	0	0	0	1	0	0	1	1
8	0	0	0	0	0	0	1	0	0	1	1
9	0	0	0	0	0	0	1	0	0	1	1

The decision row above shows that a minmum of three locations are to be opened in Abagana, Ihiala and Ajali. A visualization of the locations shows that the set covering location model provided a wide coverage for all the waste producing sites in the state.

The location allocation model was further used to determine the allocation of the various wastes to the three multiple facility locations obtained using the set covering location as noted above. The origin cost destination matrix was first developed and used in the location allocation modeling. The origin cost destination matrix of all the 10 locations used in the formation of collection radius is shown in Table 4.6:

Table 4.6: Origin cost destination matrix for location allocation modelling

	Onitsha	Orafite	Awka	Ihiala	Ajali	Akpo	Abagana	Adazi-ani	Aguleri	Omor
Onitsha	1	13.2327	34.9245	32.7025	48.1901	41.328	22.9573	24.1106	23.6949	45.8486
Orafite	13.2327	1	35.1095	34.2902	41.5605	31.318	23.9722	18.3885	33.264	55.0598
Awka	34.9245	35.1095	1	48.2437	23.3226	30.0606	12.0083	18.8496	25.2349	34.6648
Ihiala	32.7025	34.2902	48.2437	1	44.7888	29.7022	39.6113	29.4073	52.6148	73.8375
Ajail	48.1901	41.5605	23.3226	44.7888	1	15.8605	29.0611	24.1861	47.195	57.6571
Akpo	41.328	31.318	30.0606	29.7022	15.8605	1	29.2909	18.9998	48.2572	48.2572
Abagana	22.9573	23.9722	12.0083	39.6113	29.0611	29.2909	1	11.7777	16.1172	19.085
Adazi - ani	24.1106	18.3885	18.8496	29.4073	24.1861	18.9998	11.7777	1	11.9008	47.7151
Aguleri	23.6949	33.264	25.2349	52.6148	47.195	48.2572	16.1172	11.9008	1	22.1928
Omor	45.8486	55.0598	34.6648	73.8375	57.6571	48.2572	19.085	47.7151	22.1928	1

The location allocation model as stated in equation 3.16 and 3.17 was solve with excel solver, the solution of the model is shown in Table 4.7

Table 4.7: location allocation model output

P_{ij}	1 (Osha)	2 (Ora)	3 (Awka)	4 (Ihiala)	5 (Ajali)	6 (Akpo)	7 (Aba)	8 (Adazi)	9 (Agu)	10 (Omor)	**Capacity**
1 (Ihiala)	0	0	0	1752	0	0	0	0	0	0	1752
2 (Ajali)	0	0	0	0	1729	3851	0	0	0	0	5581
3 (Abagana)	12749	6086	10592	0	0	0	12976	11064	3429	205	57101
Waste qtity	12749	6086	10592	1752	1729	3851	12976	11064	3429	205	

The output of the location model shows that a processing plant with about 5.6 thousand tons processing capacity is best located at Ajali; this will serve both Ajali and Akpo location radius. Then about 1.7 thousand tons of waste generated within Ihiala location radius is best processed in a processing plant installed in Ihiala, finally a processing plant with 57 thousand tons capacity is to be located at Abagana, this will process waste generated from Oraifite, Awka, Adazi-ani, Aguleri and Omor location radial. This simply means that one big scale and two small scale biogas processing plant is to be installed in the study area to minimize the cost of allocation of agricultural waste in the state.

4.8 Economic and Site Selection Optimality Analysis

Using equation 3.8, 3.9, 3.10 and 3.11 in section 3.6.2 and Figure 3.5, the capital cost for each location was calculated and is as shown in the Table 4.9: The nominal capacity for Onitsha was estimated to be 3661.35 (kWe), while the nominal capacity for Njikoka and Dunukofia L.G.A is about 3969.46 (kWe) and 3546.18 (kWe) respectively. The total transportation cost per ton for the various locations were estimated to be ₦39640.7, ₦ 37010.45 and ₦35997.46 for Onitsha, Njikoka and Dunukofia demand points. The plant operational cost and maintenance cost was obtained as stated in section 3.6.1, the values of each of these cost is shown in Table 4.9:

Table 4.8: Bio-energy plant costs in Naria

S/N	Onitsha North	Njikoka	Dunukofia
Investment (Fixed) Cost	3,744,950,510	3,995,101,272	3,650,494,960
Maintenance Cost	67,663.36	73,357.36	65,543.97
Transportation Cost	39640.7	37010.45	35997.46
Operational Cost	74899010.2	79902025.44	73009899.2
Total Variable Cost	75,006,314.26	80,012,393.25	73,111,440.63
Total Cost	3,894,963,139	4,155,126,059	3,796,717,841
Biogas Profitability Index	1.498894	1.732658	1.433577

The goal of site selection optimality analysis is to select the best single site considering economic indices for bio-energy plant siting. The biogas profitability index was computed based on equation 3.18. The result is as shown in Figure 4.33: The Figure shows that Njikoka has the highest profitability index. The least total cost and alternative location with respect to least total cost is however Dunukofia L.G.A.

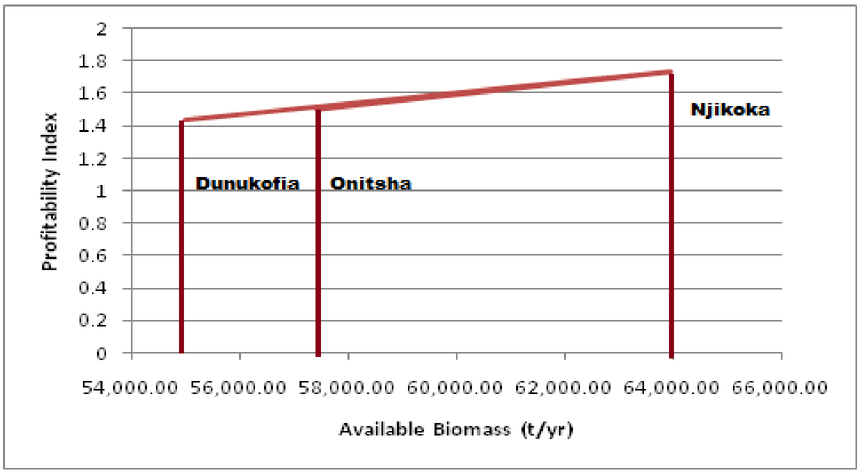

Figure 4.33: Profitability Index of Bio-energy Sites

CHAPTER FIVE

SUMMARY OF FINDINGS AND RECOMMENDTION

5.1 SUMMARY OF FINDINGS

This study developed a comprehensive GIS model for siting bio-energy using poultry and abattoir wastes as a feedstock. Considering the aim and objectives of this research work, several conclusions are drawn here:

i. There are about 2000 poultry farms in the state with about 1,844,557 total numbers of poultry birds and about 44 abattoir centres in Anambra State. About 63,646.206 t/year of poultry dropping and 6914.65 t/year abattoir wastes (paunch) are generated in poultry farms and slaughter houses in Anambra State. This is worth more than 2,096,560.65m^3/yr of biogas potential. The hotspot analysis of concentration of sources of agricultural wastes also shows that Onitsha North, Oyi, Njikoka, Dunukofia, Ogbaru and Awka North are hot spots for siting biogas plants.

ii. On the identification of suitable sites for bio-energy siting, from the combination of the economic and spatial density factor in determination of suitable sites for location bio-energy plant, the highly suitable areas include Onitsha North and Njikoka L.G.A. The most suitable locations are within Onitsha North and South, Njikoka, Idemili, Egwuiso L.G.A. However, the final analysis considering land use suitability shows that the most suitable sites are in Onitsha North, Njikoka and Dunukofia L.G.A.

iii. Economic analysis on the most suitable sites indicates that Onitsha North has a profitability index of 1.498894, while Njikoka and Dunukofia sites has a profitability index of 1.732658 and 1.433577 respectively, making Njikoka L.G.A as the best location in investment-wise.

iv. The modified capacitated location model indicates that for distance less than 40km (which is the recommended maximum distance of travel for animal waste processing because of economic reasons) the cumulative distances are 2219.948km, 2070.08km and 2049.64km respectively for Onitsha North, Njikoka and Dunukofia respectively. This indicates that Dunukofia has the least travel distance and would serve as a central point for single facility location in the study area.

v. For the multiple facility scenario, the result of set covering location modelling and location and allocation modelling indicates that a minimum of three locations are to be opened in the study area which should be sited in Abagana, Ihiala and Ajali.

Based on the results and the analysis done in this study it is concluded that Remote Sensing and GIS can be used as effective tools to determine suitable sites for siting bio-energy centre. These tools assisted in excluding areas in the study areas which are rather difficult to exclude using mathematical models alone.

5.2 RECOMMENDATION

The following recommendation should be implemented:

i. Government should digitize and update all analogue maps of the state, develop GIS database for the state, and enhance that availability of GIS datasets for researchers for effective planning of all physical developments in the state.

ii. Provision of incentives to accelerate renewable energy adoption among various stakeholders and establishment of appropriate financing schemes for investment in renewable energy projects should be implemented in Anambra State.

iii. There is need to construct and build standard abattoir across the state, this will enhance waste aggregation, collection and easy transportation.

iv. From the study carried out, it is apparent that there is an urgent need for an effective agricultural waste treatment system in the study area. Regional programs by towns, communities, L.G.A or associational efforts should be stimulated in green energy projects.

Contribution to Knowledge

i. Since optimal locations for agricultural biogas plants is a spatial problem, and not just pure mathematical problem, a branch of operation research known as location modeling was integrated with GIS in a novel approach in this research work to determine optimized locations for siting agricultural plant. Hotspots sites and high site suitability index, buffered at 10km (which is recommend distance for economic transportation of animal wastes) was incorporated to location models. Hence, a novel approach of integrating GIS and set-covering location problem was used to determine optimal locations for siting agricultural biogas plant in this study.

ii. Several research works carried out on suitability analysis of bio-energy plant either omitted or does shallow work on the economic aspect of their suitable sites. Since profitability is the major drive in many business ventures, economic viability study was incorporated in this study. Final GIS analysis indicated that three locations were best sites for siting biogas plant. However, with the incorporation of profitability assessment, the optimal location(s) was more specific in this study contrary to previous research with wide range of suitable sites and no clue on the economic implication.

iii. Combinations of factors necessary in siting plants were adequately incorporated in this study. Socio-environmental factors like distance from residential areas, water-bodies and reserved areas are a norm in site suitability analysis. The incorporation of electric transmission lines of Anambra State, biomass sources proximity and hill-shade view extracted from the DEM is a major and unique input in site suitability analysis for the study area. Thus the suitability analysis was based on local preference criteria and additional criteria unique to this study.

iv. Another major contribution to knowledge is the production of GIS data base of agricultural waste generation across the state through: spatial/point density map of poultry production; the spatial/point density map of paunch wastes and hotspot/coldspot graphical models. This has eliminated rigorous exercise in determining spatial and biogas potential relationship of agricultural wastes. Thus, areas of low or high concentration of animal wastes can be seen in a glance using these GIS spatial graphical models.

v. Waste generation capacity estimation of the study area study is obviously a major contribution to knowledge, in addition to that, specific location for agricultural waste processing centres was determined and allocation strategy based on minimised transportation cost also developed in this study.

Published Journals from this study include:

1. E. C. Chukwuma, G. O. Chukwuma, L. C. Orakwe (2016) Application of facility location models with hotspot analysis for optimal location of abattoir bio-energy plant in Anambra State of Nigeria. Inter. Jour. of Sc. & Tech. Research 5(4) 172-177.

2. E. C. Chukwuma, G. O. Chukwuma and L. C. Orakwe (2016) GIS Suitability Analysis for Anaerobic Treatment Facility for Slaughter Houses in Anambra State of Nigeria. Archives of Current Research International 4(4): 1-10.

3. E. C. Chukwuma, G. O. Chukwuma, L. C. Orakwe (2016) Application of Set Covering Problem For Central Abattoir Bio-energy Treatment Facilities In Anambra State of Nigeria. Presented at Faculty of Engineering International Conference, held on 6th and 7th September, at Nnamdi Azikiwe University, Awka, Nigeria.

4. E. C. Chukwuma, L. C. Orakwe (2016) Economic viability of location sites for bio-energy plants in Anambra State of Nigeria. Presented at Faculty of Engineering International Conference, held on 6th and 7th September, at Nnamdi Azikiwe University, Awka, Nigeria.

5. E. C. Chukwuma, G. O. Chukwuma, L. C. Orakwe (2016) Spatial Statistics of Poultry Production in Anambra State of Nigeria: A Preliminary for Bio-energy Plant Location Modelling. Nigeria Journal of Technology, Vol. 35 (4) 940-948.

Under Peer Review are:

6. E. C. Chukwuma, L. C. Orakwe, C. C. Odoh P-median location/allocation model for Abattoir treatment facilities in parts of Anambra State of Nigeria. International Journal of Agric. Engineering.

7. E. C. Chukwuma, G. O. Chukwuma, L. C. Orakwe (2016) Applications of Geographical Information System Technology in Agricultural And Bioresource Engineering: A review.Inter. Jour. of Sc. & Tech. Research. International Journal of Agric. Engineering

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APPENDIX A

Table A.1: Anambra State Slaughter Houses, Locations and Number of Animals Slaughtered Daily

S/N	NAMES OF SLAUGHTER HOUSES	LOCATION IN LGAs	No. Of slaughtered Animal daily		No. Of Live Cow	No. Of Live Goat/Sheep
			Cow	Goat/sheep		
1	Nkwo-Igboukwu Slaughter House	Aguata	5	8	60	-
2	Eke Ekwulobia Slaughter House		5		25	
3	Orie Uga		10		47	58
4	Afor-Udo Nanka Slaughter House	Orumba North	3		15	
5	Eke Oko Slaughter House		8		30	
6	Nkwo Umunze Slaughter House	Orumba South	4	11	18	32
7	Nkwo-Ogbe Mkt Slaughter House	Ihiala	10-15	20	49	-
8	Uli Slaughter House		3-5	10	10	-
9	Nkwo Okija Slaughter House		5	10	30	-
10						
11	Amorka Slaughter House		4	None	35	-
12	Iseke Slaughter House		4	None	24	-
13	Nteje Slaughter House	Oyi	10-15	None	42	None
14	Oye-olisa Slaughter House		40-75	-	155	-
15	Umunya Slaughter House		60-70	60	130	-
16	Awkuzu Slaughter House		10-15	O.I.W	38	-
17	Nkwo-Nnewi Slaughter House	Nnewi North	6-15		50	
18	Orie-Agbo Slaughter House		2-4	None	15	
19	Oba-Isi Edo Slaughter House		9-20		51	
20	Amichi Slaughter House	Nnewi South	1-8	O.I.W	3	-
21	Afor-Ukpo Slaughter House		3	O.I. W	5	-

22	Osumenyi Slaughter House		2-4	O.I.W	14	-
23	Unubi Slaughter House		Twice Weekly	O.I.W	5	None
24	Amikwo, Awka Slaughter House	Awka South	13-25	24-32	13-25	24-32
25	Amansea Slaughter House	Awka North	23	16	293	72
26	Ebonyi Indigene managed Slaughter House		20	5-7	65	-
27	Ozubulu Slaughter House	Ekwusigo	7-9	-	30	-
28	Oraifite Slaughter House		2-5	-	65	-
29	Ochanja Slaughter House	Onitsha North/South	65-75	-	223	-
30	Bridge-Head Slaughter House		10-13	-	205	-
31	Marine Slaughter House		25-27	-	205	-
32	Ugwunabamkpa Slaughter House		1-2	-	25	-
33	Main Mkt Slaughter House		18-21	-	250	-
34	Iyi-owa Odekpe Slaughter House	Ogbaru	2	15	5	-
35	Nkwo-Ogidi Slaughter House	Idemili North	13-16	-	43	-
36	Obosi Slaughter House		15-17	-	71	-
37	Nkpor Slaughter House		10-20	100	175	-
38	Afor-Oba Slaughter House	Idemili South	6-9	None	30	None
39	Afor-Nnobi Slaughter House		15-20	None	52	None
40	Eke-Awka Etiti Slaughter House		30-40	None	257	None
41	Afor-Igwe Umudioka Slaughter House	Dunukofia	5-8	7-12	34	-
42	Oye-Agu Abagana Slaughter House	Njikoko	4-8	None	34	None
43	Eke-Agu Abagana Slaughter House		2-6	None	49	None
44	Nwagu-agulu Slaughter House	Anaocha	7-9	None	67	None
45	Nkpor (Private Slaughter House)	Idemili North	5		45	

I.O.W = Once in a While

Table A.2: Aguata LGA Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	TYPE OF BIRDS	NO. OF BIRDS
1	Umekafor Chidinma	Igboukwu	Broiler	140
2	Dumex Farms	Igboukwu	Layer	1500
3	Fanza Nig. Ltd	Ekwulobia	Broiler, Layer, Turkey	600, 1500, 50
4	Chriscol Farms	Igboukwu	Broiler, Layer, Turkey	4000, 2500, 40
5	Eze Farms	Ekwulobia	Broiler, Layer, Turkey	50, 100, 10
6	Vivian	Achina	Broiler	600
7	Evelyn	Igboukwu	Broiler	140
8	B. Mmaduka	Ezinifite	Broiler	500
9	Chijugo	Ikenga	Broiler	300
10	Onyejikwe	Achina	Broiler	200
11	Mr. Simeon	Umuchu	Broiler, Layer	300, 500
12	Emmanuel	Ezinifite	Broiler	150
13	Chisom	Ezinifite	Broiler	450
14	Chibuike	Achina	Broiler	500
15	Chidi	Ezinifite	Broiler	400
16	Chimerendu	Ezinifite	Broiler, Layer	500, 2000
17	Chinemerem	Achina	Broiler	150
18	Obiageli	Ezinifite	Broiler	70
19	Ebere	Uga	Broiler	150
20	Emegwu Godwin	Umuchu	Broiler	50
21	Emeka Okpala	Uga	Broiler	200
22	Emelife Ifek	Uga	Broiler	400
23	Isaac	Uga	Layer, Broiler	800, 200
24	Izuegbu Willam	Achina	Broiler	150
25	Mrs. Ezenwaobo	Ekwulobia	Broiler	100
26	Mr. Ezeokafor	Ekwulobia	Broiler	150
27	Mr. Obiora	Ekwulobia	Layer	200
28	Oga Obinna	Achina	Broiler, Layer	300, 500
29	Onyeka	Umuchu	Broiler, Layer	300, 700
30	Virginia Okeke	Ihuokpala	Broiler	100
31	Isaac	Uga	Broiler, Layer	200, 600
32	Mrs. Mbachu	Ogboji	Broiler	100
33	Oga Samuel	Akpo	Broiler	250
34	Okpala Chinedu	Ula-Ekwulobia	Broiler	300
35	Ezeonuogu	Umuojogo Umuchu	Broiler	200
36	Nweke Onyekwere	Eziagu-Ekwulobia	Broiler	700
37	Achia Farm	Achina	Broiler	100
38	Okpala Chinedu	Ula-Ekwulobia	Broiler	25
39	Chinedu Ndukwa	Ekwulobia	Broiler	200
40	Theresa	Ula-Ekwulobia	Broiler	150
41	Eze. C. Eze	Uga	Layers	500
42	Obinna	Ula-Ekwulobia	Broiler	200
43	Pst. Eze	Uga	Broiler	50
44	Amarachi	Uga	Broiler	200
45	Ganus Farm	Ekwulobia	Layer, Broiler	3000, 400
46	Genno	Ekwulobia	Layer	1500
47	Odika Farm	Ekwulobia	Layer	1500

48	Anselin Farm	Ekwulobia	Layer	4500
49	Eagle Farm	Umuchu	Layer, Broiler	5000, 1000
50	Oshimili Farm	Umuchu	Layer, Broiler, Turkey	25000, 5000,600
51				
52	Jeffcon Farm	Nkpologwu	Layer	11,000, 4000
53	Johny	Nkpologwu	Layer	4000, 1500
54	Oliver Farm	Amesi	Broiler, Layer	1000, 2500
55	Nnoli Farm	Oraeri	Layer, Broiler	3000, 400
56	Ntugu Farm	Uga	Layer, Broiler	6000, 1000
57	Ekemene Farm	Amesi	Broiler	600
58	Mrs. Faith Okpala	Akpo	Broiler	150
59	Oby Izundu	Ula-Ekwulobia	Broiler	75
60	Nnadozie Farm	Ezinifite	Layer	800
61	Ozomena Bessy	Agulu-Ezechukwu	Turkey	200
62	Umeokeke Grace	Ezinifite	Broiler	200
63	Uzondu Chinwe	Nkpologwu	Broiler	200
64	Melody Livestock Farms	Ifite-Ezinifite	Broiler, Layer, Turkey	1000, 400, 100
65	Sophyn Olisakwe	Ifite-Ezinifite	Layer	200
66	Ogochukwu	Agulu	Broiler	100
67	John Paul	Akpo	Broiler	50
68	Fidelis Ukachukwu	Igboukwu	Broiler	65
69	Ezeakonam Alodime	Igboukwu	Broiler, Turkey	12, 7
70	**GRAND TOTAL**			**159407**

Table A.3: Anambra East Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	TYPES OF BIRD	NO. OF BIRDS
1	Douglas ivendinezi	Aguleri	Layers, Broilers	3000, 600
2	Manafa Igbonasi	Aguleri	Broilers, Turkey	150, 100
3	Ngozi Igweze	Aguleri	Layers, Broilers	500, 400
4	Georgina Nnaemeka	Aguleri	Layers, Broilers	500, 300
5	Florence Chijindu	Aguleri	Broilers	300
6	Nwafada	Aguleri	Layers, Broilers	300, 200
7	Rapheal Ajide	Aguleri	Broilers	300
8	Chief Onuigbo	Umueri	Layers, Broilers, Turkey	2000, 800, 400
9	Sunday Eziagulu	Nando	Layers, Broilers, Turkey	1000, 200, 150
10	Udemezue Farms	Nando	Layers, Broilers, Turkey	1000, 300, 2000
11	Love Farms	Umueri	Layers, Broilers	500, 300
12	Samuel Chibuzo	Igbariam	Layers, Broilers	300, 300
13	Emechie Farms	Igbariam	Broilers, Turkey	1200, 250
14	Godwin Okolo	Nando	Layers, Broilers	2000, 500
15	Odikpo Farms	Igbariam	Layers, Broilers, Turkey	1500,200, 400
16	Muorah Chinedu	Umueri	Layers	1000
17	Joy Meze	Nsugbe	Layers, Broilers, Turkey	1000, 250, 10
18	Eucharia Adike	Nsugbe	Broilers, Turkey	150, 15
19	Ikechukwu Ibezi	Nsugbe	Broilers	250
20	Okonkwo Dorathy	Nsugbe	Broilers, Turkey	200, 25
21	Anthonia Okwudili	Nsugbe	Layers, Broilers, Turkey	500, 200, 100
22	Veronica Adeh	Nsugbe	Broilers, Turkey	300,130
23	Ngozi Obalim	Nsugbe	Broilers	500
	GRAND TOTAL			**26,480**

