

The Potentials of Geospatial Database Management Systems in Shelterbelt Development and Monitoring

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Abstract

Shelterbelts and other forms of afforestation in arid zones are faced with a lot of challenges that hinders their successful development. These are as a result of both ecological as well as human induced influences. Hence, there is the need to properly manage and monitor the shelterbelts in arid zones if they are to fulfill the objectives of their establishment. This study therefore, developed a Geospatial Database Management Systems in order to proffer solutions to some of the challenges encountered in managing and monitoring shelterbelts in arid and semi-arid environment and by extension other afforestation projects around the world. Object-relational database model was used in the development of geospatial database management systems for this study. The study showed that the incorporation of geospatial database management systems in shelterbelt management and monitoring will provide timely and up to date information needed for a successful silvicultural practice.

KEYWORDS: Geospatial, Database, Arid environment, Shelterbelts, DBMS, Afforestation, Entity relationship, Yobe State.

Introduction

Shelterbelts are special ecosystems that require careful planning involving the use of appropriate silvicultural techniques to ensure success. They need well thought-out strategies to achieve the desired objectives especially by ensuring that they retain their physiognomy. Proper maintenance of shelterbelt's structure has been a daunting task especially in the arid environment due to extreme conditions leading to high rate of failure observable in the field. Most of the shelterbelts that are located above 12⁰⁰⁰' N of the equator show high prevalence of gaps as a result of failures witnessed in the early period of establishment (Gadiga, 2012). This can be avoided with appropriate planning and management by the stakeholders. To achieve a stable morphological structure of the shelterbelt, Salem, (1985) proposed that the vigor and growth of individual trees be maintained and improved as well as the structure so that they function as an effective barrier in reducing wind velocity. Therefore, in order to ensure that shelterbelts achieve their objectives of providing shelter against wind and its associated consequences, it is important to develop a monitoring procedure. This can be accomplished through the development of a geodatabase that will be responsible for storage, analysis and retrieval of information on shelterbelts from inception to maturity.

Database Management System

Database is a large, computerized collection of structured data. The structure of the collected data in a database is done to relate facts and situations that were previously separate. For example, retrieval of facts in a database such as address associated with a person's name can be done (Rolf, 2004). According to Aronolf, (1989) Database Management System (DBMS) is a system that comprises a set of programs that manipulate and maintain data in a database. Rolf (2004) presented a similar view of DBMS as a software package that allows the user to set up, use and maintain a database. They all share the view that DBMS are developed to manage the sharing of data in an orderly manner and to ensure that the integrity of the database is maintained.

Geospatial Database Management System

Spatial data are data that can be displayed, manipulated and analyzed by means of a spatial attribute that refer to a location on or close to the surface of the Earth. This spatial attribute is normally provided in the form of coordinate pairs that allow the position and shape of a particular spatial feature to be measured and represented graphically. Spatial data are also called geographically referenced data or geospatial data. They are collected and stored in two fundamental forms called vector and raster.

Although many people use desktop GIS to view spatial data, new developments in Internet technology and forms of data representation and presentation (for example, Geography Markup Language [GML], Keyhole Markup Language [KML] and Scaleable Vector Graphics [SVG]) have made it possible to view spatial information in a remote spatial database with the use of an Internet browser. Processes for data integration and transfer between spatial and non-spatial databases do not generally require the use of a GIS. Similarly, spatial decision support is feasible without a GIS, but this is achieved with the loss of GIS-based data visualization (Yeung and Hall, 2007).

Benefits of Using Database Management System (DBMS)

There are many benefits derived from the use of DBMS. Some of the benefits include;

- Storage and manipulation of large data sets, for example, national census data.
- Ensuring data correctness; this is done by applying constraints to the inputted data. The rules applied are known as integrity constraints and it is an integral part of database design. Database does the following:
 - ✓ It allows concurrent use of the same data by many users and this functionality is called concurrency control.
 - ✓ It provides a high-level declaration query language. This programming language is used to retrieve information from the DBMS (for example SQL).
 - ✓ It supports data back-up and recovery functions to ensure data availability at all times. Regular back-ups of data set and automatic recovery schemes provide insurance against data loss.

- ✓ It allows the control of data redundancy; multiple data storage reduces the usefulness of the data due to contradiction that may occur among data. This can be easily controlled in a DBMS.

