

Geographic Information Science as a Paradigm Shift

'Bola Ayeni*

*Regional Centre for Training in Aerospace Surveys (RECTAS),
Ile -Ife, Nigeria.*

Abstract

This paper demonstrates that the advent of GIS has led to situations in the processes of scientific investigation that are indicative of a paradigm shift in both research focus and efforts in the environmental and social sciences, delivery of health facilities and services and in numerous areas of urban and regional planning. It is argued that the deep involvement of Geographic Information Science and Technology (GIS&T) in various national development activities have also led to greater understanding of socio-political systems. It is demonstrated that GIS&T possesses potentials to change how we abstract the world, how we reason about the world and also how we organize and communicate with one another, thus opening new research frontiers. Furthermore, it is argued that as it is already changing the way people work in advanced countries, it could also change the way we work and interact in Nigeria. While recognizing the yawning gaps in the current level of awareness and usage of GIScience and Technologies in the Nigerian development process, some modest efforts of research addressing the needs of the technology were discussed. Of course, GIS offers geography as a science to develop a new *macroscope* with which to view the world and possibly revive its glory as the king or queen of the sciences.

Keywords: GIS, GIS&T, GIScience, Geography, Development, Paradigm Shift

*E-mails: maoayeni@ymail.com; maoayeni@rectas.org
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Website: www.rectas.org

Résumé

Ce papier démontre que l'avènement du Système d'Information Géographique (SIG) a conduit à des situations dans les processus d'investigation scientifique, qui sont indicatives d'un changement de paradigme tant dans les objectifs que les efforts dans les sciences environnementales et sociales, la fourniture des installations et des services de santé et dans beaucoup d'autres domaines d'aménagement urbain et régional. Il est discuté que l'implication profonde de la Science et de la Technologie de l'Information Géographique (GIS*T) dans les diverses activités de développement national a aussi mené à une compréhension plus grande des systèmes sociopolitiques. Il est démontré que GIS*T possède des potentiels pour changer notre manière d'entrevoir le monde, notre manière de raisonner au sujet du monde et notre manière d'organiser et de communiquer entre nous, ouvrant ainsi de nouvelles frontières de recherche. En outre, il est discuté que comme il est entrain de changer déjà la façon dont les gens travaillent dans les pays avancés, il pourrait aussi changer la façon dont nous travaillons et interagissons au Nigeria. En reconnaissant les écarts bâillants dans le niveau actuel de conscience et l'utilisation des Sciences et Technologies de l'Information Géographique dans le processus de développement du Nigeria, quelques efforts modestes de la recherche abordant les besoins de la technologie ont été discutés. Bien sûr, les SIG présentent la géographie comme une science pour développer un nouveau microscope avec lequel voir le monde et si possible ranimer sa gloire comme le roi ou la reine des sciences.

Mots clés : SIG, GIS&T, Science de l'Information Géographique, Géographie, Développement, Changement de Paradigme

1. Introduction

The principle of GIS was first conceived in the 1960s and the first system (the Canadian Geographic Information System) was implemented in 1964 (Maguire 1989; p 173). However, it was not until the 1980s that rapid progress was made as a result of rapid reduction in the cost of hardware, and the development of very versatile software, that overcome the organizational problems underlying the collection, storage, manipulation and display of geographical data is a major reason for this development (Haining, 1990, p. 3). Nevertheless, the development of

GIS has been rapid for other reasons. First as a result of increases in activities of government, there is a great proliferation of data in computer readable format from different sources through maps, air photography, remote sensing from satellites and other platforms, field surveys and national censuses. Secondly, recent advances in geographical theory and techniques have led to the development of integrated systems while the need to appreciate the multi-dimensional nature of geographic data has also played an important role. Today, a lot of existing georeferenced information has become available for display, manipulation, decision support and analysis through a whole spectrum of technologies generally referred to as Geographic Information Systems (GIS). In addition, the practical use of GIS in the commercial world has also been a major factor as the business community has spearheaded strongly application-oriented research

This paper sets out to demonstrate that the advent of GIS has gradually led to situations in the processes of scientific investigation that are indicative of a paradigm shift in both research focus and efforts in the environmental and social sciences, delivery of health and medical facilities and services and in numerous areas of urban and regional planning etc. It is argued that the deep involvement of Geographic Information Science and Technology (GIS&T) in various national development activities have also led to greater understanding of socio-political systems. It is argued and shown that GIS&T possesses potentials to change how we abstract the world, how we reason about the world and also how we organize and communicate with one another (Dangermomd, 2009). Furthermore, it is argued that as it is already changing the way people work in advanced countries, it could also change the way we work and interact. While recognizing the yawning gaps in the current level of awareness and usage of GIScience and Technologies in the Nigerian development process, some modest efforts of research addressing the needs of the technology were discussed. Of course, GIS offers geography as a science to develop a new *macroscope* with which to view the world and possibly revive its glory as the king or queen of the sciences.

2. GIS&T, the Unseen Guest at the Table of Development

Geospatial technologies are many and continue to evolve. They are driven by information and communication technologies and so are properly positioned for dominating events in this century. Today, their

influence has become pervading in many aspects of our lives. In the area of national development planning, they can constitute the uniting force for making planning relevant by providing mechanisms for relating goals to peoples' developmental aspirations. Geospatial technologies are important because of their ability to produce or use specialized information that has been described as spatial data, geospatial information or geo-information or geographic information.

In 1966, Stolper, the architect of the First National Development Plan in Nigeria wrote about the unfortunate situation of planning without facts. Stolper's dilemma arose because of the paucity of data for making projections about Nigeria and for developing plans designed to effect the shaping of national priorities and directions. Today, Nigeria is yet faced with a related issue- the absence of yet reliable data especially about its cultural and socioeconomic situation. However, since Stolper wrote his book and since the First National Development Plan, our understanding of planning had changed tremendously. We have for instance come to appreciate more greatly the role of data and information for planning and have placed much emphasis on getting accurate data. The 2006 national population census of houses and population is a case in point.

Over the years, we have also rediscovered the multiregional and multi-ethnic nature of the country and regional planning became a major strategy for development. Certain actions like state and local government creation since 1976 and subsequently democratic governance encouraged the production of data and statistics at the locality, community, ward, local government area and state levels. What had also changed over the years is the nature of the data and the requisite training of planners with using modern contrivances like computers and associated software for processing data and for making these information more useful than before.

The information revolution is universal. For instance, within the last twenty five years, information became more easily available in quantity and quality all over the world. Furthermore there had been immense changes in the mode of transmission and hence utilization especially through the development of information and communications technology which not only culminated in the globalization of the world system but also opened up areas of research and investigations. Constituting the basis of some disciplines that emerged to address these issues is the increasing use of computers and principles of modern information technology. The field of Geographic Information Systems (GIS) is one of such areas of study that have evolved and have become important in the ways they assist in the provision of solutions to certain types of societal

problems. They have also become important mechanisms for bridge building between disciplines

Geographic information systems use information that is locationally defined and support operations, planning, and decision by organizing and providing access to useful information in a spatial context. Geographic Information Systems are technical systems, involving information modelling and management, spatial analysis, visualization and display, and network of clients and servers. All of these take place in an evolving landscape of computing technology, standards, fads and fashion, and competing software approaches' GIS software features a modern design that embraces the current standards pervasive throughout the information technology (IT) arena.