Table A.4: Aniocha LGA Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	TYPES OF BIRD	NO. OF BIRDS
1	Chriscol Farms	Agulu	Layers	3500
2	Roni Farms	Nri	Layers	4000
3	Denco	Agulu	Layers, Broilers	300, 100
4	Enemuo Associates	Agulu	Layers, Broilers	500, 300
5	Bonee Farms	Adazi-Enu	Layers	3000
6	Elder Samuel Oli	Nri	Layers	700
7	Mr. CY Okafor	Agulu	Layers, Broilers	1500, 100
8	Mrs. Lucia Uchenabo	Agulu	Layers, Broilers	300, 100
9	J. C. Agro Farms	Adazi-Enu	Layers	200
10	Chinelo	Adazi-Enu	Layers	1500
11	Miss Orji Ogoo Nneka	Agulu	Layers	100
12	Rev. Fr. Anagbogu Robert	Agulu	Layers, Broilers	350,200
13	Chinenye Josephine	Adazi-Enu	Local Chickens	45
14	Nwakuche Chinenye	Adazi-Enu	Layers, Broilers	50,100
15	Onuegbu Farms	Adazi-Ani	Layes, Broilers	300, 250
16	Adama Farms	Adazi-Ani	Layers	2000
17	Felly Okpala	Adazi-Ani	Layers	500
18	Amaka Farms	Adazi-Ani	Layers	500
19	Mama Hari	Adazi-Ani	Layers	500
20	Mama Big Boy Farms	Adazi-Ani	Layers	500
21	Mama Ikenna	Adazi-Ani	Layers	1500
22	Mama Jeno Farms	Adazi-Ani	Layers	500
23	Mama Obi Farms	Adazi-Ani	Layers	1000
24	Mama Uche Farms	Adazi-Ani	Layers	2000
25	Mrs. Adima Farms	Adazi-Ani	Layers	1500
26	Mrs. Alhaji Farms	Adazi-Ani	Layers	1500
27	Mrs. Ezeobi Farms	Adazi-Ani	Layers	500
28	Mrs. Eze Farms	Adazi-Ani	Layers	500
29	Oddy Man Farms	Adazi-Ani	Layers	1000
30	Anaeri-aku Farms	Adazi-Enu	Broilers	200
31	IK Farms	Adazi-Enu	Broilers	300
32	Ichie Ekunie Farms	Adazi-Enu	Broilers	500
33	Mrs. Ofojebe Farms	Adazi-Enu	Layers	2000
34	Ugwu Awus Farms	Adazi-Nnukwu	Layers	200
35	Abba Man	Neni	Layers	500
36	Amaelo Filling Station	Neni	Layers	500
37	Back to Land Poultry Enterprises	Agulu	Layers, Broilers	3000, 1000
38	I.K Nnajiofor	Agulu	Layers, Broilers, Local Chicken	200, 300, 15
39	Ezeani Godson	Agulu	Broilers	200
40	Sunday Ebieluonwu	Agulu	Broilers	200
41	Augustine Obiozor	Agulu	Broilers	200, 50
42	Vivid Poultry Farm	Agulu	Broilers	2000
43	Dr. Brendan Duhu Farms	Adazi-Enu	Broilers	1000
44	Mr & Mrs. Adimorah	Agulu	Broilers	500
	GRAND TOTAL			**43,210**

Table A.5: Awka North LGA Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	TYPES OF BIRD	NO. OF BIRDS
1	Chima Agro Farm	Mgbaukwu	Broiler, Layer, Turkey	2000, 5000, 50
2	Onochie Farm	Mgbaukwu	Broiler, Layer, Turkey	500, 3500, 20
3	Nelson Chika Farm	Mgbaukwu	Broiler, Turkey	150, 60
4	Afamefuma Farm	Mgbaukwu	Broiler, Turkey	400, 70
5	Holy Trinity Farm	Mgbaukwu	Broiler, Layer, Turkey	300, 1000, 25
6	Chukwunyere Christian	Mgbaukwu	Broiler, Turkey	397, 75
7	Akum Udeozor	Mgbaukwu	Broiler	300
8	Chukwuma Nnenna	Mgbaukwu	Broiler, Turkey	200, 40
9	Oraebuka Farm	Mgbaukwu	Layers, Turkey	4000, 20
10	Ikechukwu Onuora	Mgbaukwu	Broiler, Turkey	500, 10
11	Titus mmadu	Umuji Ebenebe	Broiler, Layer, Turkey	250, 300, 35
12	Jeo Nwegwu	Umuji Ebenebe	Broiler, Layer, Turkey	500, 700, 25
13	Igwe Christ	Amagu	Broiler, Layer, Turkey	1600, 400, 75
14	Eunice Chinwuko	Uwana Ebenebe	Broiler, Layer, Turkey	700, 1200, 8
15	Elochukwu Nka	Uwana Ebenebe	Broiler, Turkey	500, 29
16	Albert Okoye	Uwana Ebenebe	Broiler, Layer, Turkey	600, 100, 20
17	Jeremiah Alor	Obuno Ebenebe	Broiler, Turkey	500, 50
18	Emme Onwuteaka	Uwana Ebenebe	Broiler, Layer	1000, 3000
19	Joseph Chukwuma	Umuogbuefi Ebenebe	Broiler, Turkey	550, 30
20	Nonso Isaac	Mgbaukwu	Broiler, Layer, Turkey	300, 350, 10
21	Ikechukwu Onuorah	Mgbaukwu	Broiler, Layer, Turkey	200, 250, 5
22	Rapulu Chukwu Farm	Mgbaukwu	Broiler, Layer, Turkey	500, 2000, 27
23	Agbalusia Farm	Mgbaukwu	Broiler, Layer	300, 250
24	Chukwuma	Mgbaukwu	Broiler, Layer, Turkey	200, 200, 10
25	Ralph Agbolu	Mgbaukwu	Broiler, Layer, Turkey	300, 250,5
26	Uche Mozie	Mgbaukwu	Broiler, Layer	300, 250
27	Boniface Muokwugo	Mgbaukwu	Broiler, Layer, Turkey	250, 150, 15
28	Anala Farm	Amansea	Broiler, Layer, Turkey	500, 3250, 55
29	Obi Okoye	Amansea	Broiler, Turkey	1000, 5
30	Ehisi Farm	Isuanocha	Broiler, Layer	500, 11000
31	Stella Okonkwo	Amansea	Broiler, Layer	1000, 700
32	Davian Farm	Isuanocha	Broiler	1000
33	Chike Farm	Isuanocha	Broiler	3000
34	Onyinye Farm	Amansea	Broiler, Turkey	500, 30
35	Ogochukwu Enukaora	Umuji Ebenebe	Broiler, Turkey	300, 33
36	Barnabas Ajuora	Umuji Ebenebe	Broiler, Turkey	400, 23
37	Fr. Unegbu Jonas	Umuji Ebenebe	Broiler, Layer, Turkey	300, 350, 30
38	Christopher Okoye	Umuji Ebenebe	Broiler, Turkey	250, 110
39	Orakwe Simon	Amanuke	Broiler, Layer, Turkey	1000, 1000, 20
40	Mrs. Orakwube	Achalla	Broiler, Layer, Turkey	500, 1500, 33
41	Okafor hycienth	Amanuke	Broiler	200
42	Nwakeze Chidinma	Amanuke	Broiler, Turkey	500, 20
43	Okafor Ebenezar	Amanuke	Broiler, Turkey	600, 10
44	Okoye Eunice	Amanuke	Broiler	650
45	Nwoye Jonathan	Amanuke	Broiler, Layer, Turkey	200, 500, 15
46	Pastor Beniah Okeke	Amanuke	Broiler, Layer	500, 500
47	Roseline Ndinyelu		Broiler, Turkey	450, 29
48	Enemuo Linus	Amanuke	Broiler, Turkey	200, 27
49	Nwarinne Nonyelum	Amanuke	Broiler, Turkey	150, 73

50	Onwudiofu Farm	Urum	Broiler, Layer, Turkey	250, 750, 15
51	Egwu Grace Farm	Urum	Broiler, Turkey	300, 17
52	Chinenye Farm	Urum	Broiler, Turkey	600, 35
53	Anna Emeka Farm	Urum	Broiler, Layer, Turkey	250, 550, 17
54	Obiekezie Chukwudi Farm	Urum	Broiler, Layer, Turkey	500, 500, 7
55	John Farm	Urum	Broiler, Turkey	300, 8
56	Bamidele Akojenu Farm	Urum	Broiler	300
57	Ndudiebe Ifeanyi Farm	Urum	Broiler, Turkey	200, 33
	GRAND TOTAL			**162,658**

Table A.6: Awka South LGA Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	TYPE OF BIRDS	NO. OF BIRDS
1	Okeke Martha	Umueze Village Amawbia	Broiler	600
2	Amamasi Bethel	Umueze Village Amawbia	Broiler	1800
3	Nwankwo Emmanuel	Umueze Village Amawbia	Broiler	2600
4	Nnonyelu Edith N	Umueze Village Amawbia	Broiler	300
5	Okonkwo Helen	Umueze Village Amawbia	Broiler, Turkey	100, 100
6	Owunu Augustina	Umukabia Village Amawbia	Local Birds	50
7	Nnama Cyprian	No. 5 Agulu Road Amawbia	Broiler, Turkey	2000, 170
8	Anene Okechukwu	No. 2 Nnama Close Ezimezi Amawbia	Broiler	2500
9	Okonkwo Ifeyinwa	No. 13 Egbengwu Ezimezi Amawbia	Broiler, Layer, Turkey	2500, 180, 1500
10	Okonkwo Chinwe	Egbengwu Ezimezi Amawbia	Broiler	300
11	Peace Nworah	Umueze Village Amawbia	Broiler	400
12	Beatrice Nwangwu	Umueze Village Amawbia	Broiler	400
13	Ekene Okoye	Umueze Village Amawbia	Broiler	150
14	Edith Nwafor	Umueze Village Amawbia	Broiler	250
15	RapuChukwu Nwanna	Umueze Village Amawbia	Layer	300
16	Okonkwo Ifeoma	Umueze Village Amawbia	Broiler	200
17	Josephine Chukwu	Umueze Village Amawbia	Broiler	100
18	Nnadu Chukwunwuba	Umueze Village Amawbia	Broiler	1000
19	I.k Anene	Umueze Village Amawbia	Broiler, Layer	100
20	God’s time	Umueze Village Amawbia	Broiler	600
21	Elder Sam Nworah	Umukabia Village Amawbia	Broiler	1400
22	Ngini Helen	No. 5 Agulu Road Amawbia	Broiler	700
23	Osai Hillary	Umuanum-Nibo	Broiler, Layer	1700, 500
24	Alice Arinze	Ifite-NIbo	Broiler	200
25	Ben Nwosu	Umunon-Nibo	Broiler	900, 200
26	Anachina Anayo	Ifite-Nibo	Broiler	500
27	Condial Samuel	Ifite-Nibo	Broiler	700
28	Nwagu Cecilia	Ifite-Nibo	Broiler	800
29	Augustine Nnabuenyi	Ifite-Nibo	Broiler	500
30	Asiegbo Nnabuenyi	Umuanum-Nibo	Broiler, Layer	500, 300
31	Agha Mercy	Ifite-Nibo	Broiler	600
32	Enemuo Dozie	Umunon-Nibo	Broiler	400
33	Ezenagu Nwanneka	Ifite-Nibo	Broiler, Layer	800, 200
34	Ngozi Enemuo	Ifite-Nibo	Broiler	500
35	Edina Eke	Ifite-Nibo	Broiler	1000
36	Phoebe	Ifite-Nibo	Layer	700
37	Osita Nwekenechi	Ezeawulu-Nibo	Broiler	400
38	Ngozi Ekeh	Ezeoye-Nibo	Broiler	80000
39	Mrs. Cecila	Ifite-Nibo	Broiler	500

40	Onudiogu K. C	Ifite-Nibo	Broiler	400
41	Ekene Stella	Ifite-Nibo	Broiler	100
42	Mrs. Agbata	Ifite-Nibo	Broiler	100
43	Edinaeke	Ifite-Nibo	Broiler	1000
44	Blessing	Ifite-Nibo	Broiler	50
45	Bridgeth Uzo	No.1 Umueze Rd Ifite-Awka	Broiler	600
46	Nebuwa Ngozi	Govt. House Anambra St.	Broiler	150
47	Anene Patricia	Umudioka-Awka	Broiler	500
48	Egbutu Ngozi	Okpuno-Awka	Broiler, Layer	1500, 300
49	Chigozie Caleb	Okpuno-Awka	Broiler	1000
50	Ndidika Chidinma	Okpuno-Awka	Broiler	600
51	Chidiebere Okoye	Okpuno-Awka	Broiler	200
52	Ifechukwu Sunday	Okpuno-Awka	Broiler	700
53	Nweke Faith	Okpuno-Awka	Broiler	500
54	Nweke Jerry	Okpuno-Awka	Broiler	700
55	Obiora Ogochukwu	Umudioka-Awka	Broiler	800
56	Obuneme Charity	Ezi-Awka Awka	Broiler	2000
57	Anne Blessing	Nkwelle-Awka	Broiler	500
58	Agnes	Umubiobu-Awka	Broiler	6000
59	Mr. & Mrs. Molokwu	Ifite-Awka	Broiler, Layer	600, 200
60	Mummy Chijindu	Amikwo-Awka	Broiler	100
61	Mrs. Anumba	Nodu-Okpuno-Awka	Broiler	300
62	Abel Ezeaku	Awka	Broiler	400
63	Azubuike Stanley	Awka	Broiler	350
64	Mrs. Grace	Awka	Broiler	450
65	Eunice Nwakama	Awka	Broiler	1000
66	Chinweuba Jekwu	Awka	Broiler	200
67	C. Y Christian	Awka	Layer	800
68	Anekwe Christian	Awka	Turkey	1200
	Ausco farms	Awka	Layers, boiler	20,0000, 60,000
	Aroma farms	Awka	Layers, boiler	4,000, 3,200
69	Ezenebo A. A.	Awka	Broiler	500
70	Ikenna	Umubele-Awka	Broiler	700
71	Buchi Jipeobi	No. 3 Ezechiolo-Awka	Broiler	300
72	Violla	Umuogbu-Awka	Layers	700
73	Ugochukwu	Umuogbu-Awka	Broiler	1500
74	Mrs. Nwankwo	Ifite-Awka	Broiler	100
75	Uzo/Son	Agu-Awka	layer	200
76	Chinyere	Umuike-Awka	layer	200
77	Mrs. Anumba A	Umuike-Awka	Broiler	100
78	Chigozie omene	Okpuno-Awka	Broiler	1500
79	Afrocate Farm	Udoka-Estate-Awka	Broiler	50
80	Rebecca Akachukwu	Umudioka-Awka	Broiler	100
81	Paul Ngozi	Umuko-Awka	Broiler, Layer	600, 100
82	Josephine Onwukwu	Umubele-Awka	Broiler	300
83	Blessing Anyika	Umubele-Awka	Broiler	300
84	Nwobu Mercy	Umuanyim-Awka	Broiler	500
85	Ekelem ifeoma	Umuokpu-Awka	Broiler, Layer	300, 1500
86	Anieze Gladys	Amikwo-Awka	Broiler	300
87	Nwankwo Grace	Amikwo-awka	Broiler	500
88	Theresa okoloma	Umudioka-Awka	Broiler	600
89	Rose Igboanugo	Umudioka-Awka	Broiler	300
90	Chukwuma okoroma	Umudioka-Awka	Broiler	800
91	Chukwuebuka Elijah	Amaenyi-Awka	Broiler	800
92	Nkechi okoroma	Umudioka-Awka	Broiler	600
93	Chibuzo Obu	Umuokpu-Awka	Broiler	700
94	Mrs. C. Obu	Umuokpu-Awka	Broiler	600
95	Egbutu Ngozi	Okpuno-Awka	Broiler, Layer	1500, 300

96	Okpazene Chinyere	Akabio-Mgbaukwu	Broiler	1600
97	Godwin Ejie	Uvulu- Mgbaukwu	Broiler	600
98	Edwin Egeh	Akabio-Mgbaukwu	Broiler	500
99	Edwin okafor	Uvulu- Mgbaukwu	Broiler	800
100	Ifeoma Okpazene	Akabio-Mgbaukwu	Broiler	300
101	Mmaduabuchi Okwudinka	Akabio-Mgbaukwu	Layer	300
102	Okpazene Samuel	Akabio-Mgbaukwu	Broiler, Layer	700, 30
103	Adeniyi Augustine	Ojagu-Mgbaukwu	Broiler	150
104	Okafor Chidinma	Uvulu- Mgbaukwu	Broiler	100
105	Caro Chikwelu	Uvulu- Mgbaukwu	Broiler	1000
106	Emenike Onyi	Uvulu- Mgbaukwu	Broiler	100
107	Catherine Okafor	Uvulu- Mgbaukwu	Broiler	200
108	Okaforma Florence	Isiakpu-Nise	Broiler, Layer	600, 100
109	Okaforma Edwin	Isiakpu-Nise	Broiler	700
110	Ngene Ifeanyi	Isiakpu-Nise	Broiler, Layer	500, 300
111	Chizoba	Ngodo-Nise	Broiler, Layer	600, 400
112	Dorathy Anieto	Ngodo-Nise	Broiler	1700
113	Innocent Njideka	Ngodo-Nise	Broiler	2000
114	Chune Ngozi	Ngodo-Nise	Broiler	700
115	Chinedu Onwugbolu	Isiagu-Nise	Broiler	100
116	Ausin Ndigwe	Agu-Aba layout	Broiler	1000
	GRAND TOTAL			194130

Table A.7: Idemili North LGA Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	NO. OF BIRDS
1	Emma Okeke	Ogidi	205
2	Fidelis Umeh	Ogidi	50
3	Felix Onworah	Ogidi	300
4	Ifeanyi Okonkwo	Ogidi	200
5	Ugo Eze	Ogidi	70
6	Augustine Dike	Ogidi	30
7	Gowin Okafor	Ogidi	100
8	Nzube Okafor	Ogidi	120
9	Chisom Madu	Ogidi	150
10	Tochukwu Ilegbuna	Ogidi	175
11	Chibuzor Umeh	Ogidi	500
12	Daniel Eze	Ogidi	70
13	Ferdinand Okpala	Ogidi	35
14	John Efobi	Ogidi	55
15	James Efobi	Ogidi	67
16	Gladys Eze	Ogidi	80
17	Nkechi Okonkwo	Ogidi	95
18	Schola Eze	Ogidi	107
19	Oge Ariekme	Ogidi	85
20	Ngozi Felix	Ogidi	67
21	I.K Eze	Ogidi	125
22	Jane Amasiatu	Ogidi	135
23	Benjamin Onuorah	Ogidi	200
24	Fedelia Emedosi	Ogidi	255
25	Ifeoma Ibe	Ogidi	195
26	Felix Ibe	Ogidi	40
27	Nneba Okama	Ogidi	57
28	Jane Ibekwe	Ogidi	77
29	Ngozi Ibekwe	Ogidi	85
30	Linda Okafor	Ogidi	307
31	Nkechi Ibeize	Ogidi	145
32	Ngozi Onuma	Ogidi	500
33	Ikechujwu Onuma	Ogidi	200
34	Euphema Okpala	Ogidi	300
35	Regina Obi	Ogidi	700
36	Emmanuel Obi	Ogidi	1000
37	Franklin Dibia	Ogidi	800
38	Maduka Ibekwe	Ogidi	1000
39	Uju Onuma	Ogidi	380
40	Eloka Nnoli	Ogidi	1000
41	Ifunawya Nnoli	Ogidi	1050
42	Tobechukwu Ibekwe	Ogidi	900
43	Precious Nnanna	Ogidi	700
44	Eugine Dan	Ogidi	400

45	Victoria Aniwetali	Ogidi	600
46	Agallia Aniwetali	Ogidi	400
47	Regina Udealo	Ogidi	100
48	Uehe Udealo	Ogidi	500
49	Rose Egwuatu	Ogidi	150
50	Abraham Egwuatu	Ogidi	200
51	Offorokoya Hellen	Ogidi	145
52	Enenwa Anex	Ogidi	700
53	Anosike Nnonso	Ogidi	400
54	Agba Chinemere	Nkpor	300
55	Agbasiere Chima	Nkpor	700
56	Anicha Victor	Nkpor	200
57	Chijoke Chiemerie	Nkpor	250
58	Dike Faith	Nkpor	500
59	Ezeribe Blosson	Nkpor	600
60	Robinson Wimie	Nkpor	200
61	Ugochukwu Blessing	Nkpor	700
62	Egbaji Chidubem	Nkpor	200
63	Nnodu Chigamezu	Nkpor	350
64	Eboh Wisdom	Nkpor	280
65	Lodi Happiness	Nkpor	400
67	Ononyu Chinercherem	Nkpor	500
68	Ezeokeke Chiemerie	Nkpor	300
69	Chiamuka Meta	Nkpor	700
70	Oneji Precious	Nkpor	600
71	Favour Obi	Nkpor	400
72	Achenna Justine	Nkpor	250
73	Ozonkem Anthony	Nkpor	500
74	Okereke Faini	Nkpor	300
75	Nnaknorom Ogechi	Nkpor	800
76	Okafor Somto	Nkpor	700
77	Obiegwu Chimezie	Nkpor	600
78	Nwankwo Itunanya	Nkpor	900
79	Chiko Ike	Nkpor	300
80	Mmadu Gospel	Nkpor	700
81	Nweke Gloria	Nkpor	700
82	Okafor Chinaza	Nkpor	400
83	Jim Pressure	Nkpor	700
84	Nnabude Chukuwdi	Nkpor	300
85	Promise Ike	Nkpor	900
86	Chinwetala Chiedu	Nkpor	500
87	Ugwu Dabere	Nkpor	350
88	Genifer Monday	Nkpor	500
89	Oninye Obi	Nkpor	700
90	Praise Onyemem	Nkpor	700
91	Prince Will	Nkpor	550
92	Akachukwu Ike	Nkpor	500
93	Somoto Chukwudum	Nkpor	750
94	Chiama James	Nkpor	250