Classification of Database System

Database systems can be classified in a variety of ways according to different criteria. Traditionally, they were classified according to the different data models on which they were constructed. These models fell into three categories that characterize the evolution of database systems, namely hierarchical, network and relational. A fourth class called object-oriented database systems emerged in the late 1990s as a consequence of the advances in what is now commonly recognized as object-orientation technology.

Hierarchical and network database systems, which were used on mainframe and mini-computers in the 1960s and 1970s, are now of historical interest only in the database world (Ullman and Widom, 1997).

The relational database system seeks to overcome the database rigidity of hierarchical and network systems, and to insulate database users from the physical implementation of the system (Yeung and Hall 2007). The central building block of a relational database system is the table, which represents a collection of data pertaining to a particular area of interest. Advances in relational database concepts and techniques quickly established the relational class of database systems as the de facto standard in the database world.

The introduction of object-oriented programming concepts and techniques in the 1990s led to the development of object-oriented database systems. In object-oriented database concepts, the problem space is perceived as being composed of data objects, which are individually identified as observable entities that are grouped into classes by the similarity of their respective properties. Nowadays, practically all database systems are based on relational or object-oriented design principles, or a combination of both known as object-relational database management systems (Yeung and Hall, 2007). The advent of object-relational database management systems (ORDBMS) in the late 1990s has made possible the use of generic DBMS functionality to process and apply spatial data for end user applications. By using extended SQL capable of managing spatial data, an ORDBMS can be used to store not only attribute data but spatial data as well. Furthermore, an ORDBMS can be quite easily connected to other database systems in a local or global communication network, making it an integral part of the corporate computing architecture of organizations in business, government and education.

Materials and Methods

The area that was used to demonstrate the use of Spatial Database Management Systems in shelterbelt development and monitoring are located in northern parts of Yobe State between latitude $12^{\circ}52'26''\text{N}$ and $13^{\circ}01'52''\text{N}$, and longitude $10^{\circ}12'17''\text{E}$ and $10^{\circ}53'45''\text{E}$. Two of the shelterbelts that were selected for this study are Garanda shelterbelt and Jajimaji shelterbelt. The area is a part of the

Sahelian region of Nigeria where desertification is threatening the ecology and livelihood of the inhabitants of the area (UNESCO, 2000; UNDP, 2009; Orounye, 2009; Gadiga, 2012). Figure 1 shows the location of the shelterbelts.