Geospatial data is the basis of any GIS and may include information from some land or sea surveying, or measurements taken from photographs of the earth viewed from an aeroplane or satellite. Some of the measurements may be for very small areas such as a building site, a residential or an industrial layout within the city; but others may be of an entire local government area, state, country or continent. In the past, some of the measurements on the landscape were made by land surveyors and turned into maps by cartographers, while some other measurements such as plans of construction sites were made by architects and engineers. Related information such as the network of pipelines and cables could have been assembled by utility companies or by persons who inhabit a local authority; and could have preserved these as paper records and on maps. Today, professionals who are aware of the management requirements and possible uses of spatial data in a wide variety of contexts handle the data using computers and systems of investigation described as geographic information systems. Geographic Information Science explores the scientific basis of the measurements so ably done by Geoinformatics: and the descriptions so ably presented by Geographic Information Systems.

3. What We Have Missed

The developmental roles of GIS have been enhanced by national needs in different parts of the world. For instance, Canada from the mid-1960s, developed the first geographic information system - the Canada Geographic Information System (CGIS). CGIS is a large scale system that is still operating today and whose development provided many conceptual and technical contributions that brought GIS into limelight. The purpose was to analyze the data collected by the Canada Land

Inventory (CLI) and to produce statistics to be used in developing land management plans for large areas of rural Canada.

In the United States of America there were three major influences on the development of GIS. The first was academic and was fostered by researches at the Harvard Laboratory for Computer Graphics and Spatial Analysis. The Harvard Laboratory setup initially to develop general-purpose mapping software in the mid-1960s, had major influence on the development of GIS through its software such as SYMAP, CALFORM, SYMVU, GRID, POLYVRT and ODDYSEY which were widely distributed among geographers and which helped to build the application base for GIS. Furthermore, many pioneers of newer GIS "grew up" at the Harvard Lab. The second was the Bureau of the Census which saw the need for designing a method of assigning census returns to correct geographical location, and the need for a comprehensive approach to census geography. The third influence was commercial and was pioneered by ESRI which after a slow growth released Arc/Info in the early 1980s and thus began a process that changed GIS forever. ESRI remains a major influence in the propagation of the GIS idea.

It is possible to go on and on citing examples from Europe and the rest of the world in respect of factors that motivated the acceptance of GIS into the mainstream of development. The critical issue lies in the realization of the need for GIS, and the existence of institutions, institutional frameworks and persons who are prepared to champion the course of its development. Contributions from research and adoption of emerging ICT technologies are other factors. Nigeria is yet to be in good standing in any of these.

In Nigeria therefore, very little progress has been made in adopting geographic information systems as a basis for planning and decision making because of the prevailing environment of low technological capability, insufficient funding of research and a general decline in social and economic conditions. Nonetheless, Nigeria lost at least two golden opportunities to concretize the spatial organization of the society and hence institutionalize GIS as in other parts of the world. The first was in the conduct of censuses of population and housing and the second was in the conduct of elections.

Nigeria recently conducted two censuses in 1991 and in 2006. It remains a shame that none of the two censuses was based on a universally acceptable and available digital database so fundamental to development. It is a shame because over the years, the National Population Commission (NPC) had built a stock of well trained personnel in digital cartography and GIS for conducting censuses, and planning for the creation of requisite spatial bases over which censuses

must be conducted. The NPC in 1991 could argue that the country was ill-prepared for the use of GIS to create enumeration and other statistical areas on which that census was based. The organization can also argue that mapping situation in the country was so bad that creating GIS based spatial framework would have been a tall dream. We have always not shared this view as we believe where there is a will and the right leadership, it would have proved feasible to develop digital maps for the censuses even in a preliminary way as the DLG maps became precursors to the TIGER maps of the US Census Bureau.

Furthermore, that a GIS based spatial framework was not used to plan and conduct the 2006 census remains unacceptable, retrogressive and indicative of a lack of adequate foresight. There were more than ten years between the two censuses and a determined organization could have gotten such preparations done well in time. Nonetheless, the NPC has always had a good alibi. Government funding has hardly been consistent for the NPC to make medium and long-term plans to use the period between two censuses to plan for the creation of a GIS based spatial framework. Nonetheless, failing to follow the example pioneered by the US Bureau of Statistics is an opportunity lost.

The NPC is not the only organization whose activities cover the whole country and who must always use a spatial framework for the conduct of its activities and who can singly or jointly revolutionize the use of GIS in the country. The Independent National Electoral Commission (INEC) is another of such organizations. INEC must conduct the registration of voters and produce a voters' register for all its elections, it must provide sufficient polling booths all over the country, it must supervise the distribution of electoral materials and collection of voting boxes etc; and it must count and announce and publish the results of the elections. That very few election results remain uncontested in the courts should be a good reason for evaluating the conduct of elections in all its ramifications

The success of an election exercise is judged by how free and fair the underlying process had been. Thus inability to provide a comprehensive and authenticated register of voters can be a major argument for saying an election is not fair. On the other hand, not providing enough voting booths would mean disenfranchising some persons leading to imputing that the elections were not free. There are other major factors that impugn the integrity of elections - the spatial aspect of the delimitation of Nigeria into electoral districts at all levels of the electoral process is a case in point. Let us explain a little in order not to be misquoted.

Nigeria with 774 local government areas and thirty six states and a Federal Capital Territory can be a good case for such an analysis. We can examine variations in the sizes of local government areas and their populations and it will not take too long to argue that there are injustices in the ways Nigeria is structured for these exercises. The case of Lagos and Kano States had always come up in arguing for aspatial restructuring of the country but there are more examples and some worse than the case of Lagos and Kano.

Today there are 360 members of the House of Assembly and 109 Senators. So 360 members are representing at least 140,000,000 persons and one House of Assembly member represents about 39,000 persons. Population distribution between states are inherently unequal just like the areas occupied by each state. But in actual fact, how many people does each House of Assembly Member represent? How many people does each Senator represent? How many people does each Councillor at the local government level represent? How unequal are these distributions between states of the federation? How unequal are these distributions between local government areas in the same state and between states of the federation? Is the spatial configuration of the country not so inequitable that we inadvertently, are doing nothing but making a mess or mockery of democracy? These questions touch the fundamental basis of our democracy.

In the course of our researches to develop spatial databases, we have encountered very embarrassing situations. As professionals, it is good exercise but the experience has been harrowing. First, spatial digital databases usually do not *officially* exist in many organizations or departments of government where we expect to find them. Many official documents and most official maps of the country do not contain all the names of the local government areas and great inconsistencies exist in spellings and names! Maiha is a small local government area in Adamawa State. Many official documents (The National Population Commission, and the National Bureau of Statistics especially) call the place "*Disputed Area*" (by whom?). The situation will be worse and almost insurmountable if one were to map the wards or communities or localities in each and every local government area of the country. Where is the gazetteer of place names?

A third example is necessary to bring home the point. It is the issue of boundaries. The issue of the accuracy of boundaries in Nigeria is important for any GIS undertakings even those described above. Unfortunately, most boundaries shown on Nigerian maps are only approximate and *are not guaranteed* by the Surveyor General. This is to say that very few boundaries in Nigeria had been unambiguously fixed.

Indeed most boundaries were estimates made by the colonial masters. Nowhere are these observations truer than in the case of local government area boundaries. Furthermore, the recent incident of Bakassi should be an eye opener to the need for the Federal Government to have a proper survey and documentation of boundaries. So when we use a spatial database not certified by the Surveyor General, we are doing so at our own risk.