95	Umunwa Obinna	Nkpor	350
96	Blessing Chukwudi	Nkpor	850
97	Hioma Maduka	Nkpor	450
98	Chinemaven Umu	Nkpor	100
99	Chiamaka Nwachukwu	Nkpor	1000
100	Chukwu Jekwu	Nkpor	150
101	Amara Udeze	Nkpor	700
102	Chibueze Akadum	Nkpor	350
103	Onyedira Ogaraku	Nkpor	1000
104	Kingsley Igwebuike	Nkpor	2000
105	Kingsley Anyanebechi	Nkpor	550
106	Chidimma Solomon	Nkpor	660
107	Ojiako Glory	Nkpor	500
108	Umeojiako Chinedu	Nkpor	400
109	Chinedu Chukwugazie	Nkpor	350
110	David Agwuebuzada	Nkpor	400
111	David Mmesoma	Nkpor	350
112	Ebuka Nnobi	Nkpor	900
113	Chisom Ekowa	Nkpor	500
114	Mbah Chinaza	Nkpor	700
115	Chinoso Mbah	Nkpor	300
116	Ezechike Benita	Nkpor	250
117	Oluchukwu Ugunna	Nkpor	500
118	Omeghi Kosisochukwu	Nkpor	100
119	Kosi Chukwudum	Nkpor	300
120	Chisom Ugwueze	Nkpor	400
121	Chidindu Chukwere	Nkpor	500
122	Onyinye Ndionuka	Nkpor	150
123	Juliet Chemere	Nkpor	300
124	Elochukwu Chiagazie	Nkpor	400
125	Ndukwe Chidimma	Nkpor	700
126	Victor Ike	Abatete	500
127	Ezenne Okafor	Abatete	350
128	Marycynthia Chiemerie	Abatete	400
129	Chukwummaya Ibe	Abatete	700
130	Chioma Ike	Abatete	700
131	Okafor Chinoso	Abatete	800
132	Chidindu Metu	Abatete	500
133	Obiegwu Chisom	Abatete	500
134	Amobi Rose	Abatete	500
135	Amobi Ikechukwu	Abatete	400
136	Abigail Ibemesi	Abatete	700
137	Chekwube Ibegbu	Abatete	600
138	Rose Moduka	Abatete	1000
139	Okoye Ogochukwu	Abatete	200
140	Ezeiyulu Nijioke.B.	Abatete	2000
141	Chidina Ibe	Abatete	500

142	Sunday Ike	Abatete	1000
143	Emeka Ikeji	Abatete	500
144	Chita Igbo	Abatete	500
145	Ezinwanne Muo	Abatete	500
146	Ifunanya Muo	Abatete	700
147	Paul Ikeji	Abatete	300
148	Ike Kwani	Abatete	500
149	Offili Bekee	Abatete	700
150	Chioma Mmadu	Abatete	700
151	Amarachu Ibe	Abatete	300
152	Ijeoma Nkem	Abatete	300
153	Ifechukwu Njika	Abatete	300
154	Ikem Obioma	Abatete	700
155	Kayide Ibekwe	Abatete	700
156	Am Jane	Abatete	400
157	Okwei Beneditta	Uke	500
158	Hope Okpala	Uke	50
159	Jerry Okpala	Uke	1600
160	Franca Nwaezioke	Uke	100
161	Edeogu Okonkwo	Uke	200
162	Peter Nnaedozie	Uke	600
163	Ezetuluyo Ike	Uke	700
164	Banabas Nweke	Uke	880
165	Kenechi Obi	Uke	500
166	Lynda Nwafor	Uke	280
167	Nnabuf Nwankwo	Uke	480
168	Oliver Nwankwo	Uke	380
169	Chukwudi Iloanugo	Uke	180
170	Mr.Nwaosisa Ike	Uke	900
171	Nkoh Madu	Uke	300
172	Ifeoma Ijezie	Uke	300
173	Ferdinard Okereke	Uke	250
174	Foster Nnoli	Uke	600
175	Regina Ibe	Uke	100
176	Festus Mbah	Uke	500
177	Modester Mbah	Uke	250
178	James Okpala	Uke	500
179	Chisom Nwaokoye	Uke	700
180	Peter Mekiti	Uke	400
181	Anex Udeze	Uke	900
182	Johnson Ijezie	Uke	1000
183	Fustina Okeke	Uke	200
184	Ephema Anozie	Uke	150
185	Emeka Ibekwe	Uke	500
186	Julian Nnoli	Uke	700
187	Eunice Nwachukwu	Umuoji	400
188	Ebele Osigwe	Umuoji	1000
189	Josephine Amasokwu	Umuoji	1125

190	Ada Udochukwu	Umuoji	170
191	Maureen Eneanu	Umuoji	1000
192	Chioma Okafor	Umuoji	600
193	Elizabeth Ike	Umuoji	800
194	Chineyere Okere	Umuoji	700
195	Bridget Okwundi	Umuoji	500
196	Bona Ndu	Umuoji	450
197	Nonya Ihoka	Umuoji	700
198	Gerade Chukwurah	Umuoji	1000
199	Floxy Dim	Umuoji	300
200	Emeka Chito	Umuoji	400
201	Dorathy Obiakor	Umuoji	200
202	Edith Ibe	Umuoji	250
203	Stella Nnamdi	Umuoji	300
204	Anthonia Nwoke	Umuoji	500
205	Abadom Ngozi	Umuoji	700
206	Ann Okpala	Umuoji	500
207	Judge Ike	Umuoji	1000
208	Ijeoma Nnaeze	Umuoji	500
209	Ikem Ebenezer	Umuoji	200
210	Chinwe Osegbuo	Umuoji	300
211	Ekene Ilozue	Umuoji	700
212	Chinedu Nnosisi	Umuoji	250
213	Jame Ezenwa	Umuoji	500
214	Okey Emekebe	Umuoji	300
215	Nkechi Mmaju	Umuoji	270
216	Gilbeth Eze	Umuoji	1000
217	Ezenne Chiamaka	Umuoji	650
218	Felomina Ike	Umuoji	500
219	Ike Okoye	Umuoji	700
220	Uju Odukwe	Umuoji	300
221	Maxwell Okwundi	Umuoji	450
222	Jane Nsionu	Umuoji	500
223	Chionye Ndinizu	Umuoji	1000
224	Dan Shamashi	Umuoji	150
225	Kosi Ajaelo	Umuoji	350
226	Raphael Nwabueze	Umuoji	650
227	Uba Onubuobu	Umuoji	700
228	Edmund Umerah	Umuoji	750
229	Chite Obi	Umuoji	500
230	Emeka Anyawu	Umuoji	750
231	Benaiah Samuel	Umuoji	250
232	Okey Ibe	Umuoji	700
233	Chineyere Orakwe	Umuoji	350
234	Chinoso Nmufo	Umuoji	750
235	Tony Akabuike	Umuoji	550
236	Vivian Ike	Umuoji	300

237	Amachi Madu	Umuoji	400
238	Chidi Okafor	Umuoji	700
239	Chikodika Amaka	Umuoji	800
240	Calistus Onyima	Umuoji	400
241	Solomon Chinwuba	Umuoji	250
242	Azuka Ike	Umuoji	300
243	Ngozi Obi	Umuoji	700
244	Chukwuma Mbaonu	Umuoji	700
245	Chinedu Ilozuruba	Umuoji	300
246	Norbert Ike	Umuoji	300
247	Mattew Ifeatu	Umuoji	250
248	James Onuorah	Umuoji	750
249	Lawrence Obi	Orakwu	200
250	Victoria Chude	Orakwu	400
251	Greg Obi	Orakwu	250
252	Onyejeme Franca	Orakwu	700
253	Evaristud Madu	Orakwu	700
254	Rosline Egenti	Orakwu	600
255	Augustine Dim	Orakwu	600
256	Uju Ibeziem	Orakwu	400
257	Augustine O. Efobi	Orakwu	350
258	Henry Ehekehe	Orakwu	500
259	Clement Agba	Orakwu	300
260	Kingsley Asoegwu	Orakwu	700
261	Eucharia Asoegwu	Orakwu	500
262	Oby Ejezie	Orakwu	600
263	Tony Young	Orakwu	1000
264	Ezeoba Igboam	Orakwu	1000
265	Pius Ekenwe	Orakwu	500
266	Benjamn Chweruemeka	Orakwu	200
267	Eniteya Esther	Orakwu	350
268	Evyline Oputa	Orakwu	600
269	Nnaemeka Chukwu	Orakwu	1000
270	Chidiebele Iluzue	Orakwu	200
271	Chichi Ibekwe	Orakwu	250
272	Codilia Ike	Orakwu	700
273	Chinaza Ihokwu	Orakwu	1000
274	Franca Maduemena	Orakwu	150
275	Jane Ikebue	Orakwu	300
276	Jude Okafor	Orakwu	700
277	Patricia Iluozue	Orakwu	550
278	Jude Ilouze	Orakwu	400
279	Codilia Obi	Orakwu	200
280	Arinze Euphemia	Orakwu	700
281	Tochukwu Madu	Orakwu	50
282	Ebele Offmuta	Orakwu	300
283	Kenedy Onuorah	Orakwu	1000
284	Ngozi Ike	Orakwu	700
285	Ngozi Onuorah	Orakwu	1000

286	Felix Onuorah	Orakwu	700
287	Augustine Emteya	Orakwu	1000
288	Eloka Francs	Orakwu	3000
289	Chmere Nnoli	Orakwu	500
290	Chinech Ibe	Orakwu	1000
291	John Ejidike	Orakwu	1000
292	Obioma Ibebudu	Orakwu	200
293	Obiora Chike	Orakwu	500
294	Bosa Nnoli	Orakwu	1000
295	Obiagereli Chidi	Orakwu	700
296	Calister Chukwuka	Orakwu	700
297	Angela Obika	Orakwu	500
298	Munachi Mebaowrn	Orakwu	350
299	Mma Ibe	Orakwu	200
300	Chigioke Ibekwe	Orakwu	800
301	Ojo Okonkwo	Orakwu	1000
302	Ijeoma Odoejwu	Orakwu	370
303	Okonkwo Agnes	Orakwu	100
304	Precious Agwu	Orakwu	450
305	Veronica Amaka	Orakwu	500
306	Galadis Chika	Orakwu	200
307	Okora Augustina	Orakwu	200
308	Mary Celestine	Orakwu	250
309	Okoro Grace	Orakwu	450
310	Okoli Ijeoma	Orakwu	500
311	Okoye Blessing	Obosi	250
312	Chinelo Okoye	Obosi	200
313	Paulina Ibekwe	Obosi	400
314	Martina Okoye	Obosi	300
315	Marth Igbo	Obosi	1000
316	Okoye Chioma	Obosi	150
317	Okoye Onyinyechi	Obosi	700
318	Fustina Chidimma	Obosi	250
319	Chiama Akafue	Obosi	300
320	Rita Efobi	Obosi	450
321	Obinwa Chioma	Obosi	500
322	Chiamaka Nnobi	Obosi	700
323	Ifeanyi Chukwuka	Obosi	250
324	Juliana Mmekiti	Obosi	700
325	Agatha Okeke	Obosi	400
326	Obianuju Ike	Obosi	350
327	Onyebuchi Obianwu	Obosi	1000
328	Ejimaofo Madu	Obosi	100
329	Chidi Dim	Obosi	200
330	Chidubem Eze	Obosi	350
331	Anosike Ngozi	Obosi	700
332	Obidimma Ike	Obosi	700
333	Ifenyinwa Obi	Obosi	200
334	Tobias Agwu	Obosi	300

335	Chidiadu Okoye	Obosi	700
336	Ebubechukwu Ofobi	Obosi	1000
337	Chiegbunam Emeka	Obosi	700
338	Kosisochukwu Muo	Obosi	1000
339	Ejimmadu Frank	Obosi	1000
340	Beleonwu Ngozi	Obosi	1000
341	Ikediobi Jane	Obosi	2000
342	Okeke Chidiebele	Obosi	400
343	Okoye Oluchukwu	Obosi	500
344	Okeke Doris	Obosi	1000
345	Dim Victor	Obosi	350
346	Okafor Clement	Obosi	200
347	Ibezuo Francis	Obosi	700
348	Uzochi Joy	Obosi	500
349	Umerah Ngozika	Obosi	500
350	Timothy Ibekwe	Obosi	400
351	Regina Obi	Obosi	200
352	Ibeneme Blessing	Obosi	250
353	Onyegbuma Jan	Obosi	600
354	Onyemaobi Jerry	Obosi	300
355	Ogbobu Chinwe	Obosi	200
356	Stella Okafor	Obosi	300
357	Ann Okpala	Obosi	500
358	Ifenyinwa Ibeziakor	Obosi	400
359	James Buchi	Obosi	400
360	Frorea Obi	Obosi	300
361	Emeka Nwaobia	Obosi	500
362	Adaobi Okafor	Obosi	200
363	Chinwendu Charles	Obosi	700
364	Patience Nwaku	Obosi	1000
365	Chidimma Nwankwo	Obosi	400
366	Louis Obi	Obosi	500
367	Josepine Mmaduka	Obosi	600
368	Ebele Nwajiobi	Obosi	350
369	Nneka Anyaegbunam	Obosi	200
370	Chinelo Jerry	Obosi	500
371	Ndidiamaka Osuagwu	Obosi	700
372	Chinonso Osuala	Obosi	400
373	Chigozie Osuala	Eziowelle	500
374	Franca Osuala	Eziowelle	200
375	Agugu Mary	Eziowelle	300
376	Obiagwu James	Eziowelle	500
377	Chidimma Akosa	Eziowelle	300
378	Chiebele Metu	Eziowelle	500
379	Maryjane Chidi	Eziowelle	400
380	Ginika Mmadu	Eziowelle	700
381	Cynthia Ibe	Eziowelle	200
382	Nwanja Omerebele	Eziowelle	200
383	Nwaofiri Tochukwu	Eziowelle	200
384	Geradine Okeke	Eziowelle	500
385	Nkiriuks Nwaenyi	Eziowelle	200
386	Modeline Okonkwo	Eziowelle	500

387	Peace Ebe	Eziowelle	500
388	Maria Nduka	Eziowelle	700
389	Veronica Egwu	Eziowelle	600
390	Martha Ade	Eziowelle	300
391	Beatrice Ibe	Eziowelle	200
392	Blessing Njoku	Eziowelle	700
393	Chineyere Ibeto	Eziowelle	350
394	Chidi Eze	Eziowelle	400
395	Vicky Eze	Eziowelle	200
396	Anex Ibeto	Eziowelle	700
397	Job Ndu	Eziowelle	500
398	Gloria Nkem	Eziowelle	200
399	Adaeze Belonwu	Eziowelle	700
400	Muoka Eunice	Eziowelle	700
401	Jane Udeze	Eziowelle	1000
402	Rose Chukwurah	Eziowelle	700
403	Oby Onwumere	Eziowelle	500
404	Blessing Okafor	Eziowelle	500
405	Samuel Okafor	Eziowelle	1000
406	Chiwendu Ikechukwu	Eziowelle	250
407	Chidi Onyeka	Eziowelle	400
408	Ndubiuisi Obi	Eziowelle	300
409	Nkechi Ifunanya	Eziowelle	400
410	Ifeyinwa Mekwo	Eziowelle	350
411	Omezie Emeda	Eziowelle	500
412	Kate Obi	Eziowelle	300
413	Johnbosco Ajaelo	Eziowelle	500
414	Stanley John	Eziowelle	1000
415	Akachukwu Nonso	Eziowelle	500
416	Jacob Iwuobi	Eziowelle	600
417	Chinemere Ibekwe	Eziowelle	700
418	Jane Achike	Eziowelle	400
419	Ndidi Obiorah	Eziowelle	250
420	Ngozi Okoye	Eziowelle	350
421	Kelechukwu Okafor	Eziowelle	300
422	Jane Oputa	Eziowelle	350
423	Ibekwe Anastesia	Eziowelle	150
424	Sobechukwu Okeke	Eziowelle	300
425	Ifedi Mekuo	Eziowelle	1000
426	John Malife	Eziowelle	500
427	Mattew Ibe	Eziowelle	450
428	Oby Ezechukwu	Eziowelle	250
429	Chukwu Ezechukwu	Eziowelle	1000
430	Bosah Chidi	Eziowelle	750
431	Stella Oputa	Eziowelle	700
432	Ginika Obi	Eziowelle	200
433	Godwin Nnamdi	Eziowelle	300
434	Maryann Osuji	Eziowelle	450
	GRAND TOTAL		**216132**

Table A.8: Idemili South LGA Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	BROILERS	LAYERS	TURKEY
1	Kizito Farms	Nnobi	-	2100	-
2	Adawa Farms	Nnobi	480	-	100
3	Ezika	Nnobi	170	350	140
4	Ejima	Nnobi	100	400	-
5	Nnebe	Nnobi	300	-	130
6	Chinwendu	Nnobi	50	-	30
7	Ejidike	Nnobi	100	1400	100
8	Ogbuka	Awka-Etiti	155	300	-
9	Chidimma	Awka-Etiti	80	-	-
10	Ifedi	Awka-Etiti	100	200	-
11	Okwesili	Awka-Etiti	-	1000	-
12	Uzuegbunam	Awka-Etiti	-	50	-
13	Uchegbu	Awka-Etiti	-	600	-
14	Umenwa	Awka-Etiti	100	1400	100
15	Frank	Awka-Etiti	350	-	50
16	Rose	Awka-Etiti	300	-	-
17	Chuks	Awka-Etiti	350	-	50
18	Chinedu	Oba	100	200	20
19	Kingsley	Oba	50	200	-
20	Clemco Farms	Oba	100	650	50
21	Molokwu	Oba	100	400	30
22	Daniel	Oba	-	350	100
23	Amarachi	Akwu-Ukwu	100	-	50
24	st. Pius Farms	Akwu-Ukwu	450	2500	100
25	Madam Grace	Akwu-Ukwu	100	300	50
26	Osita	Akwu-Ukwu	-	300	50
27	Enuigwe	Ojoto	450	-	100
28	Tagbo	Ojoto	60	270	-
29	Ngozika	Ojoto	-	380	15
30	Mama Amaka	Ojoto	40	345	-
31	Oga ken	Ojoto	200	-	35
32	Benziff farms	Nnokwa	100	2000	-
33	Ezeofor	Nnokwa	450	-	165
34	Intestate Farms	Nnokwa	100	170	-
35	Jude	Nnokwa	100	300	25
36	Ken	Nnokwa	150	350	-
37	Rose	Nnokwa	120	350	50
38	Ezeanya	Nnokwa	115	180	-
39	Uchendu	Nnokwa	65	400	20
40	Obiefuna	Nnokwa	150	550	-
41	Ekejiuba	Nnokwa	100	450	30
42	Obioma	Nnokwa	300	-	50
43	Jokal	Nnokwa	-	-	100
44	Onyeka	Alor	180	300	-
45	Njideka	Alor	50	400	-
46	Matthew	Alor	200	-	30
47	Chiemerie	Alor	100	350	25
48	Uchenna	Alor	150	-	50
49	Tasco	Alor	120	-	35
	GRAND TOTAL		**28310**		

Table A.9: Ihiala LGA Registered Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	TYPE OF BIRDS	NO. OF BIRDS
1	Noyett Farms Azia	Umudiokpara, Azia	Broiler/Layers	500/1,000
2	J. Atusingwu Farms	Ekwuru-Abam, Azia	Turkey Broiler Layers	40 200 150
3	Ike Farms	Ihite-Azia	Broilers Layers	300 550
4	Sir. Semion Eze	Bikechuks Farms, Uli	Layers Broilers Turkeys	3,250 150 50
5	Victoria Offia	Agwunnaga, Mbosi	Broilers	200
6	Chinedu C. Iwuchukwu	Chommy Farms, Eziani, Ihiala	Layers Broilers Cockerels Turkeys	1,000 1,500 500 50
7	Model Farms	Ihiala	Broilers Layers	200 250
8	Vickas Farms	Amudo, Isseke	Broilers Layers	150 250
9	Igwe Farms	Mbosi	Broilers Layers	250 100
10	Badest Farms	Uli	Broilers Layers	150 300
11	Uchenna Farms	Ihiala	Broilers	100
12	Ozorhiri Farms	Mbosi	Broilers Pullets	100 200
13	Anulummadu Farms	Umuohi, Okija	Broilers	1,000
14	Tony Farms	Okija	Broilers	350
15	Ajakanonu Farms	Umudara, Ihiala	Pullets	1,000
16	Obi Farms	Mbosi	Pullets	500
17	Tob Farms	Okohia, Ihiala	Broilers pullets	1,000 2,000
18	Ejima farms	Ihiala	Pullets Broilers	5,000
19	Ikebasi Farms	Uli	Pullets	1,500
20	Emeka Farms	Uli	Pullets	300
21	Obi Farms	Orsumoghu	Broilers Pullets	1,000 1,500
22	Aguegbulem Farm	Isseke	Broilers Pullets	100 50
23	Izuchukwu Iheagu Farms	Edeke, Isseke	Broilers	100
24	Damian Egeuba Farms	Ukwakwa, Azia	Broilers Pullets	150 200
25	Aladozie Ihtahs Farms	Azia	Broilers Pullets	200 200
26	Edy Onyebuchi Farms	Azia	Broilers Pullets	50 150
27	Chioma C.Nwaobum	Umuadobihi, Ihiala	Broilers Pullets	500 200
28	Stephen C. Akpunonu	Umueze Isu-Mbosi, Mbosi	Broiler	50
29	Ezebuenyi Onyema	Umueze Isu-Mbosi, Mbosi	Broilers	200