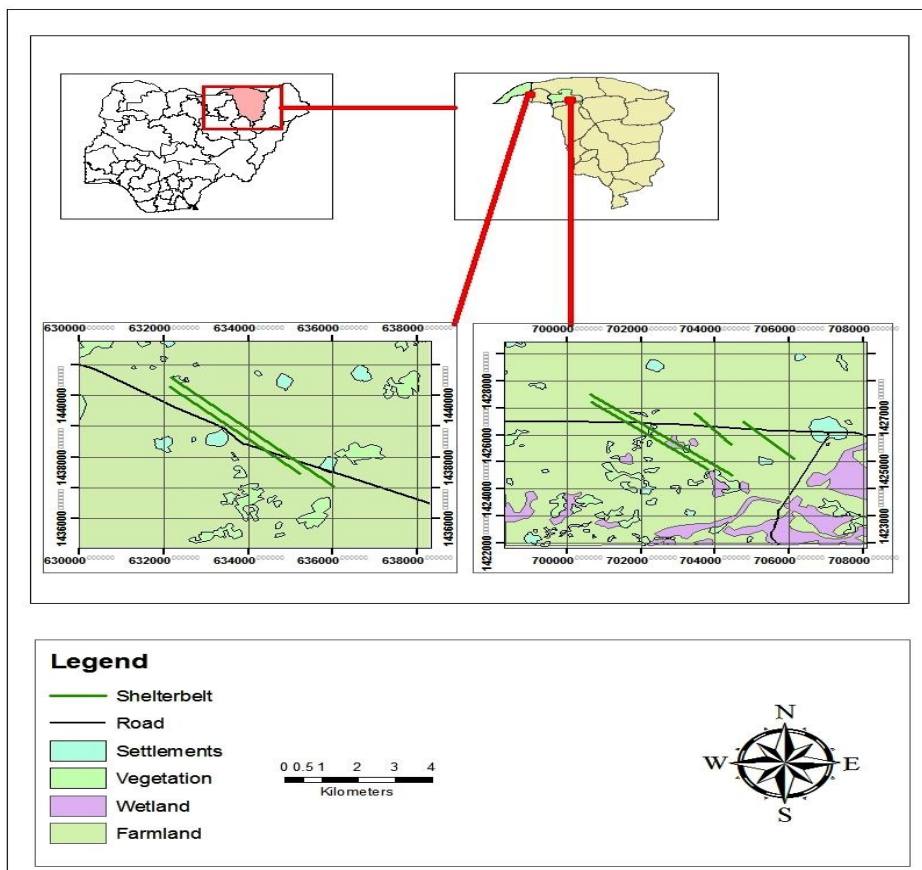


Figure 1: Location of the Shelterbelts

A geospatial database was created in order to develop a monitoring system for shelterbelt projects in the study area. Relevant spatial and attribute data were inputted to explore relations within the data sets. The inputted data included user requirement generated with the aid of a questionnaire. The object-relational database model was chosen in the development of the geospatial database because the model offers extended SQL capable for managing and storing not only attribute data but spatial data as well (Aronoff, 1993, Yeung and Hall, 2007). The model combines the transaction management capability of relational systems and flexibility of data storage and access of object-oriented systems. Figure 2 shows the procedures for the design and construction of the geospatial database management systems.

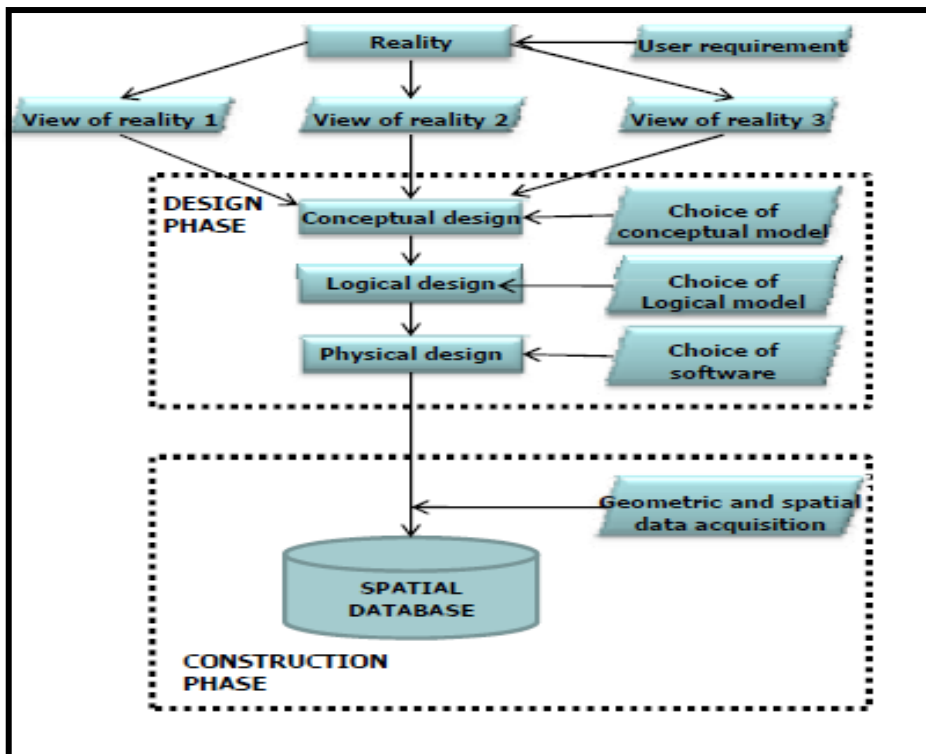


Figure 2: Database Design and Construction Phases in GIS (Kufoniyi, 1998)

Results and Discussions

Conceptualization phase of Database Design

The user requirements collected from foresters during field exercise was used in conceptualizing the database model. In this study, Entity-Relationship method of conceptual data modeling was used (Figure 3).

Reality in this study is the shelterbelts and views of reality are the components that make up the reality. Views of reality that are used in creating the geospatial database for entity relations are; shelterbelt information, species used in afforestation, soil properties, design of shelterbelt, Challenges faced, location of shelterbelt, and climate of site.