Geographic information systems made in-roads into the country in the late eighties and early nineties through programmes of teaching and research in the universities especially of Ibadan and Lagos. Other inroads came through bi-lateral and multi-lateral agencies as RECTAS at the Obafemi Awolowo University at Ile Ife, or through World Bank sponsored programmes e.g. Local Empowerment and Environmental Management Project (LEEMP), National Fadama Project, and programmes at the Federal Ministry of Environment, Housing and Urban Development. Furthermore, some states of the federation (e.g. Oyo and Lagos states) embarked on building the capacity for the creation of digital base maps on some World Bank assisted projects. Of course, some private organizations and the oil companies have embarked on developing geographic information systems for various purposes; and the Abuja GIS remains a masterpiece in the country both in terms of scope and content, versatility, usability and usefulness.

As a nation, there are great variations in the levels of awareness of GIS as a veritable management tool. The Federal Government is not totally unaware but it remains to be convinced that GIS can improve its ability to plan and govern. Mapping of the country should be a priority if it does! On the other hand, some of the important ministries that should champion the course of GIS and improve the level of awareness seem to only pay lip service. We still look on the Office of the Surveyor General of the Federation (the old Federal Surveys) to champion the course of digital data development as it is empowered by law to particularly focus on meeting the cartographic needs of the country and to utilize every available means to collect, process and distribute such digital data as are obtained from remote sensing. Furthermore, the Office is the only organization that can effect alterations on the information on maps and associated databases. In addition, the Federal Surveys is required to compile, maintain and update the *Gazetteer of Place Names* and to supply all the base maps (including digital maps?) used in the country.

4. GIS organizes Space, GIS Organizes and Analyses Data

Land reform represents one of the loudest demands by government or the elites in the Nigerian society today. Luckily, the persons heading the land reform committee understands the critical nature of the problems as arising from a bad organization of the Nigerian space and a weak collection, storage, analysis and dissemination of associated data to appropriate users.. Figure 4.1 shows how GIS organizes data and space. Of course, they know that the institution of a well-articulated GIS as decision support system is the answer that would move Nigeria from the World Bank's ranking in 2010 of 178th out of 183 economies in respect of difficulties of registering properties and doing business (Mabogunje, 2011). Both Nigerian space and the associated database remain unstructured or ill structured and disorder reigns in many situations.

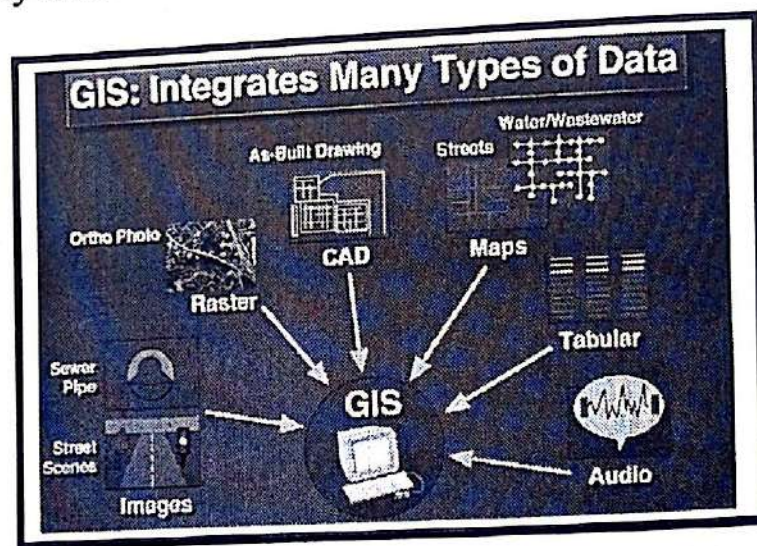


Figure 4.1 GIS and Data Integration

Geographic information systems are designed to obtain, process and harmonize data from numerous sources such as tables, maps, CAD and other engineering drawings, ortho-photo and remotely sensed data etc. (see figure 4.1). These data are then analyzed to provide solutions to certain societal problems. This ability to integrate and synthesize data constitutes the superiority of GIS over many of these other techniques with which it is intricately related.

Applications of GIS have furnished one of the greatest avenues for bridge building among professionals and disciplines because every application involves some sort of networking of ideas and persons. Applications are usually by persons of diverse qualifications in an equally set of diverse fields and depending on the level of technology available. Nonetheless, the extent of the use of GIS as bridge building

may be facilitated by an analysis of its impact on allied disciplines with which it had been associated and also by considering the range of societal problems to which GIS has provided requisite solutions.

What we have seen is how the simple tasks of developing geographic information systems had led to cooperation between various professionals in such fields as computer science and information technology on the one hand and the earth-based disciplines of geography, geology, cartography, land surveying, engineering and remote sensing on the other. With this cooperation, both GIS software and hardware development have become major economic enterprises.

Geographic information Systems had influenced Cartography through improvements in the mapmaking process and through automation and by creating new forms of maps based on spatial database manipulation. Furthermore, with GIS, objects are moved and edited very easily while issues of scale and projections are addressed by standard routines. Indeed cartography has come to play major roles in the success of GIS as software producers improve on the mapping capabilities of the software not only to improve sales but also to improve the usability of GIS.

Remote sensing systems are designed to collect store, manipulate and display raster data typically derived from scanners mounted on aircraft or satellite platforms. Nevertheless, GIS concepts have improved the quality and value of remote sensing products through the use of additional data. For example, the use of knowledge of ground elevation from Digital Elevation Models (DEM) has proved useful in removing shadows from remotely sensed images. Furthermore by combining information from remote sensing with those from GIS, one can generate sufficient and appropriate data for decision-making

Surveying and engineering, like remote sensing, continue to be major sources of obtaining geospatial data. Surveying is itself a precision science on which accurate measurements are indispensable. Advances in technology currently ensure that measurements on locations may be captured in digital form and downloaded to the database through *the total station* or through the use of *global positioning systems* (GPS). Of course, surveyors and engineers are increasingly finding DEM very useful in *cut-and-fill* studies and in the estimation of quantities of materials

Furthermore, an increasing use of GIS for scientific research to support investigations of global environment, include the routine search for factors causing patterns and spread of diseases (epidemiology), the understanding of changes in patterns of settlements, distribution of

populations, anthropology, demography and social geography; and understanding relationships between distributions and habitat ecology. This is perhaps an indication that GIS might become some sort of analysis package like the Statistical Package for the Social Sciences (SPSS), SYSTAT, etc.

Nonetheless, GIS constitutes the veritable base for developing *spatial decision support* systems for solving spatial location problems (see Ayeni, 2010). Spatial problems have a definitive and emphatic spatial dimension and involve situations that require that decisions be made over two or three-dimensional space. Spatial decision support systems (SDSS) integrate a geographical information system with computer based spatial and map analysis and display modules. The systems are typically employed to develop and analyze scenarios, analyze and evaluate them according to planning standards in vogue. Furthermore, spatial decision support systems are designed to bring the whole of the knowledge base to bear on a problem through a flexible and adaptive solution system that makes explicit use of both the analysts' *models and the expert knowledge of decision makers*.

5. GIS as Paradigm Shift.

In 1962, Thomas Kuhn wrote *The Structure of Scientific Revolutions*, and fathered, defined and popularized the concept of "paradigm shift" (p.10). Kuhn argues that scientific advancement is not evolutionary, but rather is a "series of peaceful interludes punctuated by intellectually violent revolutions", and in those revolutions "one conceptual world view is replaced by another". A Paradigm Shift therefore is a change from one way of thinking to another. It's a revolution, a transformation, a sort of metamorphosis. It just does not happen, but rather it is driven by agents of change. What we are witnessing today in GIS is a paradigm shift and must be seen in that light (see Figure 5.1)

The practitioners of GIS think the ways they do because of the ways they are taught to think about the world, which in turn arise from overarching views about how the world can be known, and what the appropriate ends of knowledge are. Practitioners have used a number of paradigms to organize their inquiry and exposition in the past and shown how different perspectives have enriched the discipline. GIS embraces the spectrum from basic research to active advocacy for the implementation of the results of geographic research in policy and programmes.