30	Akazie Nonyelum	Uzoakwa, Ihiala	Broilers	200
31	Ogechukwu Okwubike	Afam, Eziani, Ihiala	Broilers	475
32	Igbozulike Malaky	Umunnamehi, Ihiala	Broilers	200
33	Obiefughala Nwabugo	Umunnamehi, Ihiala	Broilers	
34	Linus Obiora	Orsumoghu	Layers Broilers	1,130 1,170
35	Ohachosin Farms	Isieke, Umudiokpara, Azia	Broilers Layers Turkeys	2,000 1,500 200
36	Kingsley offia	Agwunnaha, Mbosi	Broilers	150
37	Juliana Ike	Eziani, Ihiala	Broilers	100
38	Onyinye Ohasiligbo	St. Anthony maternity, Orlu Rd, Ihiala	Broilers	200
39	Leka Ugbo farms	Azia	Broilers	600
40	Esther Eze	Assemblies of God church, Ogboro Umunwaji, Ihiala	Broilers Layers Cockerels Turkeys	300 200 200 50
41	Chinenye Umeh	Mbarakpaka, Nitel, Rd, Ihiala	broilers	100
42	Anthonia Ikwuka	Umunnamehi, Ihiala	Broilers	100
43	Clementina Okeoma	Umudimogo, Ihiala	Broilers	200
44	Nnenna Nwaogbu	Umunnamehi, Ihiala	Broilers	200
45	Eto Farms	Umuohi, Okija	Broilers	2,000
46	Sylvester I. Okoli	Ihiala Timber Market	Broilers Turkey	140 50
47	Beatrice Obiajulu	Umuezeogu, Eziani, Ihiala	Turkey Broilers	3 15
48	Donates Nzeriwu	Umuezike, Mbosi	Broilers	150
49	Afamefuna ewulu	Umuadobihi, Eziani, Ihiala	Broilers	200
50	Emeka Uba	Umunnamehi, Ihiala	Broilers	30
51	Josephine Ikwuka	Umuadobihi, Ihiala	Broilers Turkey	150 55
52	Festus C. Onyeoziri	Orsumoghu	Broilers	1,200
53	Okechukwu ohaemesim	Umuezeogu, Eziani, Ihiala	Broilers Turkeys	100 50
	Grand Total			**43,373**

Table A.10: Njikoka LGA Registered Poultry Houses, Locations and Number of Poultry Birds

S/N	Names	Town/Address	No. Of Birds	Type Of Birds
1	Ozoemena Chigozie	Achalla Village Enugu-Agidi	5000	Layers/Broiler
2	Blessing Okoye	Achalla Village Enugu-Agidi	4500	Layers/Broiler
3	Nbosi James	Etiti Village Enugu-Ukwu Agidi	6000	Broiler
4	Ebonyi Tochukwu	Etiti Village Enugu-Ukwu Agidi	5000	Layers/Broiler
5	Anthony Okeke	Etiti Village Enugwu-Agidi	1000	Local
6	Rapheal Okekeazi	Ifite Village Enugwu-Agidi	1500	Local
7	Ebere Igboanugo	Iruobili Village Enugwu-Agidi	3500	Broiler/Local
8	James Mbosi	Etiti Village Enugwu-Agidi	4000	Broiler/Local
9	Anthony Nweke	Iruobili Village Enugwu-Agidi	1500	Broiler/Local
10	Mayor Nwandu	Iruobili Village Enugwu-Agidi	3500	Broiler
11	Mr. Obua Isaac	Iruobili Village Enugwu-Agidi	1500	Broiler

12	Veronica Igboanugo	Iruobili Village Enugwu-Agidi	100	Local
13	Bridget Onuorah	Abba Village Nimo	100	Local
14	Onyeze Nonye Nwekenta	Orofia Village E/Ukwu	50	L0cal
15	Amakaeze Angela	Awoto Village Nimo	50	Local
16	Eziako Elizabeth	Egbengwu Village Nimo	100	Broiler
17	Ani Ifeoma	Ezira Village Nimo	50	Broiler
18	Obana Esther	Iruokohia Village Nimo	100	Broiler
19	Okoye Amaka	Adazi-Nnukwu	100	Broiler
20	Ilonze Eucharia	Iruezehalachi Village Nimo	100	Broiler
21	Ani Nneka	Ezira Village Nimo	100	Broiler
22	Igwendu Ebere	Egbengwu Village Nimo	100	Broiler
23	Okwunego Elizabeth	Etiti Village Nimo	100	Broiler
24	Ayiba Grace	Ezira Village Nimo	100	Broiler
25	Anusobi Anthony	Iruezehalachi Village Nimo	200	Both
26	Chukwu Amaka	Etiti Village Nimo	4000	Broiler/Local Breed
27	Augustina Okeke	Uruakwo Village Nimo	6500	Layer/Broiler
28	Nwozor Comfort	Umuakwu Village E/Ukwu	1500	Local
29	Chigbo N. Patricia	Orofia Village E/Ukwu	1000	Local
30	Agwuenu Christiana	Agu-Ukwu	1000	Broiler
31	Veronica Odika	Awovu Village E/Ukwu	500	Local
32	Nwafor Eunice	Adugbe Avomimi Village E/Ukwu	500	Local
33	Akaose Caroline	Adugbe Avomimi Village E/Ukwu	501	Local
34	Theresa Okonkwo	Orofia Village E/Ukwu	500	Broilers/Layers
35	Obazie Uche	Uruekwo E/Ukwu	3000	Broiler
36	Paul Chike	Uruekwo E/Ukwu	3000	Broiler
37	Chuka Peter	Uruekwo E/Ukwu	3070	Broiler
38	Amuzie Evelyn	Orofia Village E/Ukwu	2000	Layer
39	Chimelie Amuzie	Orofia Village E/Ukwu	4000	Broiler
40	Josiah Anyanabachi	Orofia Village E/Ukwu	4000	Broilers/Layers
41	Josephine Ifeayekwu	Adeybe Village Abagana	1000	Broiler
42	Chibueze Chukwuka	Etiti Village Abagana	1000	Broiler
43	Mrs. Obinna Tagbo	Abagana	500	Broiler
44	Ebele .E. Ozugha	Umudunu Village Abagana	400	Broilers/Local
45	Amaka Okeke	Orofia Village Abagana	200	Broiler
46	Mrs. Okafor Nkiru	Umudunu Village	500	Broiler
47	Francisca Ojiakor	Orofia Village Abagana	300	Broiler
48	Esther Nweke	Abba Village	200	Broiler
49	Edna Ogbunigwe	Orofia Village Abagana	800	Broiler
50	Ifenyinwa Obiano	Orofia Village Abagana	1000	Broiler
51	Chinonye Onumonu	Orofia Village Abagana	900	Broiler
52	Okafor Beatrice	Etiti Umudunu Abagana	600	Broiler
53	Mobi Chika	Abagana	800	Broiler
54	Okoye Ugochukwu	Abagana	300	Layers
55	Lucy Nchekwube	Abagana	400	Broilers/Layers
56	Onyiagha Solomon	Abagana	400	Broilers/Layers
57	Blessing Osingor	Abagana	500	Broilers
58	Ogochukwu Igwedibia	Abagana	1000	Broilers
59	Esther Onuorah	Abagana	500	Broilers
60	Ngozi Nnaebo	Amaenye Abagana	400	Broilers
61	Odili Patience	Umudunu Village	400	Broilers
62	Stella Chimezie	Abagana	300	Broilers
63	Roseline Ekemezie	Abagana	300	Broilers
63	Roseline Ekemezie	Abagana	250	Broilers
64	Theresa Ngige	Abagana	250	Broilers
65	Caroline Okoye	Abagana	200	Broilers
66	Nwokolo Uchenna	Abagana	600	Layers/Broilers
67	Ibeh Justice	Abagana	1000	Layers/Broilers

68	Ikebudu Goodluck	Abagana	400	Broilers
69	Chidume Agnes	Abagana	600	Broilers
70	Nwaforiko Uche	Abagana	800	Layers/Broilers
71	Alike Stella	Akpu Village Abagana	400	Layers/Broilers
72	Alike Hyacenth	Akpu Village Abagana	500	Broilers
73	Azufoaku	Amanye Village Abagana	700	Layers/Broilers
74	Daniel Okeke	Orofia Village Abagana	500	Broiler
75	Mrs. Anthonia Aniekwe	Orofia Village Abagana	500	Broilers/Layers
76	Onuorah Chigozie	Adaybe Village Abagana	1000	Broilers/Layers
77	Anyanebechi Ifeoma Blessing	Umudunu Village Abagana	2000	Broilers/Layers
78	Nwagbo Divine	Umudunu Village Abagana	3000	Layers
79	Ikechukwu Solomon	Umudunu Village Abagana	3000	Broilers/Layers
80	Emeka Emmanuel	Umudunu Village Abagana	2500	Broiler
81	Chinelo Okoye	Mmimi Village Nawfia	400	Broiler
82	Okoye Josephine	Umuriam Village Nawfia	3000	Broiler
83	Onyinye Nnadi	Iridebe Village Nawfia	1000	Broiler
84	Nonyelum Ndibe	Umuriam Village Nawfia	4000	Broiler
85	Chineye Okongwu	Mmimi Village Nawfia	7000	Broiler
86	Chukwudozie Chidiebele	Mmimi Village Nawfia	6000	Broiler
87	Chinedu Ngini	Enugo Mmimi Village Nwafia	4000	Broiler
88	Ngozi Okoye	Adagbe Mmimi Village Nawfia	4000	Broiler
89	Tochukwu Udogwu	Adagbe Mmimi Village Nawfia	5000	Broiler
90	Anayo Okoye	Mmimi Village Nawfia	4000	Broiler
91	Chinedu Nwafor	Mmimi Village Nawfia	6000	Broilers/Layers
92	Maria Nwankwo	Mmimi Village Nawfia	4000	Broiler
93	Monica Ejikeme	Mmimi Village Nawfia	2000	Broiler
94	Cecilia Nwokoye	Mmimi Village Nawfia	3000	Broiler
95	Sunday Mmaduka	Mmimi Village Nawfia	6000	Broilers/Layers
96	Theresa Nwokoye	Mmimi Village Nawfia	3000	Broiler
97	Esther Nkpuluegbe	Mmimi Village Nawfia	3000	Broiler
98	Stella Okeke	Mmimi Village Nawfia	2000	Broiler
99	Eucharia Igoekwu	Eziakpaka Village Nawfia	2000	Broiler
100	Mrs. Angela Nkemka	Mmimi Village Nawfia	200	Broiler
101	Mrs. Anierobi Uchechukwu	Umuriam Village Nawfia	800	Broiler
102	Maduakor Ngozi	Umuriam Village Nawfia	200	Broiler
103	Blessing Aniemene	Umuriam Village Nawfia	200	Broiler
104	Ego Anoliefo	Umuriam Village Nawfia	100	Broiler
105	Ifeoma Udeh	Umuriam Village Nawfia	800	Broiler/Layers
106	Ann Ibenegbu	Umukwa Village Nawfia	600	Broiler
107	Chikodili Nnaemeka	Umukwa Village Nawfia	100	Broiler
108	Alice Nwankwo	Urukpaleri Village Nawfia	100	Broiler
109	Nkechi Echetabi	Umuriam Village Nawfia	200	Broiler
110	Okonkwo Ukamaka	Mmimi Village Nawfia	200	Broiler
111	Martin Aniere	Umuriam Village Nawfia	400	Broiler
112	Festus Ibenegbu	Umukwa Village Nawfia	300	Broiler
113	Matthew Okonkwo	Mmimi Village Nawfia	200	Broiler
114	Patricia Nwankwo	Urukpaleri Village Nawfia	200	Broiler
115	Paul Igwedibia	Mmimi Village Nawfia	300	Broiler
116	Lucy Etele	Umuriam Village Nawfia	400	Broiler
117	Ifeoma Nnamah	Umuriam Village Nawfia	300	Broiler
118	Okoye Louisa	Umuriam Village Nawfia	200	Broiler
119	Peace Okoye	Mmimi Village Nawfia	400	Broiler
120	Lucy Ichoku	Umuriam Village Nawfia	200	Broiler
121	Uju Ndibe	Uruoji Village Nawfia	1000	Broiler
122	Chinelo Okeke	Uruoji Village Nawfia	400	Broiler
123	Elizabeth Nwosu	Uruoji Village Nawfia	200	Broiler

124	Chinwe Opara	Umuezuru Village Nawfia	700	Broiler/Layers
125	Joy Ike	Umukwa Village Nawfia	4000	Broiler
126	Chukwudi Udeh	Umuriam Village Nawfia	600	Broiler
127	Okeke Nonye	Umuriam Village Nawfia	2000	Broiler
128	Okeke Fidelia	Umuriam Village Nawfia	200	Broiler
129	Ebuka Agu	Umuriam Village Nawfia	400	Broiler
130	Eze Fidelia	Umuriam Village Nawfia	100	Broiler
131	Chinyere Ifeagwu	Umuriam Village Nawfia	200	Broiler
132	Uju Okeke	Umuriam Village Nawfia	200	Broiler
133	Grace Okaformezue	Umuriam Village Nawfia	100	Broiler
134	Nkiru Nwokoye	Uruoji Village Nawfia	200	Broiler
135	Alor Gabriel	Umukwa Village Nawfia	600	Broiler
136	Patricia Noguluwo	Ifite Village Nawfia	1000	Broiler
137	Ifeyinwa Okonkwo	Urukpaleri Village Nawfia	2000	Broiler
138	Charity Agbata	Ifite Village Nawfia	200	Broiler
139	Nkiru Okechukwu	Umuriam Village Nawfia	4000	Broiler
140	Ebele Aniefuna	Uruoji Village Nawfia	2000	Broiler
141	Hope Okoyeifeagwu	Umuriam Village Nawfia	500	Broiler
142	Serah Okeke	Ifiteiridana Village Nawfia	500	Broiler
143	Tochukwu Nwune	Umuriam Village Nawfia	500	Broiler
144	Angela Ndubuisi	Mmimi Village Nawfia	4000	Broiler
145	Anyadika Agnes	Mmimi Village Nawfia	4000	Broiler
146	Victoria Okoyealor	Umukwa Village Nawfia	8000	Broiler/Layers
147	Celina Okoye	Uruoji Village Nawfia	3000	Broiler
148	Rose Ekpeh	Umukwa Village Nawfia	2000	Broiler
149	Elizabeth Okuani	Uruoji Village Nawfia	3000	Broiler
	Grand Total		**225271**	

Table A.11: Ayamelum LGA Registered Poultry Houses, Locations and Number of Poultry Birds

S/N	NAME	TOWN/ADDRESS	FOWL	DUCK	TURKEY
1	Theresa Ugonwa	Anaku	1	4	-
2	Chinwuba Justina	Anaku	2	-	-
3	Unoegobudike	Anaku	-	15	-
4	Theresa Obidike	Anaku	-	9	-
5	Chukwuma Ekene	Anaku	1	-	-
6	Veronica Anagor	Anaku	9	-	-
7	Philomina Ekwunye	Anaku	4	-	-
8	Okuata Iheneme	Anaku	8	-	-
9	Uchenna Nwatu	Anaku	5	-	-
10	Caroline Nebeuwa	Anaku	2	-	-
11	Patricia Aghadino	Anaku	2	-	-
12	Theresa Agbata	Anaku	11	-	-
13	Uchenwa Udemezue	Anaku	7	-	-
14	Caroline Ejimofor	Anaku	2	-	-
15	Anulika Eduno	Anaku	7	-	-
16	Patricia Chukwuma	Anaku	10	-	-
17	Sunday Okwa	Anaku	20	-	-
18	Nwanji Achebe	Anaku	3	-	-
19	Umeadi Onwualu	Anaku	7	-	2
20	Obidigwe Uche	Anaku	5	4	-
21	Mama Meche	Anaku	3	-	-
22	Helen Anagor	Anaku	10	-	-
23	Jacinta Chukwuemeka	Anaku	15	-	-
24	Mama Cele	Anaku	8	-	-
25	Christy Ejimofor	Anaku	6	-	-
26	Nnenna Ebele	Anaku	10	-	-
27	Blessing Anyanwumelu	Anaku	1	-	-
28	Simon Nwafor	Anaku	13	-	-
29	Onyeka Onyembosili	Anaku	7	-	-
30	Paul Anyanwumelu	Anaku	5	-	-
31	Nwalieji Onwudinjo	Anaku	7	-	-
32	Ezechukwu Uchenwa	Anaku	5	-	-
33	Ikegbuna Chuba	Anaku	8	-	1
34	Chuma Nwabunne	Anaku	5	-	-
35	Prince Uzoma Obidike	Anaku	15	-	-
36	Micheal Ameke	Anaku	3	-	-
37	Ngozi Onyeagolu	Anaku	5	-	-
38	Gladdys Onyejekwe	Anaku	5	-	1
39	Emmanuel Ejimofor	Anaku	4	-	-
40	Chief Onwuluba Ndife	Anaku	3	-	-
41	Chukwuemeka Okwuife	Anaku	3	-	-
42	Ignatius Nkembisi	Anaku	2	-	-
43	Chief Ntii Egwuatu	Anaku	5	-	1
44	Ikechukwu Ogbarje	Anaku	7	-	-
45	Akwausilo Anaekwe	Anaku	10	-	-
46	Ezioba Nnalue	Anaku	9	-	-
47	Chibogu Ginika	Anaku	3	-	2
48	Nwalieji Mgbakor	Anaku	4	-	-
49	Onyedika Oguejiofor	Anaku Umereagu	5	-	-
50	Owakiri Rose	Anaku Umereagu	20	-	-
51	Ezechukwu Uderika	Anaku Umereagu	20	-	-

52	Uzuama Juliana	Anaku Umereagu	10	-	-
53	Obiora Osita	Anaku Umereagu	120	-	-
54	Josephine Ndibe	AnakuUmereagu	15	-	-
55	Ogeche Ekwunife	Anaku Umereagu	1	-	-
56	Ugonnia Onuama	Omor-Atur village	-	-	-
57	Chukwujekwu Uju	,,	50	-	-
58	Nweke Juliana	,,	10	-	-
59	Sunday Chiamogu	,,	350	-	-
60	Orakei Judemary	,,	10	-	-
61	Sunday Chiamogu	,,	25	-	-
62	Emeka Godwin Okeke	,,	6	-	-
63	Ofouonye Ezekwa	,,	2	-	-
64	Emmanuel Nnonyelu	,,	5	-	-
65	Uwadiegwu Edochie	,,	20	-	-
66	Onyilukalu Simon .E.	,,	10	-	-
67	Nnenna Francis Emeka	Omor	10	-	-
68	Stella Obiora	,,	20	-	-
69	Catherine Nnaluo	,,	35	-	-
70	Christopher Amalue	,,	5	-	-
71	John Muorah	,,	15	-	-
72	Onuyah Emmanuel	,,	26	-	-
73	Okoye Michael	,,	15	-	-
74	Oliji Okoye	,,	6	-	-
75	Onyeabor Christopher	,,	5	-	-
76	Emeka Ndumuanya	,,	200	-	-
77	Ugochukwu Chukwuma	,,	5	-	-
78	Unaku Nweke	,,	4	-	-
79	Ugochukwu Emeka	,,	1	-	-
80	Nwalago Chukwuma	,,	2	-	-
81	Christiana Anekwe	,,	5	-	-
82	Udeagbor Nwanwune	,,	4	-	-
83	Emeka Ndumanye	,,	400	-	-
84	Oyibo Anekwe	,,	6	-	-
85	Ugochukwu Anekwe	,,	2	-	-
86	Christopher Uba	,,	5	-	-
87	Ngozi Emeka	,,	50	-	-
88	Umeadi Emeka	,,	20	-	-
89	Onyekwe Onyenwuba	,,	20	-	-
90	Dan Nosike	,,	5	-	-
91	Paul Umukpala	,,	5	-	-
92	Deili Joy Ijeoma	Ifite - Ogwari	25	-	-
93	Ejike Nweke	,,	5	-	-
94	William Amaluche	,,	4	-	-
95	Ignatius Igwemma	,,	21	-	-
96	Michael Tagbo	,,	15	-	-
97	Michael Chetuya	,,	18	-	-
98	Nwoji Anekwe	,,	5	-	-
99	Edochie Fabian	,,	1	-	-
100	Michael Mabuko	,,	25	-	-
101	Chukwuma Reuben	,,	4	-	-
102	Okoye Chukwuma	,,	20	-	-
103	Peter	,,	10	-	-

104	Okonkwo Benjamin	,,	20	-	-
105	Ekwegbeli Okaforigwe	,,	40	-	-
106	Nchekwube Ameke	,,	12	-	-
107	Okafor Chukwuma	,,	10	-	-
108	Egodi James	,,	10	-	-
109	Augustine Chiokwe	,,	10	-	-
110	Onwurah Igwebudu	,,	8	-	-
111	Amuluche Donatus .O.	,,	5	-	-
112	Mgbechi Patrick	,,	9	-	-
113	Onuigbo.O. Ukozor	,,	8	-	-
114	Muokwe Ikeji	,,	4	-	-
115	Boy Zeluwa	,,	4	-	-
116	Emmanuel Okafor	,,	9	-	-
117	Maduchie Augustine	Ifite-Ogwari	5	-	-
118	Anthonia Ifeka	,,	4	-	-
119	Achokuba Agnes	,,	20	-	-
120	Nwogbo	,,	10	-	-
121	Mrs. Dieli Nneoma	,,	60	-	-
122	Ejike Nweke	,,	7	-	-
123	Okoye Jerome	,,	10	-	-
124	Emmanuel Okoye	,,	10	-	-
125	Okoye Harrison	,,	20	-	-
126	Obi Okoye	,,	6	-	-
127	Nwalieji Michael	,,	11	-	-
128	Maria Boniface	,,	5	-	-
129	Ekwunife Francis	,,	15	-	-
130	Mabia Christopher	,,	2	-	-
131	Onwuria Gregory	,,	7	-	-
132	Udegbune Chiogo	,,	10	-	-
133	Achokuba Agnes	,,	12	-	-
134	Onuora Peter	,,	6	-	-
135	Okonkwo Theophilus	,,	11	-	-
136	Livinus Okonkwo	,,	16	-	-
137	Okoye Obiorah	,,	25	-	-
138	Iyoma Ukatu	,,	10	-	-
139	Dominic Afune	,,	20	-	-
140	Okonkwo Benjamin .C.	,,	25	-	-
141	Pius(12) Machi	Ifite-Ogwari	7	-	-
142	Mr. Okoye Motike	,,	13	-	-
143	Ikegbube Clement	,,	12	-	-
144	Ozene Gregory	,,	6	-	-
145	Obiorah Juliana	,,	13	-	-
146	Ngozi Obiorah	,,	10	-	-
147	Nwabuisi Innocent	,,	7	-	-
148	Rev. Oleka Nwachukwu	,,	50	-	-
149	Onwura Igwebudu.A.	,,	12	-	-
150	Okafor Mary	,,	6	-	-
151	Ozene Igbanu George	,,	5	-	-
152	Okoye George Uche	,,	7	-	-
153	Prophet Jideofor Okafor	,,	60	-	-
154	Nneli Theophilus	,,	7	-	-
155	Okoye Patricia	,,	21	-	-
156	Onuigbo Obiorah	,,	25	-	-
157	Nka Okoye Raymond	,,	12	-	-