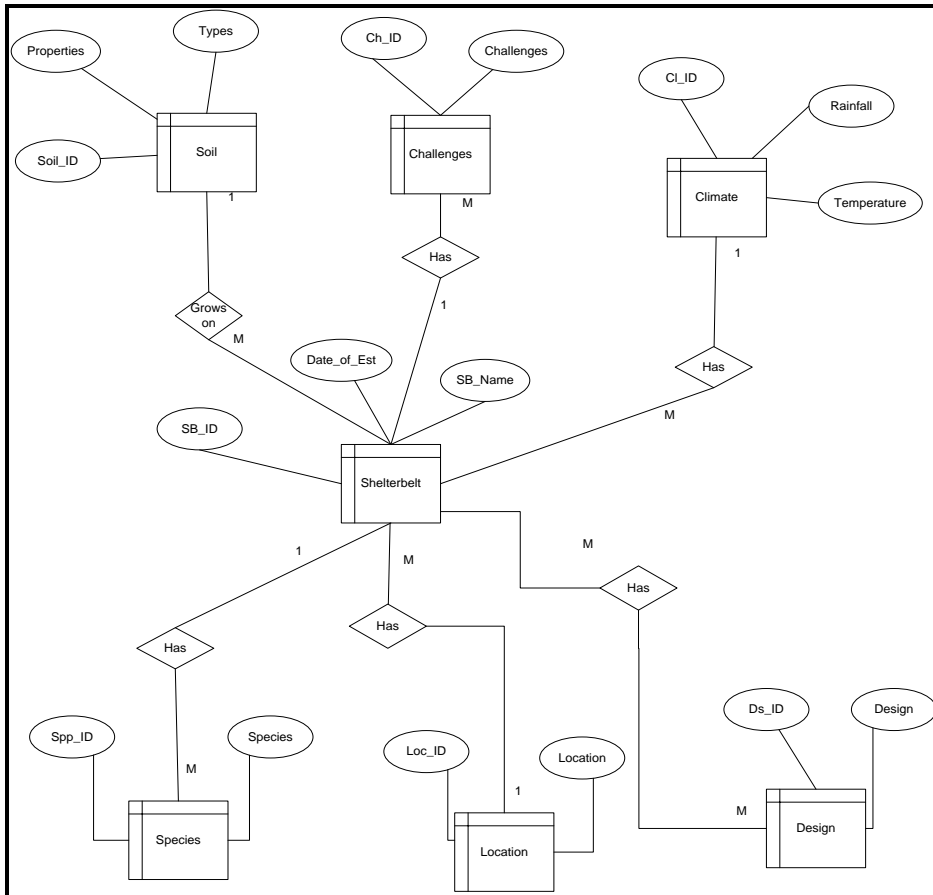


Figure 3: Entity-Relationship method of conceptual data modeling

Logical Database Design

In logical design phase, the conceptual model is translated into a format that can be implemented in the database model of particular interest. The user requirements information gathered from foresters and the data structure are refined and re-confirmed and also appropriate primary, secondary and foreign keys were identified. The logical database schema in Figure 4 was translated from the conceptual schema in Figure 3 using the conventional relational database model notation. This processes involved in the generation of the logical schema is referred to as logical data modeling.