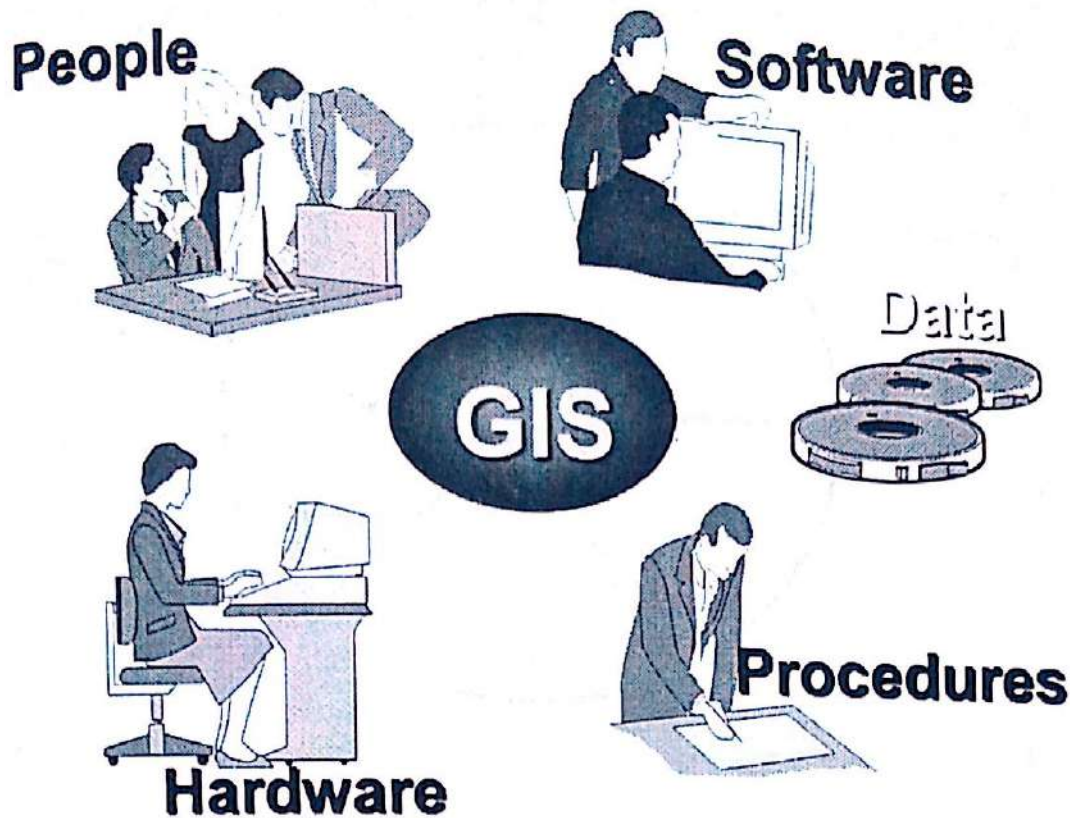


Figure 5.1: What is GIS

At the same time, GIS technical advancement and adoption are accelerating. These trends are changing everything. GIS is providing a new way to abstract our world: digital geographic knowledge (See Figure 4.2). This knowledge is being organized with geographic data and data models, mathematical models that describe geographic processes, digital maps and globes that visualize our world, and geospatial workflows that manage our work. Metadata is increasingly used to describe each of these abstractions in such a way that we can catalogue and discover more about what is known (Dangermond, 2009).

Finally, GIS is changing how we work. It provides a science-based approach, connecting geospatial measurement and data collection with data management; spatial analysis and modelling; geospatial visualization; design and planning; decision making; and ultimately, human action. The benefits of this approach are that it is systematic, holistic, analytic, quantitative, and visual. As such, it speaks to people through a new medium. This approach can handle large volumes of data; support complexity; and be transparent, repeatable, collaborative, and crosscutting, thus embodying many of the attributes of what we desperately need today to better manage our world (Dangermond, 2009).

As shown in Figures 5.3 and 5.4, GIS can change the world through how it handles spatial information. Humanity would develop better, easier and faster ways of doing things and of collaborating.

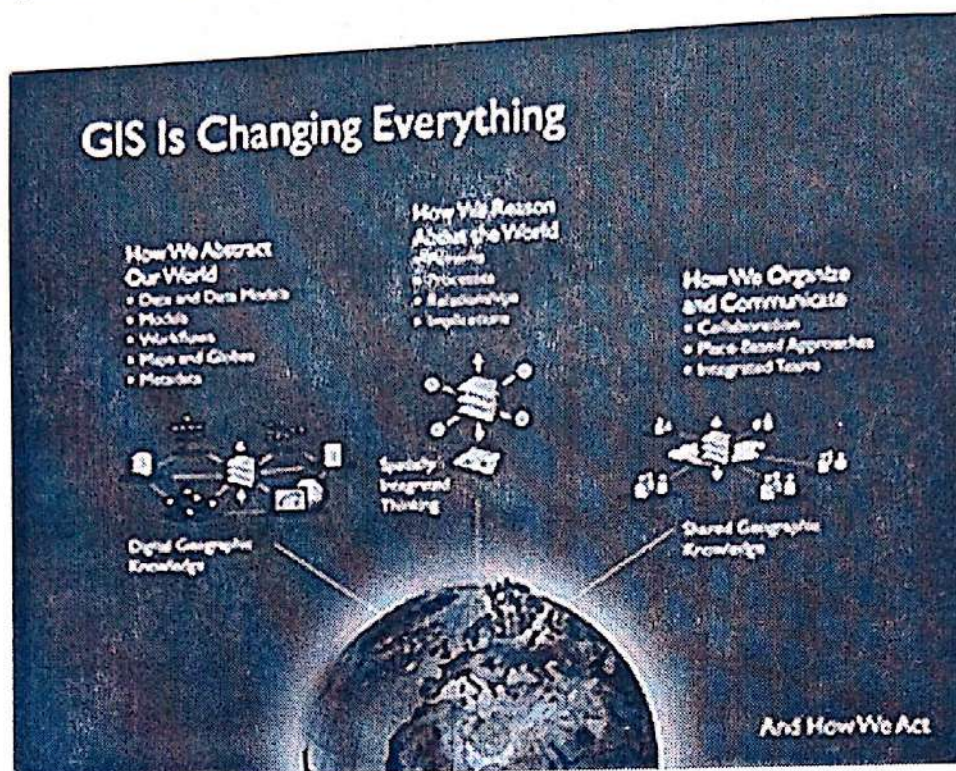


Figure 53 Geography Can Change the World Again (Source: Dangermond, 2009)

Nevertheless, what is really shaping the world today is the generation and development of innovations which are the processes of combining resources in new or extraordinary ways to generate new or improved outcomes which could be products, goods or services. Innovation is the ability to exploit systematically the effects produced by new combinations and use of pieces in the existing stock of knowledge. Innovations may range from slight improvements on existing ones to major changes in performance and changes in technological and non-technological systems and economic paradigms (Oyelaran-Oyeyinka, 2013). Discovery and innovation are extremely very related.