158	Mbanefor Okoye	,,	25	-	-
159	Joseph Muoka	,,	7	-	-
160	Ajani Obiora Anthony	,,	10	-	-
161	Ikwunne Aloma	,,	14	-	-
162	Okoye John (Ololo)	,,	6	-	-
163	Ikwunne Nwaji	,,	5	-	-
164	Chukwuma Ikwunne .A.	,,	6	-	-
165	Iyambo Lawrence	,,	5	-	-
166	Ikechukwu Okafor	,,	5	-	-
167	Okoye Chukwundu.O.	,,	10	-	-
168	Ijeka Paul ‘‘Captain’’	,,	5	-	-
169	Reuben.O. Okonkwo	,,	10	-	-
170	Ndubisi Okeh	,,	6	-	-
171	Okoye Theresa	,,	5	-	-
172	Obiorah Kachikwulu	Ifite-Ogwari	5	-	-
173	Chukwuka Okechi	Ifite-Ogwari	6	-	-
174	Nweke Anthonia	Ifite-Ogwari	12	-	-
175	Mrs. Ada Monyike	Ifite-Ogwari	5	-	-
176	Oliaku Akilika	Ifite-Ogwari	5	-	-
177	Anikpulu Joseph .M.	Ifite-Ogwari	5	-	-
178	Peter Chukwuemeka	Ifite-Ogwari	4	-	-
179	Nwonyi James	Ifite-Ogwari	7	-	-
180	Dibor Aloysius	Ifite-Ogwari	8	-	-
181	John Okeh Nweke	Ifite-Ogwari	60	-	-
182	Otimme Maduba	Ifite-Ogwari	7	-	-
183	Ndibe Kenneth	Ifite-Ogwari	10	-	-
184	Anumudu Otikpa .A.	Ifite-Ogwari	11	-	-
185	Igweze Paulina	Ifite-Ogwari	11	-	-
186	Okoye James	Ifite-Ogwari	10	-	-
187	Okoye Dandi	Ifite-Ogwari	7	-	-
188	Igweze Okeke .N.	Ifite-Ogwari	7	-	-
189	Mary Igweze Mgboye	Ifite-Ogwari	13	-	-
190	Okafor Okoye	Ifite-Ogwari	7	-	-
191	Oliver Nweke Anumudu	Ifite-Ogwari	8	-	-
192	Nweke Peter Igbegwu	Ifite-Ogwari	17	-	2
193	Udemezue John .A.	Ifite-Ogwari	23	-	1
194	Akpata Emmanuel	Ifite-Ogwari	14	-	-
195	Modokwe .E. Nwoji	Ifite-Ogwari	13	-	-
196	Ozene Gregory Igbanu	Ifite-Ogwari	3	-	-
197	Okafor James .E.	Ifite-Ogwari	14	-	-
198	Nwabuisi Augustine	Ifite-Ogwari	15	-	-
199	Okafor Augustine	Omor	2920	-	80
	Total		**6330**		

Table A.12: Dunukofia LGA Poultry Houses, Locations and Number of Poultry Birds

S/NO	NAMES	TOWN/ADDRESS	TYPE OF BIRD	NO. OF BIRDS
1	Mrs. Uzoechina	Ukwulu	Broiler	100
2	Michael Eziachala	Ukwulu	Layer	100
3	Eunice Onuekwusi	Ukwulu	Broiler	50
4	Nkeiruka Obiorah	Ukwulu	Broiler	100
5	Veronica Okafor	Ukwulu	Broiler	50
6	Mrs. Patricia Ochife	Ukpo	Broiler	200

			Turkey	120
7	Mrs. Uchenna Adubasi	Ukpo	Broiler	200
8	Omebido Kenechukwu	Ukpo	Broiler	200
9	Vincent Igbom	Ukpo	Broiler	150
10	Pauline Udenweze	Ukpo	Broiler	50
11	Ven. Emma Okeke	Ukpo	Broiler	250
12	George Ukommadu	Ukpo	Broiler Layer Turkey	200 400 20
13	Ngozi Okafor	Ukpo	Broiler	50
14	Cecilia Onyekwe	Ukpo	Broiler	350
15	Benuser Ukommadu	Ukpo	Broiler	200
16	Ngozi Ezulu	Ukpo	Broiler	50
17	Nnonye Oforah	Ukpo	Broiler	100
18	Cecilia Anyanwutaku	Ukpo	Broiler	100
19	Esther Okeke	Ukpo	Broiler	150
20	Gloria Omebede	Ukpo	Broiler	150
21	Anna Okoye Agu	Ukpo	Broiler	100
22	Christiana Egbuna	Ukpo	Broiler	100
23	Regina Nwankwo	Ukpo	Local bird /Broiler	60/100
24	Uche Okeke	Ukpo	Broiler	50
25	Ukamaka Okoye	Ukpo	Broiler	80
26	Augustine Udenka	Ukpo	Broiler	50
27	Obiajulu Okoye	Ukpo	Broiler	90
28	Ginika Nweke	Ukpo	Broiler Layer Turkey	50 100 50
29	Cajatan Ajinobi	Ukpo	Broiler	100
30	Cajetan Ajinobi	Ukpo	Layer	100
31	Lovelyn Onyeyili	Ukpo	Broiler	50
32	Ijeamaka Eze	Ukpo	Broiler/Layer	100/250
33	Florence Isiaka	Ukpo	Broiler Layer	150
34	Esther Anika	Ukpo	Broiler	150
35	Felicia Okenu	Ukpo	Broiler	100
36	NkirukaNgala	Ukpo	Broiler	150
37	Florence Isiaka	Ukpo	Broiler Layer	150 100
38	Ogo Uche	Ukpo	Broiler	100
39	Omeaku Felicia	Ukpo	Broiler Local bird	200 30
40	Patricia Okonkwo	Ukpo	Broiler/Local bird	50/30
41	Ogidika Okoye	Ukpo	Broiler	150
42	Ebele gu	Ukpo	Broiler	120
43	Chinyere Okafor	Ukpo	Broiler	100
44	Rita Ochuba	Ukpo	Broiler	100
45	Uche Isiaka	Ukpo	Broiler	50
46	Gladys Okeke	Ukpo	Broiler/Local bird	200/30
47	Peace Okafor	Ukpo	Broiler	100
48	Chinyere Udemmadu	Ukpo	Broiler	50
49	Gladys Okeke	Ukpo	Broiler	100
50	Obioma Omeaku	Ukpo	Broiler	200
51	Elizabeth Mezie	Ukpo	Broiler	200
52	Gladys Okeke	Ukpo	Broiler Local bird	100 120
53	Ebele Ozorah	Ukpo	Broiler/Local bird	100/30
54	Ifenwa Onyeyili	Ukpo	Broiler	100
55	Juliana Okafor	Ukpo	Broiler	100

56	Lucy Chikwe	Ukpo	Broiler	400
57	Nkiru Ijengala	Ukpo	Broiler	100
58	Obute Okoye	Ukpo	Broiler	200
59	Nonye Mmaduka	Ukpo	Broiler	100
60	Uju Okeke	Ukpo	Broiler	100
61	Mr. Uche	Ukpo	Broiler	100
62	Kaosisochukwu	Ukpo	Broiler	350
63	Ogochukwu Okafor	Ukpo	Broiler	100
64	Ifeoma Omeokachie	Ukpo	Broiler	200
65	Hope Okeke	Ukpo	Broiler	50
66	Ebuka Sunday	Nawgu	Broiler	50
67	Okechukwu Nwafor	Nawgu	Broiler	50
68	Stella Mmaduako	Nawgu	Broiler	40
69	Perpetua Nweife	Nawgu	Broiler	300
70	Mary Ejike	Nawgu	Layer	100
71	Pauline Okeke	Nawgu	Layer	100
72	Nweke Caroline	Nawgu	Layer	60
73	Maureen Ike	Nawgu	Broiler	100
74	Blessing Anumba	Nawgu	Broiler	100
75	Anna Nwoye	Nawgu	Broiler	150
76	Roseline Okeke	Nawgu	Layer	50
77	Angelina Benedeth	Nawgu	Layer	50
78	Benedeth Nnayelu	Nawgu	Broiler	100
79	Mrs. Menankiti .B.	Ifitedunu	Broiler	350
80	Ebere Okonkwo	Ifitedunu	Broiler	250
81	Maureen Onunkwo	Ifitedunu	Broiler	200
82	Joseph Onunkwo	Ifitedunu	Broiler	250
83	Caroline Nwafor	Ifitedunu	Broiler	300
84	Onyegbu Elizabeth	Ifitedunu	Broiler	50
85	Ukamaka Nwankwo	Ifitedunu	Broiler	150
86	Mrs. Bridget Ogbue	Umunachi	Turkey/Broiler/Layer	120/200/100
87	Mrs. Patricia Ochife	Umunachi	Broiler/Turkey	300/120
88	Mrs. Anyanwu C.O	Umunachi	Layer	800
89	Mr. Samuel Nwodu	Umunachi	Broiler	1000
90	Mrs. Sylvester Okafor	Umunachi	Broiler	100
	Grand Total			**18540**

Table A.13: Ekwusigo LGA Poultry Houses, Locations and Number of Poultry Birds

S/NO	NAMES	TOWN/ADDRESS	FOWL	TURKEY	LOCAL FOWL
1	Igwe Ozubulu farms	Ozubulu	68	148	100
2	Rev. Odili	Ihembosi	235	-	-
3	Emeka Igwilo	Oraifite	350	-	-
4	Arinze .R. Okoye	Oraifite	400	-	-
5	Francis Onyemma	Oraifite	150	-	-
6	Joseph Onuchukwu	Oraifite	300	-	7
7	Eriobuna farms	Ihembosi	530	2	20
8	Chika Ifediora	Oraifite	150	-	5
9	Oramadike Chukwu	Ozubulu	200	-	-
10	Steven Nduka	Ozubulu	200	-	6
11	Rose Igwilo	Ozubulu	200	-	-
12	Eucharia Ugbaja	Oraifite	200	-	10
13	Timothy Okeke	Ozubulu	150	-	-
14	Amaka Igwebuike	Oraifite	150	-	-
15	Lovelyn Ofoma	Ozubulu	250	-	-
16	Uche Nwachukwu	Ozubulu	50	-	-
17	Bene Ndubuisi	Ozubulu	100	-	8
18	Obiageli Chukwuemeka	Ozubulu	150	-	10
19	Dozie Atusiuba	Ozubulu	250	-	-
20	Norbert Iwuchukwu	Ozubulu	250	-	-
21	Ngozi Okonkwo	Ozubulu	300	4	-
22	Justina Maduafokwa	Ozubulu	400	5	-
23	Onyema Lewis	Oraifite	350	-	-
24	Nzom Henry	Oraifite	450	-	-
25	Veronica Nwalue	Ozubulu	500	-	-
26	Jude Arinze	Ozubulu	300	-	-
27	Obunadike Uju	Ozubulu	300	-	-
28	Nwosu Chinwe	Oraifite	100	-	5
29	Azubogu Kenechukwu	Ozubulu	300	-	-
30	Chukwudozie Amaka	Oraifite	300	-	-
31	Ojukwu Ebere	Oraifite	100	-	-
32	Ikwukanne Osita	Ozubulu	250	-	4
33	Ofouo Theresa	Ozubulu	300	-	-
34	Iwujiora Paul	Ozubulu	300	-	-
35	Okwueze Ijeoma	Oraifite	150	-	-
36	Okafor Olivia	Ozubulu	100	-	10
37	Oduba Gloria	Ozubulu	100	-	-
38	Igbokwe Onyeka	Ozubulu	150	-	-
39	Anene Elizabeth	Oraifite	150	-	-
40	Anemenam Rose	Oraifite	120	-	-
41	Anadozie Bernard	Ihembosi	500	10	-
42	Anoliefo Rebecca	Ozubulu	200	-	-
43	Agbala Boniface	Ozubulu	300	-	-
44	Azubogu Tochukwu	Ozubulu	150	-	-
45	Ejimnkonye Louisa	Ozubulu	150	-	-
46	Iloka Mary	Ozubulu	150	-	-
47	Anaekwe Christiana	Ozubulu	150	-	-
48	Uzoeto Linus	Ozubulu	100	-	-
49	Kate Okonkwo	Ozubulu	50	-	8
50	Ngozi Oku	Ozubulu	100	-	12
51	Felicia Okafor	Ozubulu	100	-	-
52	Uche Ifediora	Oraifite	200	-	-
53	Mgbenka Gloria	Ozubulu	30	-	-
54	Obunadike Ebere	Ozubulu	200	-	-

55	Benedict Obiora	Ichi	50	-	-
56	Regina Obiora	Ichi	80	-	-
57	Okemadu Alex	Ozubulu	300	-	-
58	George Ejiofor	Amakwa Ozubulu	100	-	-
59	Ifeoma Akosa	Umuezopi Oraifite	21	-	4
60	Efobi Chinenye	Umuezopi Oraifite	100	-	-
61	Anolefo Rebecca	Nza Ozubulu	100	-	-
62	Uchenna Mmaduekwe	Ozubulu	250	10	20
63	Integrated Aric	Ozubulu	30,000	150	-
64	Pastor Benson	Ichi	250	-	-
65	Amaka .C.	Ichi	300	-	-
66	Enekwizu Sunday	Oraifite	100	-	-
67	Nnenna Igwe	Ozubulu	200	-	-
68	Ifejika Uju	Oraifitte	230	-	-
69	Orazulike Boniface	Ozubulu	100	-	-
70	Igwilo Christian	Oraifite	150	-	-
71	Iloka Joseph	Ozubulu	300	-	-
72	Arinze Jude	Ozubulu	200	-	-
73	Mbadugha Florence	Ihembosi	200	-	-
74	Benedeth Anijemba	Ozubulu	250	-	-
75	Ezeoke Paul	Ihembosi	500	10	-
76	Odunukwe Michael	Ihembosi	300	-	-
77	Njubigbo Innocent	Eziora Ozubulu	600	12	-
78	Anene Michael	Oraifite	200	-	-
79	Ezeoke Chinedu	Ihembosi	200	-	-
80	Ibegbunam Bene	Oraifite	200	-	5
81	Anya Nene	Egbema Ozubulu	200	-	-
82	Iloh Agnes	Egbema Ozubulu	200	-	-
83	Okolo	Amakwa Ozubulu	200	-	-
84	Chukwuka Rose	Eziora Ozubulu	100	-	-
85	Louisa Ejimnkeonye	Eziora Ozubulu	200	-	-
86	Aghadnumuo Grace	Eziora Ozubulu	100	-	-
87	Iloka Anthonia	Eziora Ozubulu	100	-	-
88	U.K Onwumaegbu	Egbema Ozubulu	100	-	-
89	Asomugha Ogonna	Eziora Ozubulu	100	-	10
90	Obi Uche	Oraifite	200	-	-
91	Ezekwu Ogonna	Egbema Ozubulu	200	-	-
92	Eboh Hope	Egbema Ozubulu	200	-	-
93	Ejiofor Fidelis	Eziora Ozubulu	200	-	-
94	Chianumba Peter	Oraifite	1000	-	-
95	Ifediora Maria	Egbema Ozubulu	200	-	-
96	Okechukwu Ndeodo	Eziora Ozubulu	200	-	-
97	Sunday Onwusoba	Egbema Ozubulu	300	-	-
98	Mr. Obi	Ichi	500	30	10
99	Anadu Nnubia Farms	Ozubulu	500	60	-
100	Mrs. Mmadubike	Ozubulu	200	-	-
	Grand Total		**53268**		

Table A.14: Nnewi North LGA Registered Poultry Houses, Locations and Number of Poultry Birds

S/NO	NAME OF FARMER	NO. OF ANIMALS KEPT	WARD	TOWN/VILLAGE
1	Mr. Benjamin Ukatu	100	3	Ezekwuabor Otolo Nnewi
2	Mrs. Kate Mmadubugwu	50	1	Obiuno Otolo Nnewi
3	Mr. Christopher Okonkwo	60	3	Ezekwuabor Otolo Nnewi
4	Mrs.Ubajaka Justina	150	1	Ogenwakamma Otolo Nnewi
5	Mr. Martin Egbosimba	1800	2	Egbumenam Otolo Nnewi
6	Rev.Ofojebe Isaac	1500	1	Ndiakwu Otolo Nnewi
7	Mr. Onyedum Eugene Nwogu	500	3	Ezekwuabor Otolo Nnewi
8	Mr. Edith .O. Nwogu	300	3	Ezekwuabor Otolo Nnewi
9	Mrs. Edith Egosimba	62	1	Obiuno Otolo Nnewi
10	Mr. Chidozie Okafor	20	2	Egbumenam Otolo Nnewi
11	Mr. John Onwuyike	58	12	Umuenem Otolo Nnewi
12	Mr. Ikechukwu Chukwuma	500	1	Obiuno Otolo Nnewi
13	Mr. Azuka Nnoruka	1500	2	Obofia Otolo Nnewi
14	Mrs. Obiageri Arinzechi	270	3	Eziogwu Otolo Nnewi
15	Mr. Okoye Nonso	1400	2	Ogbe Otolo Nnewi
16	Obioma Emmanuel	65	1	Umuogboo Ichi Nnewi
17	Emmanuel Onwunzo	150	1	Obiofia Nnewiichi Nnewi
18	Charles Okoye	425	1	Umueze Ichi Nnewi
19	Amaka Obiapuna	600	1	Obiofia Nnewiichi Nnewi
20	Anna Chukwuemeka	100	1	Obofia Nnewiichi Nnewi
21	F.U Egenli	60	1	Okpuno Ichi Nnewi
22	Roder Amachukwu	100	1	Obiofia Nnewiichi Nnewi
23	Mrs. Obiageli Agnes	220	1	Obiofia Nnewiichi Nnewi
24	Mr.Ikechukwu Ekechukwu	50	21	Akaboedoji Umugu Nnewi
25	Izuchukwu Udechukwu	650	2	Abubo Nnewiichi Nnewi
26	Udeoye Joseph	2,000	2	Abubo Nnewiichi Nnewi
27	Onyinyechukw C. Udeoye	1,500	2	Abubo Nnewiichi Nnewi
28	Kilthen Obiajuru	1,000	2	Abubo Nnewiichi Nnewi
29	Ruffus Obiapuna	452	1	Akabubiofia Nnewiichi Nnewi
30	Louisa Moluwe	250	2	Abubo Nnewiichi Nnewi
31	Mrs. Louisa Amachukwu	15	1	Obiofia Nnewiichi Nnewi
32	Mrs. Edikwe Grace	115	1	Obiofia Nnewiichi Nnewi
33	Mrs. Alice Amachukwu	40	1	Obiofia Nnewiichi Nnewi
34	Mrs. Moudline Okeke	15	1	Obiofia Nnewiichi Nnewi
35	Mr. Obiekwe Ifeanyi	25	1	Okpuno Nnewiichi Nnewi
36	Mrs. Obiageli Okafor	300	2	Abubor Nnewiichi Nnewi
37	Mrs.Madubuike Nwanneka	30	1	Obiofia Nnewiichi Nnewi
38	Mr. Emmanuel . O. Okafor	2700	1	Mbanakwu Nnewiichi Nnewi
39	Mr. Azubugwu Onyekaonwu	45	1	Mbanakwu Nnewiichi Nnewi
40	Mr. Sunday Onunkwo	740	1	Nkpoka Nnewiichi Nnewi
41	Mrs. Elizabeth Onunkwo	600	1	Nkpoka Nnewiichi Nnewi
42	Mr. Udeh Felix	50	1	Okpuno Nnewiichi Nnewi
43	Mrs. Agudosi Ifeoma	3500	2	Abubor Nnewiichi Nnewi
44	Mrs. Madubuike Nwanneka	30	1	Obiofia Nnewiichi Nnewi
45	Mr. Emmanuel .O.Okafor	2700	1	Mbanakwu Nnewiichi Nnewi
46	Mr. Azubugwu Onyekaonwu	45	1	Mbanakwu Nnewiichi Nnewi
47	Mr. Sunday Onunkwo	740	1	Nkpoka Nnewichi Nnewi
48	Mrs. Elizabeth Onunkwo	600	1	Nkpoka Nnewichi Nnewi
49	Mr. Udeh Felix	50	1	Okpuno Nnewichi Nnewi
50	Mrs. Agudosi Ifeoma	3500	1	Abubor Nnewichi Nnewi
51	Mrs. Ogechukwu Muoka	250	2	Obuno Umudim Nnewi
52	Mrs. Mercy Ewim	10	2	Obereogo Umudim Nnewi