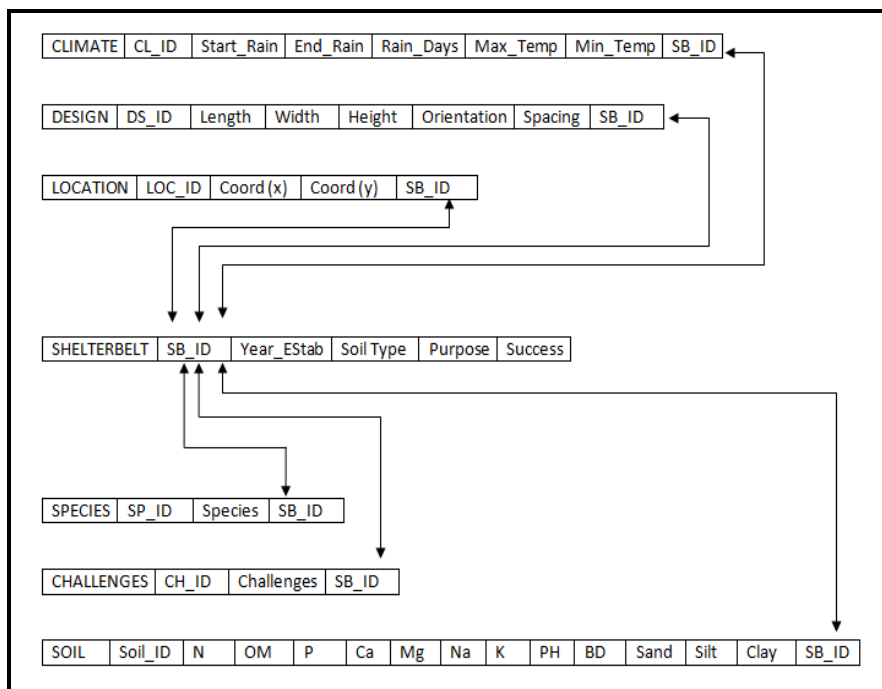


Figure 4: A Relational Logical Schema

Physical Database Design

The physical schema involves the detailed specification of the data structure of the database which includes computer and systems architecture, the physical location of data files as well as the specific allocation of storage space to data objects in respective data files. In the development of the physical schema for this study, the logical schema on Figure 4 was translated into a table form representing the physical database model.

Spatial database management system

Modelling user's View (User requirement)

The modeling of the user's view is to ensure a common understanding between the geodatabase designer and those that will be using the database. In order to achieve this goal, the designer must have a clear understanding of the functions to be carried out by the database to be developed. This is done through the identification of organizational functions, locating data sources and organizing data into logical groupings.

Questionnaires were used in collecting data on the user requirements for the database development from senior forestry staff stationed in the study area.

Entities and relationships

Entities are objects which can either be a person, place or concept about a phenomenon that is expected to be stored in the database. Entities are made up of attributes that are used to identify, classify, or describe reality. Relationships in this case are the associations existing between entities and cardinalities explain the type of relationship (for example, one to one, one to many, and many to many relationship). Figure 5 depicts the entity relational model as implemented in the database. The entity relational model helps to explain the connectivity existing between entities, hence making it easy to query the database.

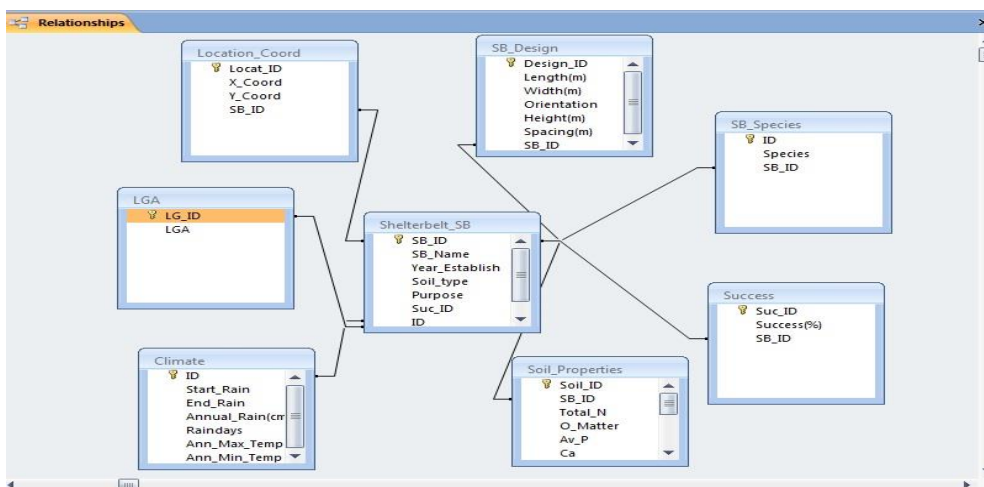


Figure 5: Entity Relational diagram as implemented in the Database

Geospatial Database Development

The purpose of developing this Geospatial Database Management Systems is to aid in decision making on the management and monitoring of shelterbelt projects in Yobe state. As discovered during the study, the organs shouldered with the responsibility of establishing and managing shelterbelt projects in the State have no proper record keeping system and this makes management and monitoring of the projects a difficult task. For this reason, a software called “TREE SHELTER BELTS” was developed with a friendly user interface that gives easy access to those with minimal knowledge of computer. The interface was developed using visual basic (Vb6) Programming language. Figure 6 shows the user interface from where other information relating to the shelterbelts could be accessed by clicking on buttons. The information pertaining the shelterbelts can be retrieved from the database in order to give information needed for the proper management and monitoring of the belts as per the user requirement gathered during field study. Some of the information that can be retrieved from the geodatabase are presented in Figure 7.