Today, Geographic Information Systems remains the most widely used set of tools within the scientific community and in all disciplines from cartography, agriculture, human medicine, epidemiology and mapping of the incidence of diseases, location analysis and location based services, transportation analysis and modelling, urban and regional planning, the analysis of vulnerability to hazards and disasters (floods, droughts) etc. The Navigator in your car, the maps on your phones and most tracking devices used by transporters are applications of Geographic Information Systems. Lagos State recently developed a

cadastre based land information system for managing landed properties in the state. Many states are following suite. A classic use of the methods of GIS in Nigeria was the identification of illegal structures in Abuja some few years ago. Geographic Information Systems has given birth to the field of geoinformation science which constitutes the basis of the rigorous research behind the tools that are so useful in advancing the field of geography. Where then is the research frontier?

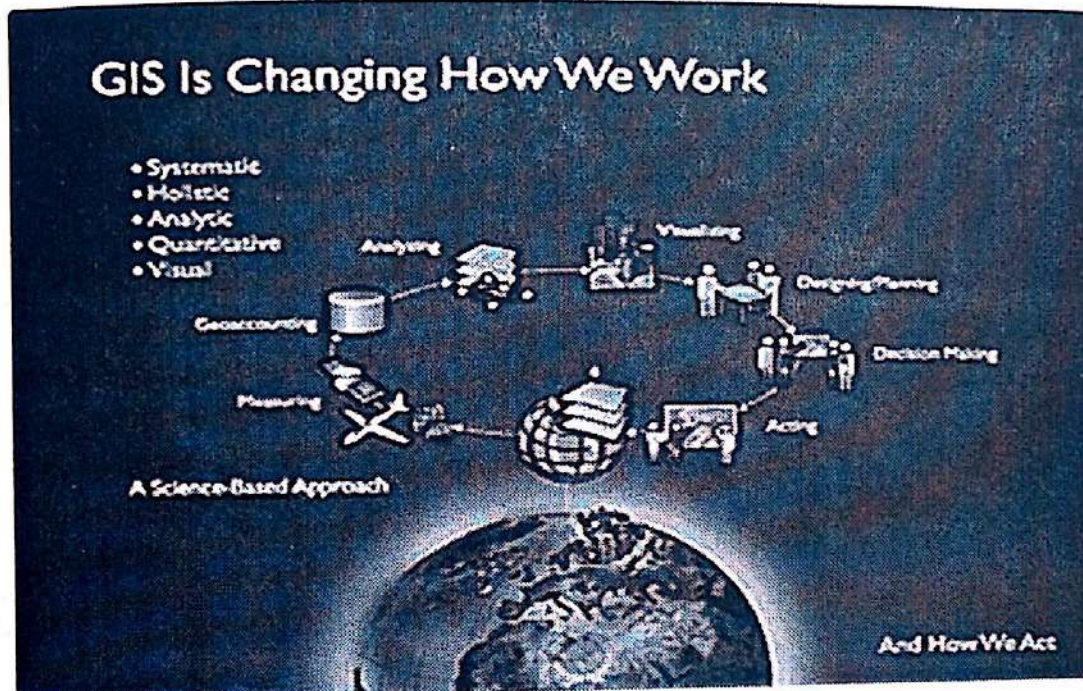


Figure 5.4 Geography Allows Us to Manage our World in A Better Way:
Source: Dangermond, 2009

5.1. The Geographic Information Science and Technologies Paradigm

Geography has some revolutionary new technologies that are poised to help shape the new landscape of science and transform the subject (Colwell, 2004). Douglas Richardson the Executive Director of the Association of American Geographers (AAG) writing the *Forward to Geographic Information Science and Technologies (GIS&T)* wrote "Geographic Information Science and Technologies (GIS&T) have today become critical components of the global cyber infrastructure, both in the university and in society. The integrative capabilities of these and related technologies have extended research frontiers across many fields, in areas ranging from biocomplexity to epidemiology to transportation engineering. Technologies such as geographic information systems (GIS) also have increasingly become the common ground for sharing data

across disciplines, or the “glue” which connects large-scale interdisciplinary research”. Let us illustrate by some examples in the contemporary societies in which we live (DiBiase *et al.*, 2006)

Governments, militaries, commercial enterprises, and other interests rely on information about the land and the location and characteristics of people and resources. For centuries, maps have served as the primary mechanism for managing and communicating geospatial information. Since the sixties when computerized Geographic Systems emerged to manage and analyze information more efficiently and effectively, computing power has increased, data have become plentiful, software has become easier to use, and the scope and complexity of questions that GIS is capable of addressing has expanded dramatically. As the demand for these technologies has grown, and as their applications have diversified, the field concerned with the development and use of these technologies has also evolved. Today, GIS software is only one component of a broad domain that we refer to as Geographic Information Science & Technology (GIS&T), which is composed of three interrelated sub-domains (Figure 5.5).

One sub-domain is *Geographic Information Science* (GIScience). GIScience is a multidisciplinary research enterprise that addresses the nature of geographic information and the application of geospatial technologies to basic scientific questions (Goodchild, 1992). Based primarily in the discipline of geography, but drawing upon insights and methods from philosophy, psychology, mathematics, statistics, computer science, landscape architecture, and other fields, GIScientists produced much of the knowledge represented in the ten knowledge areas that comprise the Body of Knowledge.

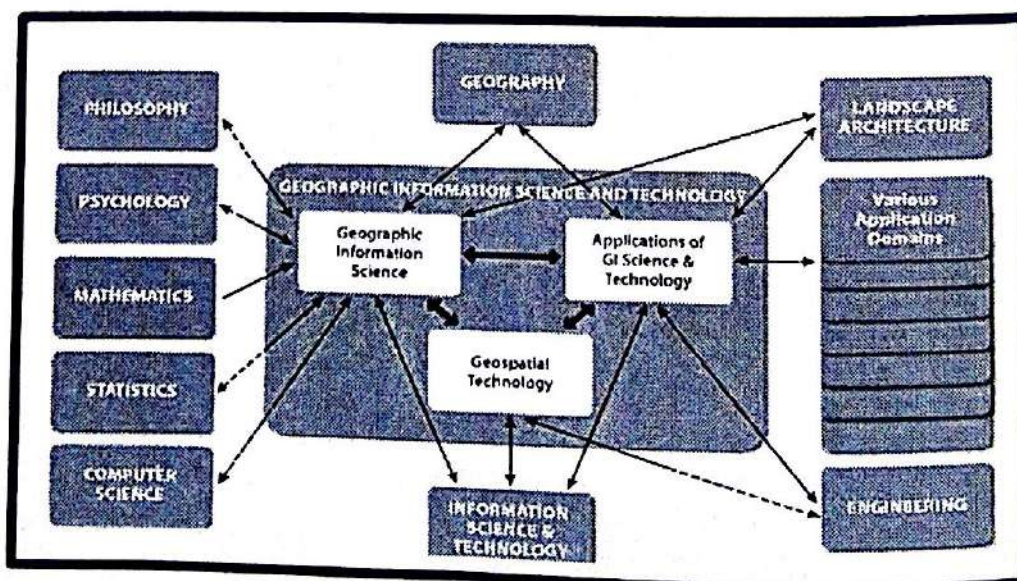


Figure 5.5: The three sub-domains comprising the GIS&T domain, in relation to allied fields. Two-way relations that are half-dashed represent asymmetrical contributions between allied fields. (Source: DiBiase *et al.*, 2006)

A second sub-domain is *Geospatial Technology*, the specialized set of information technologies that handle georeferenced data. Geospatial technologies support a wide variety of uses, from data acquisition (e.g., aerial imaging, remote sensing, land surveying, and global navigation satellite systems), to data storage and manipulation (e.g., GIS, image processing, and database management software), to data analysis (e.g., software for statistical analysis and modelling) to display and output (e.g., geovisualization software and imaging devices). GIScience and applications inform the development of geospatial technologies, but technology development requires contributions from information science and engineering.