53	Mr. Jude Muoka	250	2	Obiuno Umudim Nnewi
54	Mr. Gilbert Anazodo	200	2	Eberego Umudim Nnewi
55	Mr. Wilfred Muoneke	400	2	Eberego Umudim Nnewi
56	Mrs.Nkiru Onwudiwe	30	2	Umuezena Umudim Nnewi
57	Mr. Emeka Onwudiwe	400	2	Umuezena Umudim Nnewi
58	Mrs.Comfort Okechukwu	150	2	Uruumudim Nnewi
59	Mrs. Vic Okonkwo	100	1	Uruumudim Nnewi
60	Mrs. Cecilia Amobichukwu	100	1	Uruumudim Nnewi
61	Mrs. Geogena Ejidike	100	1	Uruumudim Nnewi
62	Mr. Innocent Okechukwu	300	1	Uruumudim Nnewi
63	Mr. Augustine Onyekwu	535	1	Inyaba Umudim Nnewi
64	Mr. Mbonu Innocent. M.	150	2	Umuezena Umudim Nnewi
65	Mrs. Anthonia Obi	55	2	Umuezena Umudim Nnewi
66	Mr. Edwin Obi	100	3	Ezekwuabor Otolo Nnewi
67	Mrs.Amaka Unachukwu	200	2	Egbuumuenem Otolo Nnewi
68	Mrs. Emeonu Nneka	250	1	Umuanoka Otolo Nnewi
69	Mr. Obi Godwin	150	3	Ezekwuabor Otolo Nnewi
70	Mrs. Uju Araku	180	3	Ezekwuabor Otolo Nnewi
71	Mr. John Unachukwu	360	2	Egbuumuenem Otolo Nnewi
72	Mrs. Mata Emedike	115	1	Mbanagu Otolo Nnewi
73	Mr. Daniel Okonkwo	8	3	Mbanagu Otolo Nnewi
74	Mrs. Uzoukwu Josephine	20	3	Umuzu Mbara Otolo Nnewi
75	Mrs. Okonkwo Ifeoma	60	2	Obiofia Otolo Nnewi
76	Mrs. Ifeoma Okoro	80	3	Eziogwugwu Otolo Nnewi
77	Mr. Tony Nwabueze	123	3	Egbuumuenem Otolo Nnewi
78	Mrs. Elizabeth Nwabueze	100	3	Egbuumuenem Otolo Nnewi
79	Mrs. Chinyere Nzeribe	70	3	Egbuumuenem Otolo Nnewi
80	Miss Chinwe Igboanugo	20	3	Egbuumuenem Otolo Nnewi
81	Mr. Mmadu Jermaih.E.	750	3	Egbuumuenem Otolo Nnewi
82	Mr. Nnajiofor Donatus	125	1	Ndiakwu Otolo Nnewi
83	Mr. Chinedu Nwabguo	63	1	Ndiakwu Otolo Nnewi
84	Mrs. Ukamaka Ezika	50	3	Ezekwuabor Otolo Nnewi
85	Mrs. Helin Ezika	100	3	Ezekwuabor Otolo Nnewi
86	Mr. Ruben Uzoewulu	520	3	Mbanagu Otolo Nnewi
87	Mr. Sunday Nnoli	200	3	Mbanagu Otolo Nnewi
88	Mr. Nnoruka Samuel .N.	300	2	Umuenem Otolo Nnewi
89	Mr. Ndubuisi Agbarakwe	100	2	Umuenem Otolo Nnewi
90	Mr. Chigboo Anthony	3600	1	Ndiakwu Otolo Nnewi
91	Mr. Paul Uzoegbunam	50	1	Obiuno Otolo Nnewi
92	Mrs. Rita Ogbenyi	450	2	Umuenem Otolo Nnewi
93	Mrs. Felicia Onyemena	440	2	Umuenem Otolo Nnewi
94	Mr. Okechukwu Ezimora	500	1	Obiuno Otolo Nnewi
95	Mrs. Virginia Uzoewulu	1200	3	Ezeogwugwu Otolo Nnewi
96	Udechukwu Nnanyerlu	200	1	Unuanuka Otolo Nnewi
97	Eleodimon Godwin	200	2	Obiofia Otolo Nnewi
98	Eleodimon Eunice	200	2	Obiofia Otolo Nnewi
99	Rose Azuka	100	3	Mbanagu Otolo Nnewi
100	Vivian Ojukwu	30	3	Mbanagu Otolo Nnewi
101	Ikechukwu Uzor	300	3	Mbanagu Otolo Nnewi
102	Regina Nduamaka	100	3	Ezekwuagbo Otolo Nnewi
103	Esther Ukatu	600	3	Ezekwuagbo Otolo Nnewi
104	Orizu Chiwuzie	100	1	Obiuno Otolo Nnewi
105	Mr. Innocent Aronu	500	2	Obiuno Otolo Nnewi
106	Mrs. Ebere Orizu	50	1	Obiuno Otolo Nnewi
107	Mrs. Margelet Anuligo	30	2	Egbaumuenem Otolo Nnewi
108	Mrs. Mbaduagha Ifeyinwa	150	1	Ndiakwu Otolo Nnewi
109	Mr. Birthrand Udologu	150	2	Okpuno Umuenam
110	Mr. Romans Chukwuanugo	420	2	Egbaumuenem Otolo Nnewi

111	Mrs. Oluchukwu Orizu	1000	1	Obiuno Otolo Nnewi
112	Mrs. Geogena Udegbe	1000	1	Umuanika Otolo Nnewi
113	Mr. Joseph Ndianaefo	1500	2	Egbaumuenem Otolo Nnewi
114	Mr. Leonard Olisaegboo	100	1	Ndiakwo Otolo Nnewi
115	Mrs. Uche Uzoetoo	1000	2	Egbaumuenem Otolo Nnewi
116	Mr. Basil Agbarakwe	2500	2	Egbaumuenem Otolo Nnewi
117	Mrs. Ogochukwu Orizu	500	1	Obiuno Otolo Nnewi
118	Mrs. Amaka Agha	91	3	Mbanagu Otolo Nnewi
119	Mr. Emma Chukwuanugo	800	2	Egbaumuenem Otolo Nnewi
120	Rev. Ernest C. Okeke	350	1	Umuanuka Otolo Nnewi
121	Mr. Morgan Ojukwu	350	1	Ndiakwo Otolo Nnewi
122	Mrs. Amaka Uzoetoo	300	2	Umuenam Otolo Nnewi
123	Mrs. Nwosu Ifeoma	100	1	Obiuno Otolo Nnewi
124	Mrs. Mary Nduka	100	1	Ogbeo Otolo Nnewi
125	Mrs. Uchenna Nwosu	50	1	Obiuno Otolo Nnewi
126	Uju Nnabuchi	100	3	Umuzungo Otolo Nnewi
127	Chinwe Arina	50	2	Obiofia Otolo Nnewi
128	Josephine Okoye	25	2	Enem Otolo Nnewi
129	Nduka Akpmonu	60	1	Obiuno Otolo Nnewi
130	Francis Iwuchukwu	50	1	Obiuno Otolo Nnewi
131	Lovina C. Azubuike	30	1	Okpuno Otolo Nnewi
132	Cyprian Onyebuchi	400	1	Ndiakwa Otolo Nnewi
133	Blessing Okonkwo	100	1	Ndiakwa Otolo Nnewi
134	Justina Chukwudinka	400	10	Egbeumunem Otolo Nnewi
135	Chika Nwanya	35	1	Obiuno Otolo Nnewi
136	Charles Ojukwu	10	3	Mbanagu Otolo Nnewi
137	Patrice Mouma	100	9	Obiuno Otolo Nnewi
138	Benson Ibeto	20	2	Egbeumunem Otolo Nnewi
139	Amaka Onuegbu	60	2	Obiofia Otolo Nnewi
140	Rose Anigbogu	60	2	Obiuno Otolo Nnewi
141	Prince Patrick Okafor	25	1	Inyaba Umudim Nnewi
142	Mrs. Grace Okafor	12	1	Inyaba Umudim Nnewi
143	Mrs. Christiana Okafor	4	1	Inyaba Umudim Nnewi
144	Lolo Ogonna Okafor	15	1	Inyaba Umudim Nnewi
145	Mrs. Bridget Okoye	15	2	Umuele Umudim Nnewi
146	Chinedu G. Okonkwo	400	2	Obiuno Otolo Nnewi
147	Nnaemeka Ojukwu	200	2	Obiuno Otolo Nnewi
148	Mrs. Nneka Arazu	200	1	Inyaba Umudim Nnewi
149	Mrs. Veronica Anigbogu	7	2	Umezen Umudim Nnewi
150	Mrs. Ngozi Eloka	300	2	Obiuno Otolo Nnewi
151	Mrs. Regina Ezimora	300	2	Obiuno Otolo Nnewi
152	Mrs. Nkoli Egbunike	500	2	Obiuno Otolo Nnewi
153	Mr. Jude Muoka	400	2	Obiuno Otolo Nnewi
154	Mrs. Vero Eloka	50	2	Obiuno Otolo Nnewi
155	Mrs. Njideka Arinzechukwu	50	1	Inyaba Umudim Nnewi
156	Uju Arinzechi	30	1	Inyaba Umudim Nnewi
157	Pius Edoka	200	2	Obiulo Umudim Nnewi
158	Obageri Egbunike	100	2	Obiulo Umudim Nnewi
159	Fidelia Ewim	500	2	Ebeleogwumili Nnewi
160	Ifeoma Ewim	200	2	Ebeleogwumili Nnewi
161	Pauline Aghagi	17	2	Akamiri Umudim Nnewi
162	Monica Okoye	15	2	Ebeleogwumili Nnewi
163	Juliana Aguina	70	2	Ebeleogwumili Nnewi
164	Cletus Okonkwo	100	2	Umueznaumudi Nnewi
165	Chukwuemeka Ogechukwu	25	2	Obiulo Umudim Nnewi
166	Okonkwo Cecilia	150	2	Umueznaumudi Nnewi
167	Louis Iwuchukwu	137	2	Obiulo Umudim Nnewi
168	Izuchukwu Onyeansi	170	2	Okponoegbu Umudim Nnewi

169	Bridget Nnabuko	25	1	Inyaba Umudim Nnewi
170	Christian Obele	8	1	Inyaba Umudim Nnewi
171	Mabel Okafor	6	1	Inyaba Umudim Nnewi
172	Benjamin Okechukwu	60	2	Umuezena Nnewi
173	Fransisca Nwarieji	25	1	Inyaba Umudim Nnewi
174	Chief Samuel Okafor	80	1	Umunnealam Nnewi
175	Hyginus Okonkwo	80	1	Inyaba Umudim Nnewi
176	Josephine Anaeme	40	2	Okponoegbu Umudim Nnewi
177	Peter Nwarieji	260	1	Inyaba Umudim Nnewi
178	John Anaeme	35	2	Okponoegbu Umudim Nnewi
179	Innocent Anigbogu	350	1	Inyaba Umudim Nnewi
180	Nkiruka Anigbogu	250	1	Inyaba Umudim Nnewi
181	Emeka Anyaora	900	1	Inyaba Umudim Nnewi
182	Palinea Uzor	100	1	Inyaba Umudim Nnewi
183	Obiageri Okoli	100	2	Umueleumudi Nnewi
184	Augustina Okoye	1000	2	Umueleumudi Nnewi
185	Christopher .U. Nebolisa	50	2	Umueleumudi Nnewi
186	Mr. Benson Esomeji	30	2	Umuezena Umudim Nnewi
187	Mrs. Uju Okoli	20	2	Umuezena Umudim Nnewi
188	Mr. Joseph Okoli	25	2	Umuezena Umudim Nnewi
189	Mrs. Elizabeth Okoli	30	2	Umuezena Umudim Nnewi
190	Mrs. Faith Okafor	150	1	Inyaba Umudim Nnewi
191	Mr. Aluokwu Onyedi	100	2	Umudinkora Umudim Nnewi
192	Mrs Njideka Nnabude	356	2	Ndiezenwankwor Uruagu Nnewi
193	Mrs. Udeakpu Veronica .U.	1500	2	Ndiezenwankwor Uruagu Nnewi
194	Mrs. Josephine Adukuru	50	2	Ndiezenwankwor Uruagu Nnewi
195	Mr. Ugochukwu Ngonadi	72	1	Akabaedoji Uruagu
196	Mrs Mabel Ekechukwu	150	1	Akabaedoji Uruagu
197	Mrs. Oguenwa Sussan	100	1	Okpunoeze Uruagu Nnewi
198	Mr. Obiafam Charles	200		Ndiojukwu Uruagu Nnewi
199	Mr. Paul Orizu	100	3	Umuejiaku Uruagu Nnewi
200	Mr. Atuegwu Igweamaka	450	3	Umuejiaku Uruagu Nnewi
201	Mr. Atuegwu Nzubechukwu	360	3	Umuejiaku Uruagu Nnewi
202	Mr. Atuegwu Amaka	70	3	Umuejiaku Uruagu Nnewi
203	Mrs. Nzewi Virginia	74	21	Okpunoeze Uruagu Nnewi
204	Mrs. Mmadu Gloria	70	1	Okpunoeze Uruagu Nnewi
205	Mr. Joseph Nnatuanya	300	3	Umuejiaku Uruagu Nnewi
206	Mr. Nkemjika Okoro	20	1	Umuejiaku Uruagu Nnewi
207	Mrs. Felicia Ngwube	500	1	Ndiojukwu Uruagu Nnewi
208	Emmanuel Okeocha	50	1	Okpunoeze Uruagu Nnewi
209	Amaobi Nzewi	60	1	Okpunoeze Uruagu Nnewi
210	Nwakaego .V. Okoye	500	3	Akabokwu Uruagu Nnewi
211	Danis Nzewi	12	1	Ndiojukwu Uruagu Nnewi
212	Obasikwe .N. Ubah	120	1	Umudim Nnewi
213	Georgina Akunyiuba	3000	2	Umuemeagba Nnewi
214	Andrew Akunyiuba	4000	2	Umuemeagba Nnewi
215	Mrs. Uzoekwe Nonyelum	20	1	Okpunoeze Uruagu Nnewi
216	Mr. Chinedu Mmadueke	1200	2	Akabokwu Uruagu Nnewi
217	Mr. Echezona Muokwe	1008	2	Akabokwu Uruagu Nnewi
218	Mrs. B.E Onyema	50	1	Ndiakwu Otolo Nnewi
219	Mr. Jonah Elemchukwu	350	1	Ndingbu Otolo Nnewi
220	Mrs. Obiekosi Ifeyinwa	165	2	Umuenem Otolo Nnewi
221	Mrs. Uzoamaka Okafor	300	2	Umuenem Otolo Nnewi
222	Mrs. Mercy Uksi	170	1	Ndingbu Otolo Nnewi
223	Mrs. Mary Nnabuike	30	2	Obiofia Umuenem Otolo Nnewi
224	Mrs. Chinwe Nkeireh	70	2	Obiofia Umuenem Otolo Nnewi
225	Mrs. Bridget Onyeuaizu	60	2	Obiofia Umuenem Otolo Nnewi

226	Chief Obimailo Eric .C.	640	1	Okpuno Otolo Nnewi
227	Mrs. Nneka Orji	5	1	Obiuno Otolo Nnewi
228	Princess Caro Mbadugha	150	1	Ndingbu Otolo Nnewi
229	Mrs. Nneka Aniebonam	31	1	Ndiakwu Otolo Nnewi
230	Hanns Plant Co-operative Society	15	3	Mbanagu Otolo Nnewi
231	Mr. Peter U. Okoye	30	3	Ezekwuabor Otolo
232	Mr. Nnabuchi Emmanuel	30	3	Umuzungo Otolo Nnewi
233	Mr. Gilbert Okoye	3600	1	Ogbe Otolo Nnewi
234	Mrs. Chinenye Chukwudimma	50	3	Mbanagu Otolo Nnewi
235	Mrs. Virginia Uba	12	2	Umuenem Otolo Nnewi
236	Mrs. Mercy Nwafor	50	2	Umuenem Otolo Nnewi
237	Mrs. Ebere Okechukwu	300	1	Obiuno Otolo Nnewi
238	Mrs. Gabriel Ngozi	10	1	Ndingbu Otolo Nnewi
239	Mrs. Ngozi Onyegbosi	50	1	Obiuno Otolo Nnewi
240	Mrs. Eucharia Okoye	15	3	Ekwuru Otolo Nnewi
241	Mrs. Ifeoma Muojekwu	40	3	Uruagu Otolo Nnewi
242	Mrs. Chukwuchekwa Catherine	450	3	Ezekwuabor Otolo Nnewi
243	Mrs. Uche Tony Atueji	300	3	Ezekwuabor Otolo Nnewi
	Grand Total	**83683**		

Table A.15a: Nnewi South LGA (Osumenyi Zone) Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	BROILER	PULLET	TURKEY	TOTAL
1	Mr.Umuamba Justina	150	-	50	200
2	Mrs. Ichiwu Juliet	40	-	-	40
3	Mrs. Aguta Mary-Jane	300	50	50	400
4	Okoma Grace	600	150	50	800
5	Mrs. Emesiofor G.N	150	-	50	200
6	Mrs. Esther Okogu	50	-	-	50
7	Amaka Ebinyua	50	-	30	80
8	Uchenna Igwe	600	1000	150	1750
9	Blessing Okeke	50	-	-	50
10	Gloria Chukwudozie	50	-	-	50
11	Nwanyi Ukpor	1000	600	50	1650
12	Mr. Anayo Umeh	-	5000	-	5000

Table A.15b: Nnewi South LGA (Ukpor Zone) Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	VILLAGE	NO OF BIRDS
1	Anurika Friday	Umuahama	30
2	Mr. Udeagu	Umuahama	200
3	Florence Ohagwu	Ndiodera	250
4	Mr. Anthony Nwaokwu	Uhuoria	200
5	Mrs. Ani Obi	Oluedika	40
6	Amadi Friday	Amadim	30
7	Mr. Cornelius Abadana	Umudike	30
8	Mr. Michael Ojiako	Amadim	40
9	Onyebuchi Onyeweaku	Amadim	50
10	Paulina Obiamaka	Uhuori	250
11	Mrs. Ibeto	Amadu	100
12	Mrs. Omata Ujubyonyu	(Odogo) Ndiodoro	30

13	Monica Obi	Ndiodoro	40
14	Theresa Obiora	Ebe	200
15	Uju Udeagu	Umuahaba	50

Table A.15c: Nnewi South LGA (Amichi Zone) Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	NO OF BIRDS	VILLAGE
1	Boniface Okafor	183	Ebenator Amichi
2	Theresa Igbokwe	64	Eziama Amichi
3	Anselem	280	Ebenator Amichi
4	Clemennt Onedibe	500	Ebenator Amichi
5	John Asoanyia	1000	Eziama Amichi
6	Simon Okonkwo	50	Obiofia Amichi
7	Sunday Aso	300	Obiofia Amichi
8	Chidi Ngwube	450	Ebenator Amichi
9	Mrs. Eunice Ajaegbo	1000	Eziama Amichi
10	1 x Mrs. Nwaogo	100	Eziama Amichi
11	Augustine Ndefor	100	Obiofia Amichi
12	1 x My wife Unigwe	2500	Afoeziama Amichi
13	Uche Ajaelo Mrs.	35	Nkwoagu Amichi
14	Azuka Uchendu	150	Afoube Amichi
15	Bene Udoye	200	Afoube Amichi
16	Charles Azubogu	1000	Obiofia Amichi
17	Ekene Emenike	20	Afoube Amichi
18	Nwadiogo Okechukwu	73	Afoube Amichi
19	Uchenna Nwogbo	100	Obiagu Amichi
20	Franca Obi	80	Obiagu Amichi
21	Uju Okafor	83	Afoeziama Amichi
22	Ebere Amachina	443	Nkwoagu Amichi
23	Ngozi Esiayaka	1000	Nkwoagu Amichi
24	(Ide) Ave Maria	2000	Umunachi Amichi
25	Georgina	200	Eziama Amichi
26	Odunukwe Georgina	200	Umunachi Amichi
27	Mrs. Chinyere Onukeme	200	Umunachi Amichi
28	Cordelia Onyemerukwe	50	Umuehi Amichi
29	Florence Okonkwo	100	Umuehi Amichi
30	Nwakaego Okoli	100	Umunachi Amichi
31	Justina Ume	100	Umunachi Amichi
32	Princess Amaka Umeukwuaka	1000	Umunachi Amichi
33	Umuonwu Anaoze Bonco wife	200	Orjiezeka Amichi
34	Paul’s wife Umeonwuiaamaogo	250	Orjiezeka Amichi
	Grand Total	**26821**	

Table A.16: Ogbaru LGA Registered Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	TYPE OF BIRD	NO OF BIRDS
1	Chigozie Nwankwo Nwosu	Okoti Odekpe	Broilers Layers	3000
2	Nwakaego Ugbomah	Ossomala	Broiler	2000
3	Paul Amobi Ugbomah	Ossomala	Broilers Cockerel	2000
4	Victor Ezekwume	24 Ichida Street	Foreign and local turkey	2500
5	Gloria Ezeh	24 Ichida Street	Broiler	1500
6	Gospel Godwin	Obodochukwu Okpoko	Layer /Turkey	2000/1500
7	St. Patrick's Farm	Ossomala	Broilers Layers	10,000 225,000
8	Umenwanne Innocent	21 Ichida Street	Layers/Broiler	1000/2000
9	Ugochukwu Obunadike	Johnny .O. Street Okoti	Broiler/Layers	2500/1000
10	Muoghalu Amaka	Ezediokpu Odo-rubber	Broilers Layers	1500 1500
11	Ngozi Oduah	Akili Ozizor	Broiler	2000
12	Ebuluzo Oduah	Akili Ozizor	Broilers Layers	2000 2000
13	Udochi Osuji	Ogbe etiti Odekpe	Broilers	2000
14	Anthonia Osuji	Ogbe etiti Odekpe	Layers	3500
15	Chukwudi Oduah	Akili Ozizor	Broiler	2000
16	Obianuju Ndupu	Akili Ogidi	Broiler	1000
17	Anthonia Onyeabor	Amesi Street Iyiowa Odekpe	Broilers Layers	2000 3000
18	Chinedu Ndupu	Akili Ogidi	Layers	2000
19	Anthonia Onyeabor	Iyiowa Oddekpe	Broilers/Turkey	1000/1000
20	Ngozi Eziokwu	Iyiowa Odekpe	Layers	2000
21	Charity Ezeoju	Akili Ozizor	Layers	1500
22	Happiness Obiano	Iyiowa Odekpe	Layers	2000
23	Nwamaka Okagbue	Ochude Umuodu	Broilers	1000
24	Benjammin Onwuchekwa	Iyiowa Odekpe	Broilers	1000
25	Ukamaka Uyanne	Akili Ogidi	Broilers	1000
26	Umaoma Ugochi	Iyiowa Odekpe	Broilers/Layers	1000/1500
27	Lydia Amuchaka	Iyiowa Odekpe	Broilers/Turkey	1000/1500
28	Ogboo Asibeli Patrick	Atani	Turkey/Local/Geese	500/800/300
29	Okoro Jude	Atani Road Idemili	Broilers/Turkey/Layers	1000/1000/2000
30	Okechukwu Ejimkonye	Atani Road Idemili	Broilers/Turkey/Layers	1500/1000/1500
31	Tochi Eze	Atani Road Idemili	Broilers/Turkey/Layers	1000/500/1500
32	Chidiebere Ezenwa	Atani Road Idemili	Broilers/Turkey/Layers	1000/500/1500
33	Onochie Obiora	Onochie Obiora	Broilers	5000
34	Osaji Obi	Ogbe Etiti Odekpe	Broilers	1000
35	Osaji Patrick	Atani	Layers	1500
36	Peace Obi	Odekpe	Layers	1000
37	Divine Obi	Odekpe	Broilers	1000
38	Chika Ogbuedi	Ochuche Umuodu	Broilers	500
39	Chuma Ogbuedi	Ochuche Umuodu	Broiler/layers	1500
40	Chukwuma Stanley	Akili Ozizor	Broiler/Turkey	1500
41	Onyechi Oduah	Akili Ozizor	Broilers	500
42	Ugbagu Dave	Atani	Broilers	1000
43	Nwagalaku Christain .C.	Atani	Broilers	1000
44	Egolum .A. Ogo	Atani	Broilers	1000
45	Uzoegwu Ada	Atani	Broilers Layers	1500 1000

46	Ifeanyichukwu Victoria	Atani	Broilers Layers	1000 1500
47	Egwuekwe Medline	Atani	Broilers Layers Turkey	1000 1500 500
48	Nweke Emmanuel	Onwuasanya Junction Atani Road	Broiler	1000
49	Fred Obinwa	Atani	Broiler Local	2000 200
50	Osayi Boniface	Ogbakuba	Broiler	1200
51	Greg Uzokwe	Ogbakuba	Layers	1000
			Grand total	348000

Table A.17: Onitsha North LGA Registered Poultry Houses, Locations and Number of Poultry Birds