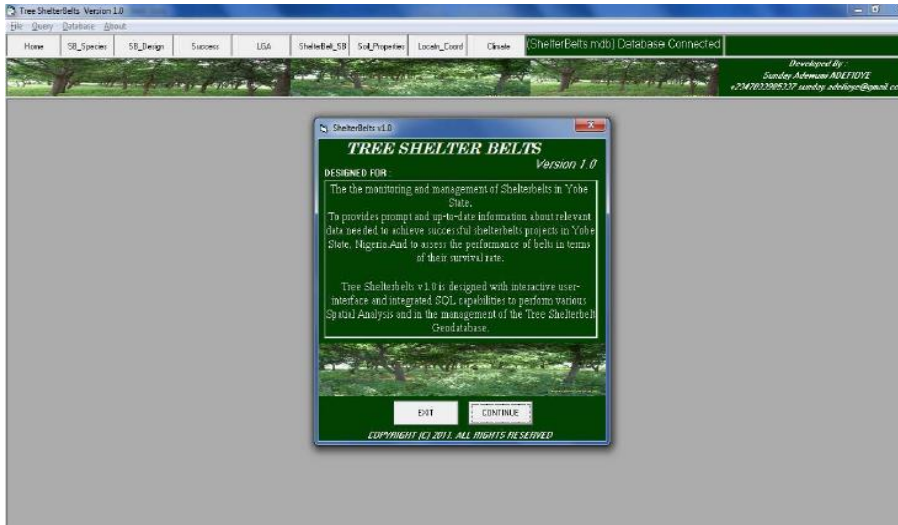


Figure 6: User interface of the Shelterbelt Database Management Systems (SDMS).

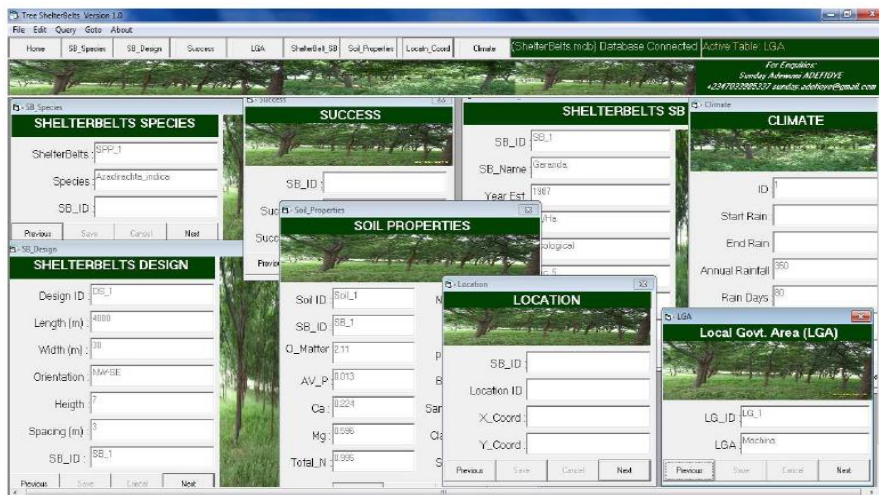


Figure 7: Some of the User required information retrieved from the Geospatial Database

For advanced users, apart from directly accessing required information, Structural Query Language (SQL) can be performed to retrieve customized information from the “Tree Shelterbelt” software developed. Example of the SQL panel is shown in Figure 8.