The third sub-domain, *Applications of GIS&T*, includes the increasingly diverse uses of geospatial technology in government, industry, and academia. A few examples include near real-time analysis of service outages in electrical networks, applications in military intelligence and operations, homeland defence planning and operations, facilities siting, environmental impact assessment, property tax and land ownership records management, and truck route optimization for solid waste pickup in urban areas. The number and variety of fields that apply geospatial technologies is suggested in Figure 5.5 by the stack of “various application domains.”

5.2. Extending the Realms of Understanding

In the next few illustrations, are presented some of the depths of understanding and interpretations that GIS and Technologies have enabled researchers and painstaking people to make in the course of their research (see also Ayeni, 2013)

5.2.1. The US 2012 Presidential Elections.

In November 2012, the US conducted a presidential election and declared that Barack Obama won. Many people including his hottest rival Mitt Romney would not believe that Obama could win even when votes from many states had been counted. Furthermore, even when Romney finally threw in the towel, most of the world watching the news on CNN would find it difficult to believe especially looking at the map of the results as presented on the election night (see Figure 5.6.).

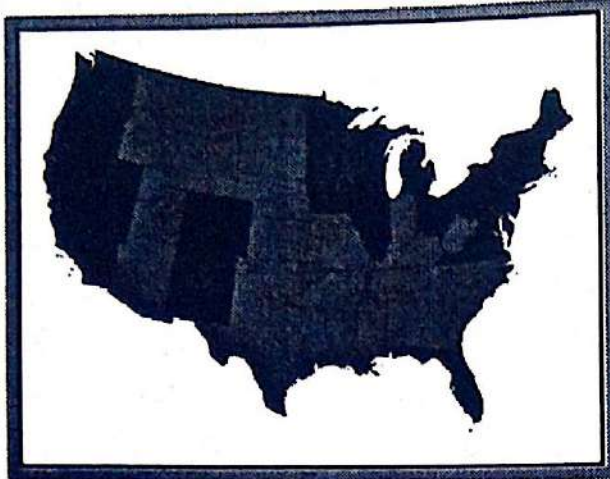


Figure 5.6 The 2012 Presidential Elections



Figure 5.7 A GIS View of the Results

Figure 5.6 shows the states won by Republicans in red and those won by Democrats in blue. In the words of the Nigerian Legislature “the reds have it”. The reds did not have it. People, not areas matter in elections. Consequently, in figure 5.7, the population of the states had been taken into consideration and it is clear that the “blues had it”. Barack Obama not only won convincingly, he won by a landslide in spite of it all, a fact that became more obvious if the voting pattern were displayed at county level. This is the power of GIS.

5.2.2. A Spatial Decision Support for the Nigerian Communications Commission

Working with my team of researchers, we had a good opportunity in 2009 to show case GIS & T by developing a decision support system for the Nigerian Communications Commission when the Universal Provision Fund (USPF) engaged us to assist them. The assignment included producing estimates for the market efficiency gap and the market access gap for key ICT infrastructure and the estimation of the maximum smart subsidy that USPF should provide for projects to be launched from 2008 to 2011 and the use of the GIS Database, to provide recommendations in which LGAs and states should be prioritized for USPF funding for universal access

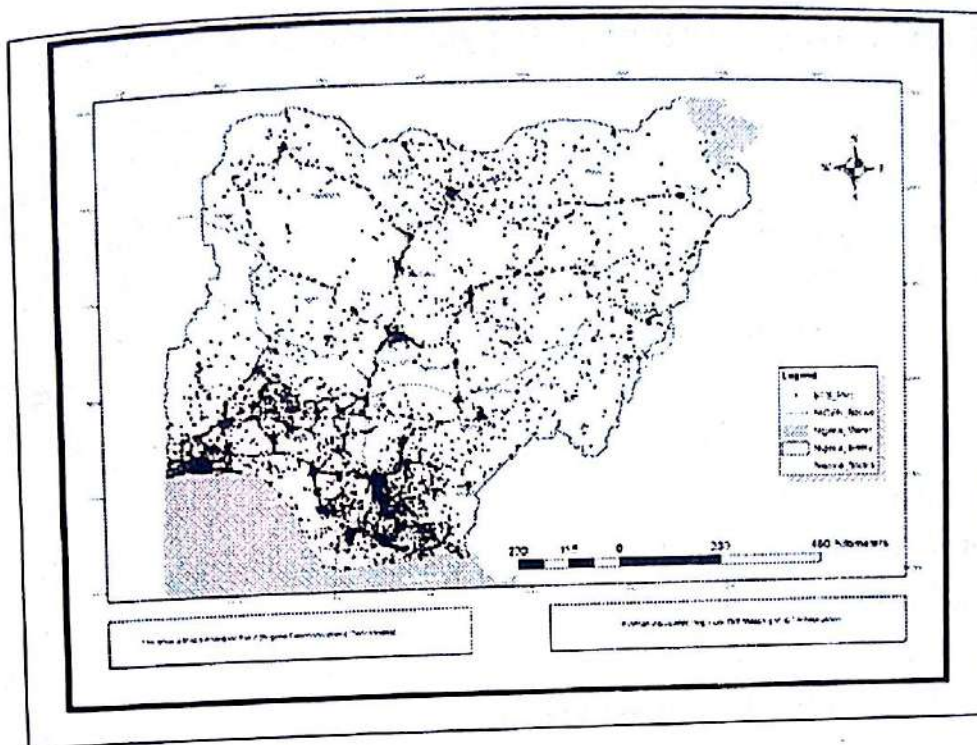


Figure 5.8. The Location of ICT Infrastructure

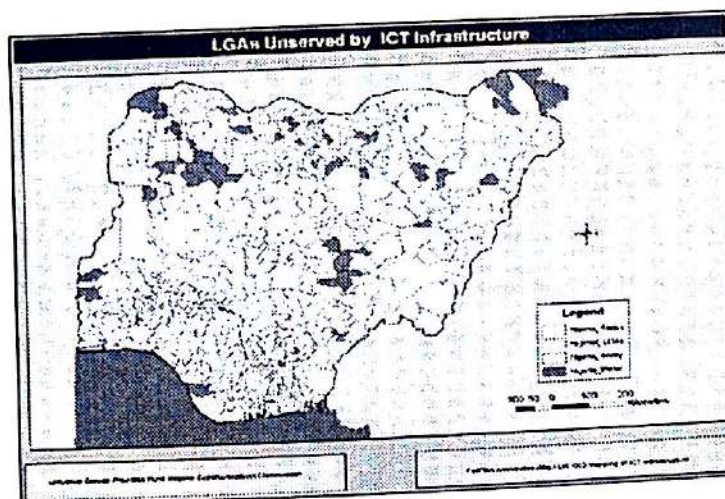


Figure.5.9 Served and Unserved Area

This task was seen as a multi-disciplinary assignment in cooperation with telecommunication engineers, seasoned economists and GIS database analysts and geographers etc. Some of the results were the location of the ICT Infrastructure and the determination of the coverage of ICT infrastructure in the country (see Figures 5.2.3 and 5.2.4). The NCC had utilized these results to canvass for investment in unserved and underserved areas and for establishing Community Communication Centres in different parts of the county and in many of their recent policies.