S/N	NAMES	TOWN/ADDRESS	Broiler	Layer	Turkey	Cockerel	Quail	Geese	Local Fowl
1	Ogbegbue Anthony	17 B Ugwunabankpa Rd. Inland Town Onitsha	1000	500	100	500	50	-	-
2	Okey Igwilo	16 Abba St. Oduma Layout	-	200	-	-	-	-	-
3	Ibuzo Virginia	8A Okosi Road Onitsha	100	-	-	-	-	-	-
4	Nkiru Udechukwu	G.R.A Onitsha	500	-	-	-	-	-	-
5	Arinze Egbneme	No. 5 Aduba Lane Onitsha	500	1500	50	-	-	-	-
6	Nnamdi Agbaogu	No. 22A Aduba Lane Onitsha	500	-	5000	-	-	-	-
7	Akunna Ifeka	No. 80 Awka Road Onitsha	-	-	50	-	-	-	-
8	Simon Molokwu	15 Ogbuli Nwawili Street	-	200	-	-	-	-	-
9	Mrs. Wilfred Mekaanfu	14 Orakwe Street	50	-	50	-	-	-	-
10	Roseline Onuorah	No. 4 Maya Street	100	-	20	-	-	-	-
11	Joseph Obaya	11 Kwuazi Street	100	-	50			-	-
12	Shagasa Amaechi	Aroli Street Inland Town Onitsha	100	200	-	-	-	-	-
13	Mr. Mbanefo	Opposite G.U.O Workshop Enugu-Onitsha Expressway	-	400	-	-	-	-	-
14	Brother Chinedu	Omaba Phase II Onitsha	500	1000	-	-	-	-	-
15	Madam Sabina	Omaba Phase II	100	200	-	-	-	-	-
16	Mr. Okocha		50	200	100	-	-	-	-
17	Ngozi Offor	49A Awka Road Onitsha	400	100	50	-	-	-	-
18	Brother Obas	Omaba Phase II Onitsha	-	500	-	-	-	-	-
19	John Obi Ogboli	9 Chimedie/Bishop Onyeagbo Ogba Ndida	200	-	-	-	-	-	-
20	Aniechina Peter	96C Awma Road Onitsha	-	-	-	50	-	-	-
21	Benedict Okwudili	15 Aroli Street Onitsha	-	-	-	500	-	-	-
22	Lady Lucy Mba	3-3 Layout Onitsha	500	-	-	1500		-	-
23	Lady Ngozi Nnezianya	3-3 Odonijisi	500	500	500	-	-	-	-
24	Henry Anyabuike	St. Ignatius of Anthioch 3-3 Odonijisi	-	2500	200	-	-	-	-
25	Nneka Iwuobi	25 Ugwunabankpa Road Onitsha	150	-	-	-	-	-	-
26	Mrs. Awatogu	13 B Oguta Road Onitsha	500	-	120	-	-	-	-
27	Mr. Asika	Ersezon Road	400	400	-	-	-	-	-
28	John Ibekwe	3.3 Mba Farms	-	500	-	-	-	-	-
29	Ogugua Nwankwo	3.3 Mba Farms	-	200	100	-	-	-	-
30	C.Y Mba	3.3 Mba Farms	-	-	200	-	-	-	-
31	Divine Favour	3.3 By Federal Government Girls College	1500	-	-	-	-	-	-

32	Divine Mercy	Inland Town	200	500	-	-	-	-	-
33	Mrs. Isimmiri	Federal Housing 3-3 Onitsha	300	-	50	-	-	-	-
34	Blessing Eze	7 James Street Onitsha	200	500	-	-	-	-	-
35	Ehimen Ogeme	Omeife 3.3	200	-	-	-	-	-	-
36	Austin Ojeme	Nka Abata Nsugbe	500	-	20	-	-	-	-
37	Valentine Chukwumah	College Road by 2^{nd} Gate	200	300	20	-	-	-	-
38	Mrs. Ezeudu	50 B Old Market Road Onitsha	1000	-	-	-	-	-	-
39	Chinwe Onwuyalu	50 Bold Market Road Onitsha	1500	-	-	-	-	-	-
40	Nwaokoro Victor	8A Emezulu Lane	200	-	10	-	-	-	-
41	Mr. Ikenwa	College Road 3.3	1000	2000	-	-	-	-	-
42	Amaechi Chukwurah	No. Benjamin Street Onitsha	1000	3300	-	-	-	-	-
43	Mr. Murph Osakwe	26 Ojedi Street	300	-	-	-	-	-	-
44	Marian Ofodili	40 St. Stephen Road Onitsha	500	200	-	-	-	-	-
45	Nwaudo Asika	Emmanuel Church	300	1000	-	-	-	-	-
46	Amadi Everest	26 Ojedi Road, Inland Town	100	-	50	-	-	-	-
47	Nnabuenyi Erokwu	80A Awka Road Onitsha	50	-	20	-	-	-	-
48	Nwando Igwebuike	20 Agba Street Inland Town Onitsha	50	-	10	-	-	-	-
49	Mike Obi	Okosi Road Inland Town	-	-	100	-	-	-	-
50	Ann Ibisi	19 Limuikem Road Inland Town	150	-	-	-	-	-	-
51	Blessing Obi	Okosi Road Inland Town	100	-	10	-	-	-	-
52	Patrick Aghadinuno	1 Oboli Street Inland Town	-	100	-	-	-	-	-
53	Nneka Egibuna	8 Egbuna Street Onitsha	80	-	5	-	-	-	-
54	Nnaoha Amaechi	5 Muzelu Street Onitsha	40	80	-	-	-	-	-
55	Ezeama Emejulu	No. 1 Arima Lane Onitsha	150	-	-	-	-	-	-
56	Azuka Areh	53 Ugwunabankpa Road	-	100	-	-	-	-	-
57	Anthony Nnamdi	17 Usuma Street Onitsha	100	-	20	-	-	-	-
58	Alex Oranekwulu	27 Ojedi Road Onitsha	-	100	10	-	-	-	-
59	Izuchukwu Francis	St. Stephen Road Onitsha	150	-	20	-	-	-	-
60	Francis Onyeyionwu	47^{C} Chukwurah Lane	-	150	11	-	-	-	-
61	Azuka Ogbogu	4 Bishop Onyeabu Street	-	100	20	-	-	-	-
62	Anulika Okolo	27 Nkisi-Aroli Street Onitsha	100	-	5	-	-	-	-
63	Grace Ejikeme	18 Christ Church Road Onitsha	-	80	6	-	-	-	-
64	Ibemesi Sunday	27 Otumoye Street Onitsha	50	-	-	60	-	-	-
65	Nkiru Areh	11 Obio Street Onitsha	50	-	-	-	-	-	-
66	Chukwudi Enebeli	5 Arima Lane Onitsha	-	60	10	-	-	-	-
67	Francis Ekwuno	6 Ogboli Road Onitsha	-	90	10	-	-	-	-
68	Peter Onochie	4 Ibekwe Street Onitsha	70	-	-	-	-	-	-
69	Chizoba Ukajiofor	G.R.A Onitsha	-	150	-	-	-	-	-
70	Chuks Nzegwu	82 Awka Road Onitsha	150	-	20	-	-	-	-
71	Cynthia Okwudili	Mba Road Onitsha	100	-	20	-	-	-	-
72	Nuel Chinedu	St.Joseph Odoakpu	-	200	-	-	-	-	-
73	Onochie Odiakosa	2 Arima Lane	100	-	5	-	-	-	-
74	Ebele Odili	3 Arima Lane Onitsha	120	-	7	-	-	-	-
75	Virginia Nwankwo	1 Nkisi Road G.R.A Onitsha	-	200	-	-	-	-	-
76	Lucy Nwokedi	14 Mba Road Onitsha	100	-	-	-	-	-	-
77	Mr. Emeka	4 Usman Street Onitsha	150	-	-	-	-	-	-

78	Dubem Emodi	8 Bishop Onyeagbor Street Onitsha	100	-	5	-	-	-	-
79	Chio Chude	31 Ojedi Road Onitsha	-	150	-	-	-	-	-
80	Ajaka Peter	15 St.Stephen Onitsha	50	-	-	-	-	-	-
81	David Ofodile	16 St. Stephen Road Onitsha	80	-	-	-	-	-	-
82	Ibisi Ifeoma	11 A Umuikem Road Onitsha Inland Town	100	-	-	-	-	-	-
83	Sylvester Obiokah Orawusi	10 A Umuikem Road Inland Town Onitsha	-	150	-	-	-	-	-
84	Jamike Okosi	Okosi Road Onitsha	100	-	10	-	-	-	-
85	Nnaweluka Izuchukwu	Osuma Street Onitsha	50	-	-	-	-	-	-
86	Chinyere Peter	Obeleagu Street Onitsha	60	-	-	-	-	-	-
87	Chuka Nnayeluso Okwosa	32 Nkisi Alori	50	-	100	-	-	-	-
88	Ibagbu Chukwuma	1 Oni Street Onitsha	100	-	-	-	-	-	-
89	Fidelia Amene	55 Okosi Road	200	-	-	-	-	-	-
90	Olisa Amene	55 Okosi Road	100	-	-	-	-	-	-
91	Ugbo Bonaventure	11 SSQ Niger Street CIWA Quarter	100	-	220	-	-	3	-
92	Ikeogu Chika	Akpaka Forest G.R.A	-	1500	-	-	-	-	-
93	Capuche	College Road 3.3 Onitsha	-	1500	-	-	-	-	-
94	Omodi Ebere	Mkt Obidike Street Inland Town	20	15	-	-	-	-	3
95	Jacinta Eze	18^{B} Okosi Road Inland Town	50	-	-	-	-	-	-
96	Ifeanyi Obaji	18^{B} Okosi Road Inland Town	100	-	-	-	-	-	-
97	E.B.A Okoye	11 Akpaka Forest G.R.A Onitsha	1000	-	-	-	-	-	-
98	Mr. Christopher Edeogu	Nkisi Aroli	20	1000	150	-	50	-	-
99	Mrs. Rosemmary Wahab	D Block Army Barrack Onitsha	-	200	-	-	-	-	-
100	Bridget Nweke	D Block Army Barrack Onitsha	200	-	-	-	-	-	-
101	Onyema Chika	D Block Army Barrack Onitsha	200	-	-	-	-	-	-
102	Ruth Onwe	D Block Army Barrack Onitsha	200	-	-	-	-	-	-
103	Ogodimma Onyema	D Block Army Barrack Onitsha	200	-	-	-	-	-	-
104	Blossom Farms	College Road 3.3 Onitsha	150	-	-	-	-	-	-

TOTAL NUMBER OF BIRDS = 55,865

Table A.18: Onitsha SouthNnewi South LGA Poultry Houses, Locations and Number of Poultry Birds

S/NO	NAMES	TOWN/ADDRESS	TYPE OF BIRDS	NO. OF BIRDS
1	Emegwali Victoria	100H Awka Road Onitsha	Broiler	200
2	Abigali Ezinwa	75 Iweka Road Onitsha	Broiler	200
3	Onuche Edith	Onitsha	Broiler,Cockerels	250
4	Jane Igwe	Onitsha	Broiler	200
5	Chinwe Odoh	70 Iweka Road Onitsha	Broiler	100
6	Obinna Umezinwa	10A Iweka Road Onitsha	Broiler	300
7	Ikechukwu Okoye	61 Okosi Road	Broiler	300
8	Eric Elobike	Ogwari Nsugbe	Layer	500
9	Onyinye Okoye	Oba	Turkey,Broiler	350
10	Juliana Arubuaja	13 Eruku Street Okpoko	Broiler	150
11	Our Ladys High School	Onitsha	Broiler	25
12	Christ the King College	Onitsha	Broiler	100
13	Egbosiuba Azuka	Block 30 MTI Fegge Housing Estate	Broiler	150
14	Chinedu Ogbuagu	23 Orumba Lane Okpoko	Broiler	250
15	Esther Eze	Agulu	Broiler, Cockerels	200
16	Elizabeth Okpala	Agulu	Broiler	350
17	Nuriam Chinyere	Obosi	Broiler,Layer	2000,10,000
18	Emmanuel Unaegbu	Onitsha	Broiler	500
19	Ebere Onu	10A Iweka Road Onitsha	Broiler	150
20	Udenkwu Chinyere	27b St. John Street	Broiler	200
21	Amaechi Ezenwata	19 Kano Street	Broiler	200
22	Onochie Maureen	6 Okosi Estate Onitsha	Broiler, Layer	300
23	Chinwe Ibe	Housing Estate Onitsha	Broiler	400
24	Nneka Morah	Oguta Road Onitsha	Broiler, Layer	350
25	Onuorah Egbuna	Onitsha	Broiler	500
26	Okafor Obiageli F.	Woliwo Onitsha	Layer	200
27	Chuma Nzelu	Onitsha	Broiler	400
28	John Fidelis	Housing Estate Onitsha	Broiler	400
29	Tina Aniebonam	Onitsha	Layer	250
30	Uche Onyekwuije	Ajakpani Umunya	Broiler	500
	Grand Total			**19975**

Table A.19: Orumba North LGA Registered Poultry Houses, Locations and Number of Poultry Birds

S/NO	NAMES	TOWN	NO. OF BIRDS
1	Mazi Nwankwo Angus	Ajalli	2500
2	Mr. Adimorah Chukwuma	Ajalli	2500
3	Mr. Orji Joseph	Ajalli	300
4	Bro. Umeh Raphael	Ajalli	250
5	Mrs. Umeh Rachael	Ajalli	150
6	Mr. Mbanefo Kenneth	Ajalli	250
7	Mr. Onyi Okechukwu	Ajalli	500
8	Mrs. Nwafor Stella O.	Ajalli	500
9	Mrs. Walter Ifeoma	Ajalli	200
10	Mr. Timothy Nwangwu	Ajalli	500
11	Mr. Nwangwu Chukwudi	Ajalli	350
12	Mr. Ezekanagha John	Amaokpala	1100
13	Mrs. Uwaezuoke Esther	Amaokpala	700
14	Mr. Enwerenmadu Young	Amaokpala	400
15	Ichie Obieke Simon	Amaokpala	1000

16	Mrs. Nwankwo Nkechi	Amaokpala	200
17	Mrs. Nwafor Chizoba	Amaokpala	300
18	Mrs. Chinelo Nwafor	Amaokpala	100
19	Mrs. Nwafor Obiageli	Amaokpala	150
20	Mrs. Azubuike Ukamaka	Amaokpala	50
21	Mr. Obele Ugochukwu	Nanka	400
22	Mrs. Obele Chioma	Nanka	150
23	Mrs. Obika Uche	Nanka	600
24	Mr. Izuegbu Ernest	Nanka	650
25	Chief Ezenekwu Uta. S.	Nanka	1500
26	Mrs. Odinaka Eyisi	Nanka	200
27	Mrs. Ezeokoli Patricia	Nanka	50
28	Mr. Chijioke Okeke	Ndikelionwu	2500
29	Sir S.A Nwafor	Ndikelionwu	300
30	Mrs. Eke Agnes	Ndikelionwu	150
31	Dr. Echezona Nwafor	Ndikelionwu	3000
32	Mrs. Onor Ogechukwu	Ndikelionwu	2500
33	Mr. Ezemadubom Augostos	Oko	240
34	Mrs. Ezenwa Linda	Oko	300
35	Mr. Ezenwa Ben	Oko	1000
36	Mr. Obiako Anthony	Oko	150
37	Mr. Okeke Chijioke	Oko	20
38	Mrs. Ezeobele Ebele	Oko	25
39	Mr. Onuchukwu Emmanuel	Ufuma	200
40	Mr. Nwankwo Chinedu	Ufuma	5000
41	Mr. Nnabugwu John	Ufuma	1500
42	Mrs. Ndigwe Agnes	Ufuma	300
43	Mrs. Ike Felicia	Ufuma	300
44	Mrs. Okoli Virginia	Ufuma	400
45	Mr. Ilorah Sampson	Ufuma	300
46	Mr. Enemuo Basil	Ufuma	500
47	Mr. Okolimuo Peter	Ufuma	500
48	Mr. Orah Sampson	Ufuma	1000
49	Mr. Okeke Nicodemus	Ufuma	200
50	Mr. Onyebueke Charles	Ufuma	450
51	Chief Mmogbo Joseph	Ufuma	1500
52	Mrs. Nwankwo Virginia	Ufuma	500
	Grand Total		**38385**

Table A.20: Orumba South LGA Registered Poultry Houses, Locations and Number of Poultry Birds

S/NO	NAMES	CAPACITY	LOCATION
1	Nwokolo Farm	1000	Umunze
2	Oborie Farm	1300	Umunze
3	Onu Farm	1000	Umunze
4	Umendu Farm/Agro Ventures	2000	Umunze
5	Hyseed Ago Ventures	1200	Ogbunka
6	Nnamdi Farm	500	Umunze
7	Elochukwu Farm	350	Umunze
8	Chinedu Farm	150	Umunze
9	Ifeanyi Farm	500	Umuomakpu
10	Chukwujekwu Farm	350	Umuchukwu
11	Umeh`s Farm	1000	Umuchukwu
12	Bellegoes Farm	12,000	Umuchukwu
13	Chukwuma Farm	150	Ezira
14	Esomchi Farm	200	Ezira
15	Theresa Stephen	100	Ezira
16	Arinze Eze	1000	Ezira

17	Orji Esther	150	Ezira
18	Helen Osuduba	250	Ezira
19	Ngozi Okoli	150	Umunze
20	Perpetual Okoro	120	Umunze
21	Amaka Obi	250	Umunze
22	Ogochukwu Onyebueke	150	Umunze
23	Hycenth Orji	350	Umunze
24	Merry Nwaeke	150	Umunze
25	Pastor Osita	150	Umunze
26	Pastor Emeka	250	Umunze
27	Nwankwo Ifeoma	350	Umunze
28	Emma Ibeh	150	Umuomaku
29	Chris Ohizu	100	Umuomaku
30	Irechukwu J.A.S.O.N	350	Umuomaku
	Grand Total	25750	

Table A.21: Oyi LGA Registered Poultry Houses, Locations and Number of Poultry Birds

S/NO	NAMES	TYPE OF BIRDS CAPACITY		LOCATION
		layer	broilers	
1	Emeka Farm	50,000		Nteje
2	Multihome Farm	10000	10000	Umunya
3	Sam Udefi	150	100	Awkuzu
4	Ngozi Oraekee	14	300	Awkuzu
5	Justina Obalum	-	100	Awkuzu
6	Charles Ekwunife	-	100	Awkuzu
7	Chinedu	-	500	Awkuzu
8	Orakwe	-	50	Nteje
9	Geoffrey	100	100	Awkuzu
10	E.M Farms	10,000	-	Umunya
11	Onyeka Okuku	1000	1000	Awkuzu
12	Eucharia Edede	-	38	Nteje
13	Onyibor Josephine	-	60	Nteje
14	Gbakwus Ibeh	105	-	Nteje
15	Nwoye Chiamaka	16	-	Nteje
16	Ogbuli Chikwedu	-	20	Nteje
17	Chinwuba Chinwike	-	40	Nteje
18	Chris Chinyeaka	27	-	Nteje
19	Chuma Nwafor	-	20	Nteje
20	Adanma Ojadi	-	17	Nteje
21	Ifeyinwa Ejimofor	-	24	Nteje
22	Amaechi Chinweze	40	-	Nteje
23	Akujeli Asigwe	15	-	Nteje
24	Ejiobi Augustina	-	20	Nteje
25	Angela Izaa	25	-	Nteje
26	Anthony Odiaka	30	-	Nteje
27	CY Okeke	25	-	Nteje
28	Victor Echezona	40	-	Nteje

29	Okwuji Ozee	11	-	Nteje
30	Edede Mathew	40	-	Nteje
31	Akweze Godwin	1500	-	Ogbunike
32	Ogochukwu Odiaka	25	-	Nteje
33	Edoo Okuku	-	1000	Nkwelle Ezunaka
	Grand Total	**86, 652**		

Source: Authors research and, Anambra State Veterinary Department (2015), Anambra State Ministry of Agriculture and Rural Development, Awka.