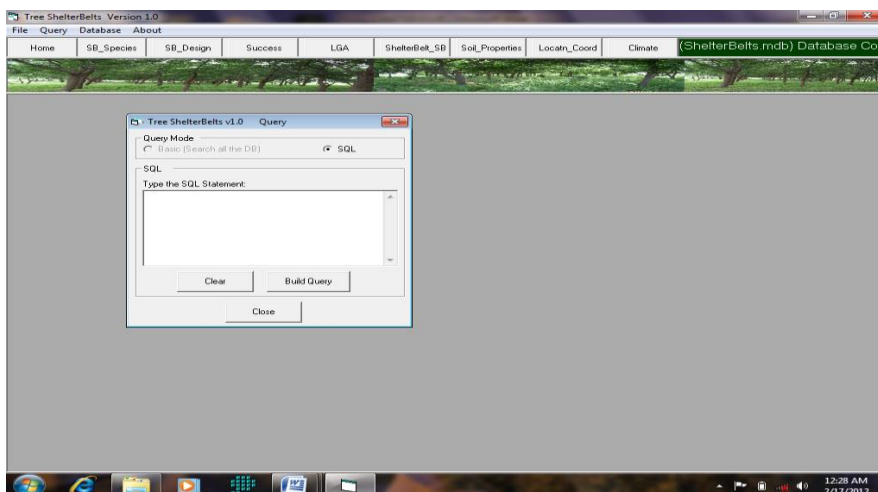


Figure 8: A Query panel of the SDMS

The database was designed to connect with Geographic Information Systems (GIS) software and web based spatial databases for retrieval of spatial information. For example, the map of the project site can be retrieved interactively for analysis and decision making. To do this, the maps of the belts which were created in shape files have to be converted to KML format. The conversion is necessary in order to have easy access to internet based spatial infrastructure like the Google Earth. Google Earth is internet based visualization software where high resolution satellite images of less than one meter (0.8 m) spatial resolution can be downloaded for analysis. The high resolution image found on the Google Earth interface makes it ideal for the study of shelterbelt in the study area than using medium resolution satellite images like Landsat. This is because the width of the belt is 30 m which is approximately the pixel size of Landsat images. Gaps in shelterbelt cannot be clearly identified using the medium resolution image. That is why the high resolution satellite images provided by the Google Earth are ideal for visualization of the shelterbelts. The ability of this database to link to other web enable spatial databases satisfies the requirements of it being a spatial database as reported by Yeung and Hall, 2007.

Conclusion

The monitoring of shelterbelts using geospatial analytical tools is imperative because of its problem solving capabilities. It also provides timely and up to date information needed for a successful silvicultural practice.

The development of a geospatial database management system has the potential of aiding storage, manipulation and retrieval of information for proper management and monitoring of shelterbelt projects. The software developed for the shelterbelts in this study is user-friendly and takes cognizance of the level of computer knowledge by the end users. It has the capability of retrieving information with the click of a button or by using the SQL environment for advance user. It can

equally be adopted for use by any afforestation projection in both humid and arid environments. The ability to update, modify and retrieve data makes the software a ready tool for decision making and planning of shelterbelts in any location.

References

- Aronoff, S., 1989. Geographic Information Systems: A Management Perspective. WDL publications, Ottawa, Canada
- Gadiga, B. L. (2012). The Functioning of Shelterbelts in Soil and Floristic Restoration in the Sudano-Sahelian Region of Yobe State. PhD. Thesis. Obafemi Awolowo University, Ile-Ife, Nigeria
- Kufoniya, O. (1998). Database design and creation. Principles and applications of geographic information system. Series in surveying and geoinformatics, Panaf Press, Lagos.
- Oruonye, E. D. (2009). Geographical aspects of Yobe State, Nigeria. Jos, Fab Education Books.
- Rolf A. de By (2004). Principles of Geographic Information Systems: An Introductory Textbook (ed). Enschede, The Netherlands: ITC
- Salem B. B., (1985). Management and renewal of Shelterbelt. In FAO (2005) Sand dune stabilization: Shelterbelts and Afforestation in dry zones. FAO conservation Guide 10.
- Ullman, J.D. and Widom, J. (1997). A First Course in Database Systems, Upper Saddle River, NJ: Prentice Hall.
- UNDP, (2009). Climate Change in African Drylands: Adaptive Livelihood Options. UNDP-UNEP-UNCCD papers (May, 2009) retrieved from www.undp.org/drylands
- UNEP. (2008). "Africa: Atlas of Our Changing Environment." Division of Early Warning and Assessment (DEWA) United Nations Environment Programme (UNEP) P.O. Box 30552, Nairobi 00100, Kenya
- UNESCO. (2000). Combating Desertification: Freshwater Resources and the Rehabilitation of Degraded Areas and Drylands. UNESCO-MAB Drylands Series No.1. <http://unesdoc.unesco.org/images/0012/001276/127651e.pdf> (Accessed on 4th September, 2009)
- Yeung, A. K. W. and G. B. Hall, (2007). Spatial Database Systems Design, Implementation and Project Management. Published by Springer, P.O. Box 17, 3300 AA Dordrecht, The Netherlands