5.2.5. Flood Risk Management and Flood Early Warning System

For Flood Risk Analysis we also had the opportunity to study the river basins in Nigeria and characterize them on the basis of their vulnerability to flooding and the development of Flood Early Warning Systems (FEWS) on them. We identified, collated and analyzed existing flood data in the country for flood risk mapping; identified high risk areas and flood hazard zones, nationwide for major rivers considered to be persistently flooded. Vulnerability to flooding maps are what GIScientists would produce in a jiffy given the right equipments. We also identified suitable locations within hydrological areas nationwide for establishment of weather radar observation stations

This work provided a synthesis of information on flood monitoring and vulnerability studies. It also collated and analyzed flood data with a view to achieving flood risk mapping, the identification of high risk areas and flood hazard zones, nationwide for major rivers considered to be persistently flooded. The information assembled and put in a digital format consist of text, tables and maps, and every other information on which the maps were based. This type of collection of information on floods did not exist hitherto anywhere in this country. The research project had therefore set in place the elements of a *Flood Information System in Nigeria* and was subsequently used by the Federal Ministry of Environment to develop prototype early warning systems.

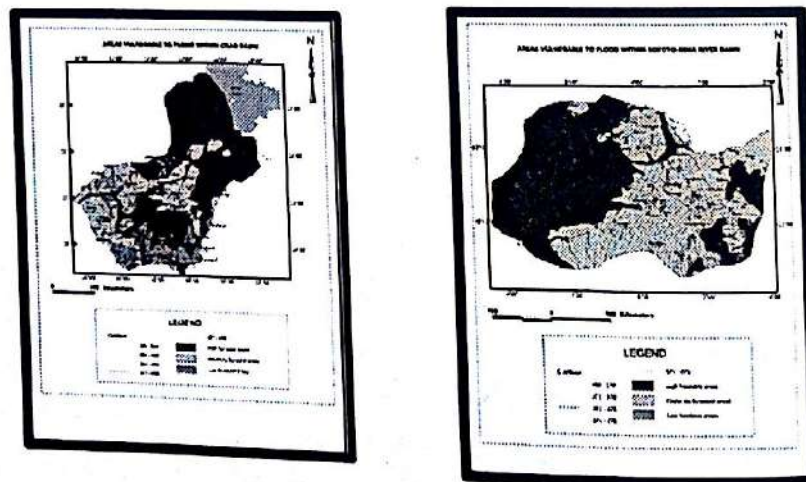


Figure 5.10: The Two River Basins Most Vulnerable to Flooding

5.2.3. The Deployment of GIS for the Dugbe Business Unit of the Ibadan Distribution Company of the PHCN

This project is both multidimensional and multidisciplinary as it involved cooperation between electrical engineers, GIS specialists, remote sensing experts, MIS consultants and geodatabase developers. The project

involved the preparation in digital form, of the roads and street maps of the study area, the preparation of the buildings footprints for consumer indexing and database creation, and the preparation of base maps of Electrical Network using GPS mapping of Injection Sub-Stations, Distribution Transformers, High Tension and Low Tension Poles. For each of these elements of electricity distribution infrastructure, we also collected associated composite characteristics and attributes. The end product is the development of a consumer database that is tied to the infrastructure for the delivery of the services Figures 5.11 and 5.12 are indicative of this trend in the project development.

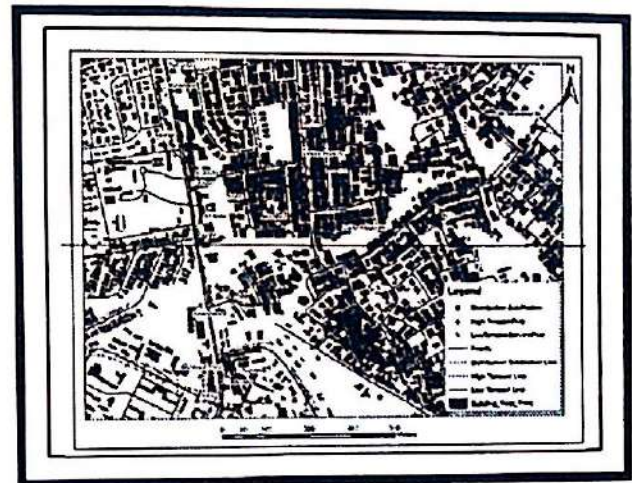
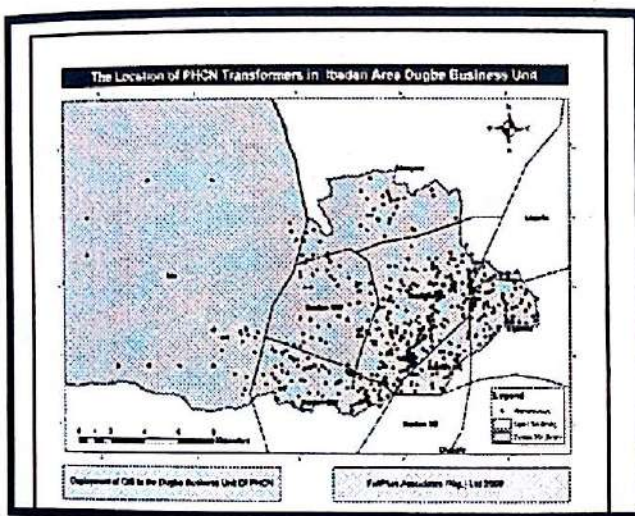


Figure 5.11. Location of PHCN Transformers

Figure 5.12 Connectivity of Consumers

With the database and when fully developed and integrated with SCADA technology, PHCN officials would remain in their offices and monitor problems as they arise in the distribution of electricity to buildings in which the problems occur.

5.2.6. The Creation of a Digital Database at the National Emergency Management Agency (NEMA)

Thematic maps portray good baseline information for decision making. Our research team located and *digitally* mapped from all available data, the incidence and distribution of all forms of disasters for which NEMA is responsible. Figure 5.11 is one of the outputs