APPENDIX B

Table B.1: Abattoir GPS Coordinate points and mass of paunch content per day/annually

S/No	Location	X Coordinate	Y Coordinate	Amount Paunch (kg/day)	Amount Paunch (Kg/yr)
37	Afor Nanka	7.065565	6.051811944	67	24455
7	Afor-Igwe Umudioka	6.92293167	6.1790836	217.75	79478.75
15	Afor-Nnobi	6.94893639	6.046831667	569.5	207867.5
14	Afor-Oba	6.8297403	6.0725219	234.5	85592.5
28	Afor-Ukpor	6.92855972	5.942223611	67	24455
6	Amansea	7.136735	6.248326667	770.5	281232.5
27	Amichi	6.97982167	5.993021389	150.75	55023.75
5	Amikwo, Awka	7.05941194	6.212848056	603	220095
18	Amorka	6.88103472	5.743306667	201	73365
33	Bridge-Head	6.76877167	6.131866389	385.25	140616.25
2	Eke Ekwulobia	7.08009139	6.018026944	284.75	103933.75
38	Eke Oko	7.10202167	6.045285278	268	97820
17	Eke-Agba, Uli	6.8592236	5.7808097	167.5	61137.5
23	Eke-Agu	6.9851875	6.186026667	134	48910
16	Eke-Awka Etiti	6.962635	6.03555	1172.5	427962.5
21	Isseke	6.91965139	5.832136667	134	48910
31	Iyi-owa Odekpe	6.76018667	6.109338333	67	24455
36	Main Mkt	6.77203167	6.151048056	670	244550
34	Marine	6.77681167	6.165645	871	317915
13	Nkpor	6.83111472	6.152293056	502.5	183412.5
12	Nkpor Private	6.85801833	6.126923611	167.5	61137.5
1	Nkwo Igboukwu	7.01855528	6.017395	167.5	61137.5
19	Nkwo Ogbe	6.86535639	5.850741944	335	122275
20	Nkwo Okija	6.84139167	5.910508056	167.5	61137.5
39	Nkwo Umunze	7.22054639	5.250685278	134	48910
24	Nkwo-Nnewi	6.90853028	6.019105	351.75	128388.75
10	Nkwo-Ogidi	6.8667	6.15	485.75	177298.75
40	Nteje	6.92105667	6.243793611	435.5	158957.5
4	Nwagu-Agulu	7.031785	6.093185	268	97820
26	Oba-Isi Edo	6.9162402	6.016755	485.75	177298.75
11	Obosi	6.816085	6.097141667	536	195640
32	Ochanja	6.78500833	6.133826667	2345	855925
9	Oraifite	6.81602139	6.030126667	100.5	36682.5
43	Orie Awkuzu	6.94442333	6.224766667	418.75	152843.75
25	Orie-Agbo	6.922315	6.030278333	100.5	36682.5
29	Osumenyi Slaughter House	6.99163667	5.951456667	100.5	36682.5
3	Oye Uga	7.08316	5.952746944	335	122275
22	Oye-Agu Abagana	6.95743667	6.186866667	201	73365
41	Oye-olisa Ogbunike	6.87018694	6.183493056	1758.75	641943.75
35	Ugwunabamkpa	6.79899216	6.14584573	50.25	18341.25
8	Ugwu-oye Ozubulu	6.87352667	5.965326667	268	97820
42	Umunya	6.90559387	6.207611667	2177.5	794787.5
30	Unubi Slaughter House	7.04231972	5.960568333	16.75	6113.75
				Total	**6914651.25**

Table B.2: Aguata GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Kg/year
1	Achina	7.1224782	5.9610377	240	87600
2	Akpo	7.1	5.95	48	17520
3	Amesi	7.1	5.9166667	428	156220
4	Ekwulobia	7.0794263	6.0246282	1500.5	547682.5
5	Nkpologwu	7.0848063	5.9877795	1556	567940
6	Oraeri	7.016666667	6.0166667	288	105120
7	Ifite-Ezinifite	7.016666667	5.9833333	152	55480
8	Agulu-Ezechukwu	7.0794263	6.0036087	55	20075
9	Igboukwu	7.0175879	6.0122865	770.49	281228.85
10	Isuofia	7.01758774	6.0289009	488	178120
11	Ikenga	7.02	6	24	8760
12	Uga	7.08316	5.9527469	1427	520855
13	Umuchu	7.116666667	5.9166667	4441	1620965
14	Ogboji	7.150073	6.0177963	12	4380
				Total	4,084,346.35

Table B.3: Anambra East GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Aguleri	6.8806743	6.3276114	723.5	264077.5
2	Igbariam	6.9450688	6.3901861	530.75	193723.75
3	Nando	6.9074977	6.3114076	1151.25	420206.25
4	Nsugbe	6.8203621	6.2637042	411	150015
5	Umuleri	6.8645856	6.296128	618	225570
				Total	**1253592.5**

Table B.4: Aniocha GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Adazi-Ani	6.987768	6.079966	1763.5	643677.5
2	Adazi-Enu	7.052906	6.084646	1065.4	388871
3	Agulu	7.0390904	6.1172035	1143.2	417268
4	Neni	7.0014657	6.0808532	120	43800
5	Nri	7.0310262	6.156804	564	205860
				Total	**1699476.5**

Table B.5: Awka North GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Adazi-Nnukwu	7.0122134	6.101763	36	13140
2	Achalla	6.988033	6.3367475	76	27740
3	Amagu	7.1965386	6.029666	196.63	71769.95
4	Amansea	7.136735	6.2483267	738.75	269643.75
5	Amanuke	7.0404345	6.3056706	582.55	212630.75
6	Isuanocha	7.0404345	6.268719	1680	613200
7	Mgbakwu	7.0579108	6.2724424	1737.44	634165.6
8	Ebenebe	7.1332456	6.3400569	1722.41	628679.65
				Total	**2457829.7**

Table B.6: Awka South GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Amawbia	7.0678	6.2069	2016	735840
2	Nibo	7.0667	6.1667	7628	2784220
3	Okpuno	7.0619444	6.247325	620	226300
4	Awka	7.082116	6.222	7814	2852110
5	Mgbaukwu	7.076365	6.1325031	359.5	131217.5
6	Nise	7.052533	6.1617884	728	265720
				Total	**6995407.5**

Table B.7: Ayamelum GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Anaku	6.9289642	6.4591936	44	16060
2	Omor	6.9611773	6.5117189	517.9	189033.5
3	Ifite-Ogwari	6.9504378	6.6020095	109.8	40077
				Total	**245170.5**

Table B.8: Dunukofia GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Ukwulu	6.9719184	6.2735916	36	13140
2	Ukpo	6.9713512	6.1938756	745.8	272217
3	Nawgu	6.9826614	6.2576162	114.4	41756
4	Ifitedunu	6.95094013	6.18997	132	48180
5	Umunachi	6.916666667	6.1666667	302.1	110266.5
				Total	**485559.5**

Table B.9: Ekwusigo North GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Ichi	6.883333333	6.0166667	150.65	54987.25
2	Ihembosi	6.872629	5.961955	306.2	111763
3	Oraifite	6.8297424	6.0305136	695.4	253821
4	Ozubulu	6.8485009	5.9592535	5235.44	1910935.6
				Total	**2331506.85**

Table B.10: Idemili North GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Eziowelle	6.9333	6.15	3496	1276040
2	Obosi	6.8333	6.1167	3828	1397220
3	Orakwu	6.9835007	6.0976946	4298.4	1568916
4	Umuoji	6.8833562	6.1034228	3949.8	1441677
5	Uke	6.92378998	6.1002736	1764	643860
6	Abatete	6.9263	6.1239	2214	808110
7	Nkpor	6.8333	6.15	4342.8	1585122
8	Ogidi	6.8667	6.15	1956.84	714246.6
				Total	**9435191.6**

Table B.11: Idemili South GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Nnobi	6.9477532	6.0499814	743.5	271377.5
2	Awka-Etiti	6.9584922	6.02881	595.8	217467
3	Oba	6.8297403	6.0725219	299	109135
4	Akwu-Ukwu	6.8094635	6.0463331	492.75	179853.75
5	Ojoto	6.8645856	6.0641892	220.65	80537.25
6	Nnokwa	6.9799755	6.0706082	831	303315
7	Alor	6.9584922	6.0814074	228.5	83402.5
8				**Total**	**1245088**

Table B.12: Ihiala GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Azia	6.8940846	5.8825825	859.45	313699.25
2	Ihiala	6.8511814	5.8516439	1789	652985
3	Isseke	6.9114899	5.8365728	60	21900
4	Mbosi	6.94934988	5.85359	170	62050
5	Okija	6.84046	5.9147239	268	97820
6	Orsumoghu	6.9316481	5.8663858	306.4	111836
7	Uli	6.8592236	5.7808097	643.75	234968.75
				Total	**1495259**

Table B.13: Njikoka GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Abagana	6.9799755	6.1864553	3696	1349040
2	Abba	6.9786326	6.2167874	36	13140
3	Enugu-Agidi	7.0095263	6.2203343	4452	1624980
4	Enugu-Ukwu	7.009739	6.1729818	2954.52	1078399.8
5	Nawfia	7.0220429	6.1880561	11952	4362480
6	Nimo	6.9880335	6.1573677	1932	705180
				Total	**9133219.8**

Table B.14: Nnewi North GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Osumuenyi	6.9799755	5.9654844	577.45	210769.25
2	Ukpor	6.9101806	5.9296078	184.8	67452
3	Amichi	6.9799755	5.9864945	1693.62	618171.3
4				**Total**	**896392.55**

Table B.15: Nnewi South GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	nnewichi	6.90586996	6.0486497	2618.04	955584.6
2	Uruagu	6.883333333	6.0333333	541.59	197680.35
3	Umudim	6.9001	6	1578	575970
4	otolo	6.9536295	6.0087657	5028.34	1835344.1
5				**Total**	**3564579.05**

Table B.16: Ogbaru GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Kg/year
1	Akili Ogidi	6.641097	5.727106	320	116800
2	Akili Ozizor	6.733333333	5.9833333	1252.5	457162.5
3	Atani	6.7467229	6.0130639	3206.8	1170482
4	Odekpe	6.7380287	6.0467008	2500	912500
5	Ogbakuba	6.73171	5.960357	216	78840
6	Okpoko	6.7842015	6.1178447	652.5	238162.5
7	obeagwe	6.666666667	5.78337	680	248200
8	Ossomala	6.71017	5.87637	28312	10333880
9	Umuodu	6.73006111	5.9500611	280	102200
				Total	**13658227**

Table B.17: Onitsha South/North GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Onitsha	6.778846	6.138931	939	342735
2	Fegge	6.8029489	6.1413122	7085.95	2586371.75
				Total	**2929106.75**

Table B.18: Orumba North GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Ajalli	7.2032754	6.0492865	960	350400
2	Amaokpala	7.0955675	6.0454448	480	175200
3	Nanka	7.0659783	6.0484587	426	155490
4	Ndikelionwu	7.1601715	6.0814069	1014	370110
5	Oko	7.0888415	6.0363325	208.2	75993
6	Ufuma	7.1924968	6.0809781	1518	554070
				Total	**1681263**

Table B.19: Orumba South GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Ezira	7.2194468	5.9965299	222	81030
2	Ogbunka	7.248144	5.961955	144	52560
3	Umuchukwu	7.283333333	6.0166667	1602	584730
4	Umunze	7.2383178	5.962154	986.4	360036
5	Umuomaku	7.16463089	5.9654122	132	48180
				Total	**1126536**

Table B.20: Oyi GPS Coordinate points and mass of poultry droppings per day/annually

S/No	Towns	X Coordinate	Y Coordinate	Mass (kg)/day	Mass Kg/year
1	Umunya	6.9155468	6.208386	1400	511000
2	Awkuzu	6.9397002	6.2423547	327.68	119603.2
3	Nteje	6.9182301	6.2637451	6055.48	2210250.2
4	Nkwelle Ezunaka	6.84046	6.2093598	120	43800
5	Ogbunike	6.8833562	6.1771711	120	43800
6				**Total**	**2928453.4**

Table B.21: Optimization table for single centralized bioenergy treatment facility Scenario

			Onitsha		Njikoka		Dunukofia	
S/N	Label	P_i (Kg/year)	d_{ij} (km)	Pid_{ij}	d_{ij} (km)	P_id_{ij}	d_{ij} (km)	Pid_{ij}
1	Achina	87600	39.3058	3443188.08	29.85	523045.584	35.31	3093401.28
2	Akpo	17520	37.7366	661145.232	29.97	4682678.878	35.17	616199.424
3	Amesi	156220	39.7739	6213478.658	33.43	18312257.3	38.49	6013235.862
4	Ekwulobia	547682.5	32.038	17546651.94	21.4848	12202077.31	26.84	14700236.45
5	Nkpologwu	567940	34.2317	19441551.7	25.4808	2678541.696	30.69	17431441.66
6	Oraeri	105120	26.0438	2737724.256	20.7097	1148974.156	24.94	2622638.88
7	Ifite-Ezinifite	55480	27.9665	1551581.42	24.379	489408.425	28.51	1581962.268
8	Agulu-Ezechukwu	20075	32.9346	661162.095	23.6366	6647293.836	28.86	579531.1225
9	Igboukwu	281228.85	26.3646	7414486.139	21.1987	3775912.444	25.44	7155024.402
10	Isuofia	178120	25.5276	4546976.112	19.3714	169693.464	23.67	4217418.488
11	Ikenga	8760	27.2758	238936.008	22.5701	11755749.44	26.82	234946.704
12	Uga	520855	35.9882	18744633.91	29.0726	47125667.06	34.09	17759072.08
13	Umuchu	1620965	41.2886	66927375.5	34.0716	149233.608	39.28	63683014.05
14	Ogboji	4380	39.6975	173875.05	26.1753	106908991	32.08	140527.044
15	Aguleri	264077.5	23.3821	6174686.513	19.3325	3745164.397	13.34	3525355.402
16	Igbariam	193723.75	32.5882	6313108.31	21.5557	9057839.863	17.17	3327883.439
17	Nando	420206.25	22.9533	9645120.118	15.9804	2397299.706	10.12	4255050.508
18	Nsugbe	150015	15.0178	2252895.267	21.4434	4836987.738	15.61	2343144.291
19	Umuleri	225570	19.5169	4402427.133	18.5283	23226937.92	12.37	2792263.359
20	Adazi-Ani	643677.5	20.4529	13165071.54	13.7991	5366069.816	17.41	11211445.96
21	Adazi-Enu	388871	27.4134	10660276.27	14.2413	5942438.768	19.65	7642442.876
22	Agulu	417268	25.4855	10634283.61	10.3367	452747.46	15.81	6597716.436
23	Neni	43800	21.9032	959360.16	13.5855	2796711.03	17.67	774182.52
24	Nri	205860	24.7662	5098369.932	6.0096	10213173.97	11.84	2437876.464
25	Adazi-Nnukwu	13140	22.6566	297707.724	11.3131	313825.394	15.88	208702.62
26	Achalla	27740	30.3602	842191.948	14.7489	1058527.816	11.70	324802.112
27	Amagu	71769.95	44.3023	3179573.856	28.7638	7755978.896	34.86	2502087.059
28	Amansea	269643.75	38.6583	10423968.98	15.5391	3304090.487	19.91	5370305.818
29	Amanuke	212630.75	32.247	6856703.795	11.922	7310570.4	12.02	2557522.661
30	Isuanocha	613200	29.9449	18362212.68	8.2063	5204153.163	9.88	6062524.44
31	Mgbaukwu	634165.6	31.8251	20182383.64	9.6369	6058522.919	11.84	7512198.864
32	Ebenebe	628679.65	42.8651	26948416.07	20.7705	51050351.78	22.66	14246006.6
33	Eziowelle	1276040	13.915	17756096.6	9.8592	13775471.42	9.76	12466655.59
34	Obosi	1397220	2.8738	4015330.836	21.2738	33376805.2	19.03	26596921.03
38	Orakwu	1568916	19.568	30700548.29	11.9445	17220110.93	15.40	24174014.62
39	Umuoji	1441677	8.5909	12385302.94	17.4019	11204387.33	16.71	24101811.92
40	Uke	643860	13.0097	8376425.442	14.5037	11720585.01	15.34	9877005.558
41	Abatete	808110	12.9318	10450316.9	12.3539	19582438.68	12.75	10304776.29
42	Nkpor	1585122	3.5492	5625915.002	19.8824	14200936.6	16.73	26522261.3
43	Ogidi	714246.6	6.7522	4822735.893	16.3791	154539946.7	13.81	9867531.053
44	Nnobi	271377.5	17.5618	4765877.38	18.102	3936587.634	6.04	1641828.827
45	Awka-Etiti	217467	19.8	4305846.6	19.9744	2179906.144	22.74	4946112.941
46	Oba	109135	6.5026	709661.251	24.1942	4351417.598	22.90	2499278.808
47	Akwu-Ukwu	179853.75	9.0114	1620734.083	27.7465	2234626.807	26.56	4777796.883
48	Ojoto	80537.25	9.2932	748448.7717	21.8605	6630617.558	21.51	1732646.182
49	Nnokwa	303315	19.9215	6042489.773	14.9532	1247134.263	18.29	5549693.892
50	Alor	83402.5	17.2833	1441470.428	13.7828	17160798.89	16.94	1413038.516
51	Ukwulu	13140	24.1194	316928.916	8.4634	2303881.358	4.52	59512.374
52	Ukpo	272217	19.3471	5266609.521	3.7961	158509.9516	4.77	1299210.076
53	Nawgu	41756	23.9294	999196.0264	6.3715	306978.87	3.70	154743.5604
54	Ifitedunu	48180	17.0892	823357.656	6.096	672184.584	5.02	242282.766
55	Umunachi	110266.5	12.5977	1389104.287	10.5425	5119011.029	8.82	973333.4222
56	Osumuenyi	210769.25	26.0427	5489000.347	26.4431	1783639.981	29.82	6286993.804
57	Ukpor	67452	24.5569	1656412.019	32.0126	19789270.56	34.10	2300450.46
58	Amichi	618171.3	24.5048	15148164.07	24.1387	21637750.85	27.51	17011888.72
59	Ajalli	350400	44.5568	15612702.72	27.9543	4897593.36	34.09	11946187.2
60	Amaokpala	175200	33.0145	5784140.4	20.2314	3145780.386	25.89	4537522.32
61	Nanka	155490	29.7681	4628641.869	18.4854	6841631.394	23.81	3703414.173

62	Ndikelionwu	370110	28.9062	10698473.68	21.9989	1671762.408	28.13	10413563
63	Oko	75993	32.5944	2476946.239	20.7561	11500332.33	26.29	1998357.524
64	Ufuma	554070	42.8202	23725388.21	24.956	41957599.43	31.10	17234568.98
65	Ezira	81030	47.7545	3869547.135	33.1148	1740513.888	39.18	3175355.022
66	Ogbunka	52560	52.0189	2734113.384	38.0578	22253537.39	44.11	2318684.4
67	Umuchukwu	584730	54.0133	31583196.91	37.2854	13424086.27	43.43	25397981.44
68	Umunze	360036	50.9905	18358415.66	37.2717	1795750.506	43.30	15592547.1
69	Umuomaku	48180	43.297	2086049.46	31.7943	35817423.54	37.56	1809905.79
70	Akili Ogidi	116800	48.0595	5613349.6	66.2958	30307953.67	66.18	7730840.16
71	Akili Ozizor	457162.5	18.0951	8272401.154	38.6961	45293088.52	37.34	17070722.05
72	Atani	1170482	14.5018	16974095.87	35.5124	32405065	33.92	39706963.18
73	Odekpe	912500	12.0187	10967063.75	34.2744	2702193.696	32.08	29273273.75
74	Ogbakuba	78840	20.443	1611726.12	40.4738	9639341.393	39.37	3104506.332
75	Okpoko	238162.5	3.0781	733087.9913	26.2093	6505148.26	23.23	5534777.419
76	obeagwe	248200	41.2331	10234055.42	59.6584	616502746.6	59.42	14749508.38
77	Ossomala	10333880	29.902	309003679.8	48.7112	4978284.64	48.21	498197388.2
78	Umuodu	102200	21.5515	2202563.3	41.3716	565062704.2	40.37	4126089.94
79	Nnewichi	955584.6	13.7893	13176842.72	20.3117	4015223.965	21.35	20408898.09
80	Uruagu	197680.35	13.2478	2618829.741	23.1134	13312625	23.74	4693702.462
81	Umudim	575970	17.3115	9970904.655	25.292	46419522.98	26.71	15384273.89
82	Otolo	1835344.1	20.683	37960422.02	22.2503	79312953.24	24.96	45810188.74
83	Ichi	54987.25	14.741	810567.0523	24.634	2753169.742	25.47	1400783.698
84	Ihembosi	111763	19.5978	2190308.921	30.4307	7723950.705	31.58	3529486.716
85	Oraifite	253821	10.978	2786446.938	27.226	52027132.65	26.68	6773061.092
86	Ozubulu	1910935.6	19.1042	36506895.89	32.0552	74736918.38	32.76	62609129.62
87	Abagana	1349040	19.9591	26925624.26	3.2973	43326.522	5.88	7939370.208
88	Abba	13140	21.1449	277843.986	3.1521	5122099.458	3.04	40055.976
89	Enugu-Agidi	1624980	24.4002	39649837	1.9034	2052626.179	6.06	9860378.64
90	Enugu-Ukwu	1078399.8	22.744	24527125.05	3.4801	15181866.65	8.93	9636580.613
91	Nawfia	4362480	24.477	106780423	2.6669	1880644.542	8.8011	38394622.73
92	Nimo	705180	20.0475	14137096.05	5.4409	49692935.61	9.1905	6480956.79
93	Onitsha	342735	3.6661	1256500.784	26.0297	8921289.23	22.5541	7730079.464
94	Fegge	2586371.75	1.6648	4305791.689	23.3877	60489286.58	20.0925	51966674.39
95	Azia	313699.25	28.6441	8985632.687	37.5001	24487002.8	39.5201	12397425.73
96	Ihiala	652985	30.8336	20133878.3	42.4175	928943.25	43.9258	28682888.51
97	Isseke	21900	34.0736	746211.84	41.8131	2594502.855	44.2542	969166.98
98	Mbosi	62050	34.0048	2109997.84	39.1252	3827227.064	42.0834	2611274.97
99	Okija	97820	23.7746	2325631.372	39.1252	4375605.867	37.67	3684879.4
100	Orsumoghu	111836	31.8719	3564425.808	38.0984	8951933.425	40.7671	4559229.396
101	Uli	234968.75	38.696	9092350.75	49.3778	73832599.85	51.2937	12052416.57
102	Amawbia	735840	29.941	22031785.44	7.097	19759609.34	12.589	9263489.76
103	Nibo	2784220	28.8435	80306649.57	8.0913	1831061.19	14.2358	39635599.08
104	Okpuno	226300	30.9373	7001110.99	8.0183	22869073.61	11.6305	2631982.15
105	Awka	2852110	31.9673	91174256	8.9047	1168452.472	13.8667	39549353.74
106	Mgbaukwu	131217.5	29.604	3884562.87	11.2625	2992671.5	17.3437	2275796.955
107	Nise	265720	27.208	7229709.76	7.1247	49840179.82	13.2499	3520763.428
108	Anaku	16060	38.8576	624053.056	29.3581	5549664.396	24.9404	400542.824
109	Omor	189033.5	45.5448	8609492.951	34.2736	1373583.067	30.5259	5770417.718
110	Ifite-Ogwari	40077	54.574	2187162.198	44.303	10861788.66	40.4927	1622825.938
111	Umunya	511000	14.7046	7514050.6	9.8413	1177050.972	40.7594	20828053.4
112	Awkuzu	119603.2	19.1547	2290963.415	8.3039	18353696.64	2.1894	261859.2461
113	Nteje	2210250.2	19.208	42454485.84	11.5877	507541.26	5.5565	12281255.24
114	Nkwelle Ezunaka	43800	9.594	420217.2	18.183	796415.4	13.3644	585360.72
115	Ogbunike	43800	9.792	428889.6	13.7293	40205615.26	10.4643	458336.34
	Total	≥ 40km	**2873.26**	**1.59E9**	**2504.51**	**2.91E9**	**2698.23**	**1.63E9**
		< 40km	**2219.948**	**1.43E9**	**2070.08**	**1.6E9**	**2049.64**	**9.93E8**

Note: Distance above 40km are in red

Appendix C

(1a) Bridge Head Slaughter

(1b) Eke Abagana Slaughter House

(1c) Iyiowa Odekpe Slaughter House

(1d) Main Market Slaughter House

Plate 1: Abattoir structures of some sites in the Study area

(2a) Amasea Slaughter House

(2b) Umunya Slaughter House

(2c) Ozubulu Slaughter House

(2d) Orie Abagana Slaughter House

Plate 2: Abattoir structures of some sites in the study area (contd.)

(3a) Okija Slaughter House

(3b) Ochanja Slaughter House

(3c) Obosi Slaughter House

(3d) Ogbunike Slaughter House

Plate 3: Abattoir structures of some sites in the study area

(4a) Open dump site

(4b) Nnobi pit disposal

(4c) Okija pit disposal system

(4d) Awkuzu open dump site

Plate 4: Waste disposal systems of some of the abattoirs