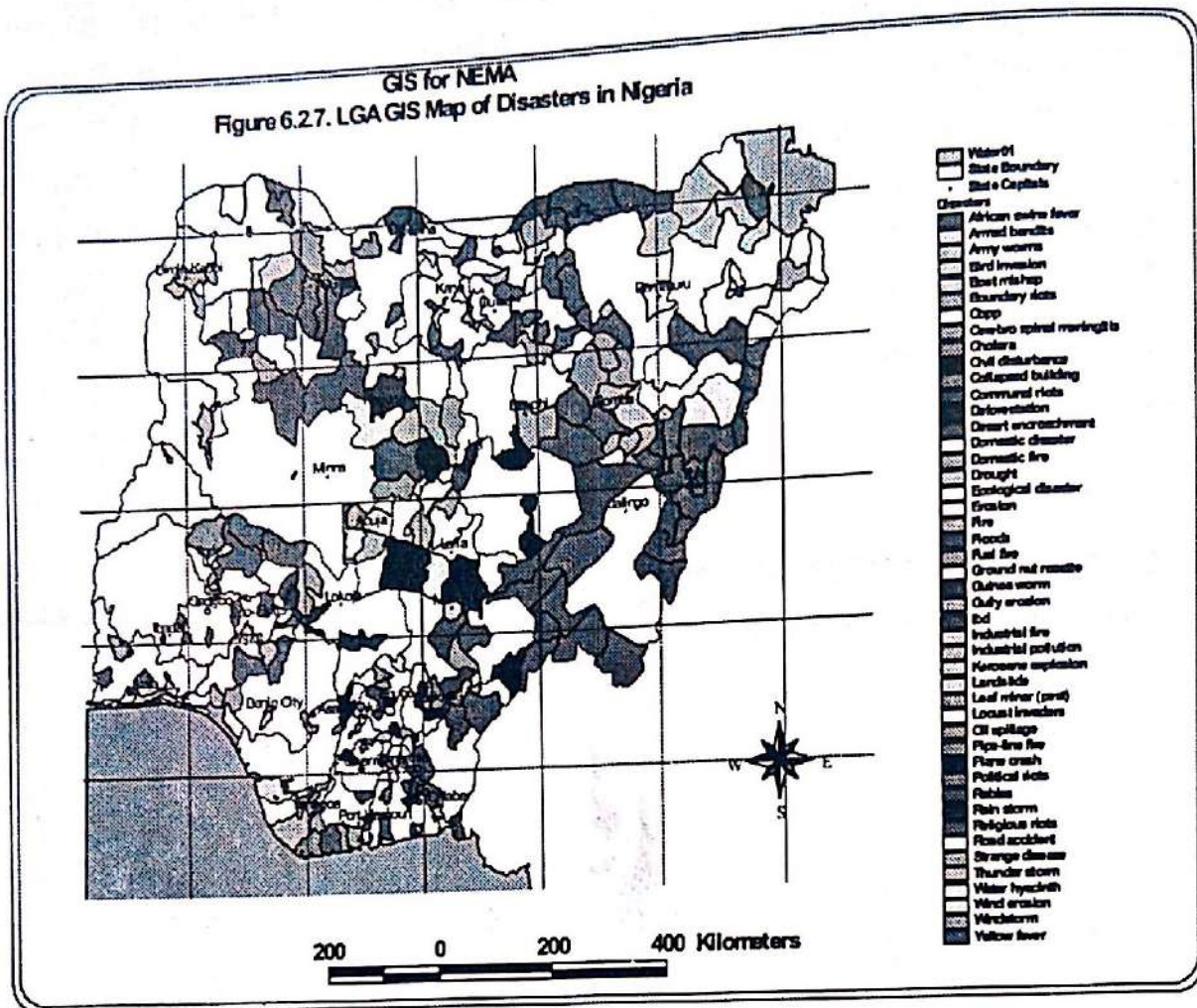


Figure 5.13. LGA GIS Map of Disasters in Nigeria 2004

5.2.4. Digital Mapping of Umuahia

Map making has always been of interest to geography. GIS has not only facilitated the process but has also shown us how to make intelligent maps. A few years ago, our team had the opportunity to demonstrate this when the Office of the Surveyor General of the Federation granted us the opportunity to produce the database for a Guide Map of Umuahia. What we did was to be armed with the best technologies including high accuracy global position systems (GPS), ability to capture current images and very accurate software. With only two assistants in a motorized three wheeler vehicle; we completed the field survey and produced our first draft within three days. The whole assignment lasted less than two weeks. This feat could not be achieved by traditional land survey methods in so short a period and with the level of accuracy that we had!

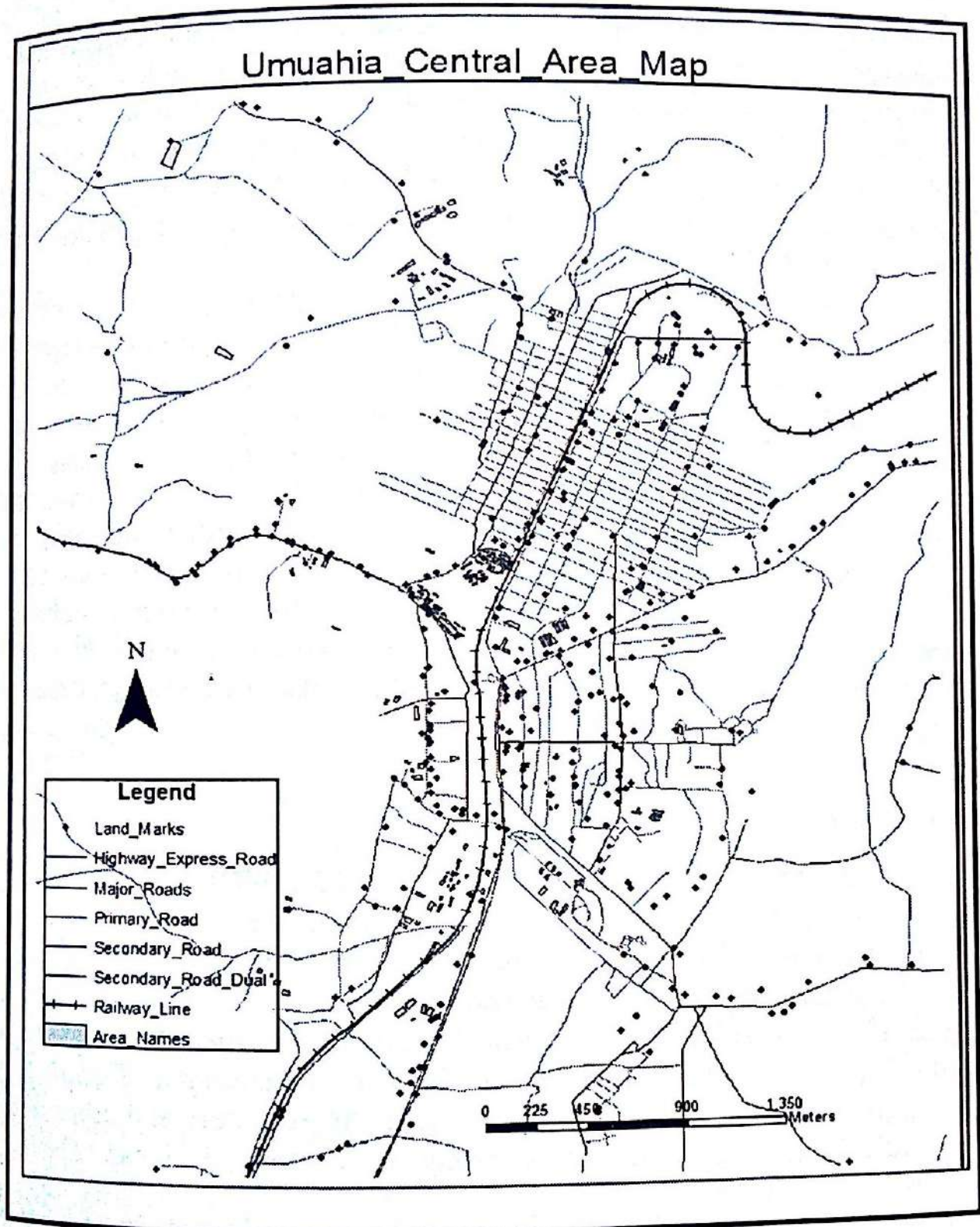


Figure 5.12. Digital Mapping of Umuahia

6. Conclusion

Geographic Information Systems and Technologies continue to provide tools and methodologies that people from many scientific disciplines need and are learning to use. GIS has taken root in some institutions but are yet to be firmly established in most others. The establishment of a

GIS&T facility goes beyond the purchase of a few computers and stabilizers. Figure 1 is incisive. However, integration into the institutional research network is as important as the integration into new and evolving developments in Information Technology in particular and technology and the generation of new ideas and innovations. All these are a boost to Geography who can see this as opportunity to rescue the discipline from oblivion.

Agents of change continue to drive the new paradigm shift and the signs are all around us, some of which had been discussed in this paper. Although human beings will resist change, the processes have been set in motion and we will continue to recreate our experience. As a form of awareness and using the words of Kuhn (1966), "awareness is prerequisite to all acceptable changes of theory" (p. 67). It all begins in the mind of the person. What we perceive, whether normal or metanormal, conscious or unconscious, are subject to the limitations and distortions produced by our inherited and socially conditional nature. However, we are not restricted by this for we can change. We are moving at an accelerated rate of speed and our state of consciousness is transforming and transcending".

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