A COLLABORATIVE SPATIAL DATABASE FOR THE INVENTORY OF TREES IN THE UNIVERSITY OF THE PHILIPPINES DILIMAN CAMPUS

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ABSTRACT

Urban trees are defined as individuals, groups, and stands of trees and remnant forests with amenity values found in urban areas or areas with human structures on site. These resources provide a wide variety of ecologic and economic uses. These assets need to be accounted for and protected, hence the need to monitor their status by inventory. Urban trees management would be greatly enhanced by setting up a spatial database system. Activities to be undertaken include spatial database design, data acquisition, database build-up, web GIS set-up and installation, and developing methods for collaboration. Through the use of modern technology i.e. mobile and web technology, we were able to come up with an initial database for tree inventory of UP Diliman. The utilization of open source platform facilitates easier and cheaper option for updating of the components of our prototype. Latest developments in mobile technology i.e. GPS technology, Android OS and Smart Measure app in the market enables us to propose a viable option for updating our tree database. Data integration from different field observations is facilitated through an initial spatial database model as proposed in this research.

1. INTRODUCTION

1.1 Rationale

Urban trees are defined as individuals, groups, and stands of trees and remnant forests with amenity values found in urban areas or areas with human structures on site. These include trees in urban woodlands, parks and streets (Evans, 2001). Urban street trees are important in providing shade, improving air quality, assisting with storm water runoff, raising property values, decreasing utility bills, and enhancing the look and feel of communities among others("OpenTreeMap", 2011). These assets need to be accounted for and protected, hence the need to monitor their status by inventory. Such an inventory may be used to determine critical areas that may need a community forestry program. It can also be used to educate residents about the benefits of a healthy, well-managed community forest, and to inform them about the species best suited to the community.

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Urban trees management would be greatly enhanced by setting up a spatial database system. According to Güting (1994), a spatial database system is a database that offers spatial data types in its data model and query language and supports spatial data types in its implementation. He adds further that spatial database systems offer the underlying database technology for geographic information systems and other applications. Spatial analyses and queries can be leveraged to answer questions about the condition and spatial distribution of trees. This can be used in turn for tree resources management and community planning. However, making an inventory of trees from scratch would be too expensive and time-consuming. Also, individuals, organizations and government agencies may already have existing partial datasets. To avoid duplication of data and to speed up database build-up, interested parties may be enjoined to contribute to populating the database using various tools available to them.

1.2 Related Studies

Urban and community trees management, implemented through the development of spatial databases and community-based Geographic Information System (GIS) applications, has been a subject of many researches and projects in different localities and states in other nations. The common goals of said studies include, among others, tree resources management, species conservation, and inputs to local planning. These also deal with other practical applications including the acquisition of derivative information such as environmental constants and economic values ("City of Allen GIS Tree Inventory", n.d.), promotion of green infrastructure in the urban setting(Namwamba, et. al, 2005), and in relation, fostering community welfare through cultivation of greens (Wood, 1999).

Data from tree inventories comprise the base information in developing the spatial databases. Tree locations and attributes are the primary contents of said databases. There are several techniques which can be used in mapping tree locations at varying accuracy. These include aerial photo interpretation, Global Positioning Systems (GPS), surveying, and use of existing maps. On the other hand, tree attributes such as species, diameter, tree conditions, and other characteristics can be collected using site visits and actual tree examination (Goodwin, 1996). More advanced method of tree locations and attributes identification incorporate remote sensing application particularly feature analysis and image classification (Cooke III & Lambert, 2002). In several studies, GIS is used to integrate and manage the gathered data and information, and facilitate further processing for use in various applications.

The value of a tree inventory spatial database can be described by the access privilege of end users and the ability to be integrated with other project components for various applications. Updating and maintenance of data shall be more likely facilitated with more access given to variety of users. Data sharing can also provide for the full utilization of database by different organizations and institutions. (USDA Forest Service, 2002)

Another approach to urban forestry or community tree inventories is the implementation of collaborative efforts to efficiently undertake data population, integration, sharing, and updating. Collaborative efforts entail an online facility which serves as the depository of data and information.   Due regard is given to data accuracy, consistency and currency among others.("Philly Tree Map", n.d.)

In the Philippines, the practice of urban forestry and community tree inventory and management is starting to grow. Based on the results of online searches, there are existing projects initiated by international organizations, government offices, and local government units

which deal with national, regional and urban forest inventories. Among these projects are the National Forest Inventory sponsored by the Food and Agricultural Organization, regional urban trees inventories facilitated by some Regional Offices of the Department of Environment and Natural Resources, and local urban trees inventories initiated by some local government units. An improvement to these would be the employment of appropriate tools and available technology, and implementing a collaborative engagement amongst officials, conservationists and enthusiasts.

The collaborative approach shall provide for the sharing of data, and economic and human resources among all organizations concerned. This shall also help fast track the development stages of spatial database systems and at the same time ensure that no efforts are duplicated. As a result, management and maintenance of urban forests would be more effective and efficient as it is bound by accurate and current inventory of trees. ("Philly Tree Map", n.d.)

1.3 Research Objectives

This paper reports on an attempt to build a spatial database and provide an easy-to-use publicly accessible website that would enable concerned individuals, organizations and government agencies to collaboratively contribute to an interactive and dynamic map of tree population in UP Diliman Campus. The output is a prototype web GIS application with the associated tree inventory database developed using existing open source software. Eventually, this can be accessed by the members of the academe, concerned offices and organizations, and other enthusiasts. The application can be used generally for tree resource management, species conservation and local planning within the UP Diliman Campus. Other applications can be developed by users for their specific purposes.

This research shall address the concern on having several data silos from different organizations which may be poorly managed and outdated. It shall also demonstrate how sharing of data and resources, and use of available technologies can be employed for obtaining an accurate and up-to-date tree inventory to support urban trees maintenance and management.

1.4 Scope and Limitations

This urban tree spatial database and web-GIS application prototype is based on available open-source technology. This shall serve as a foundation of an anticipated full-scale collaborative engagement between the academe, organizations, institutions, and other enthusiasts concerned. Since collaboration entails formulation and finalization of formal agreements between parties, this paper shall only set the tone and give recommendations for such arrangements to be possible and be actually implemented.

2. STUDY AREA

The University of the Philippines Diliman campus is the flagship campus, seat of administration and the fourth oldest constituent unit of the University of the Philippines system. It is also home to the U.P. Arboretum which has been dubbed as the last stand of man-made forest in the metropolis. The entire campus covers an area of 493 hectares according to the approved U.P. Land Use Plan (1994). Figure 1 shows the boundaries and area covered by the campus.
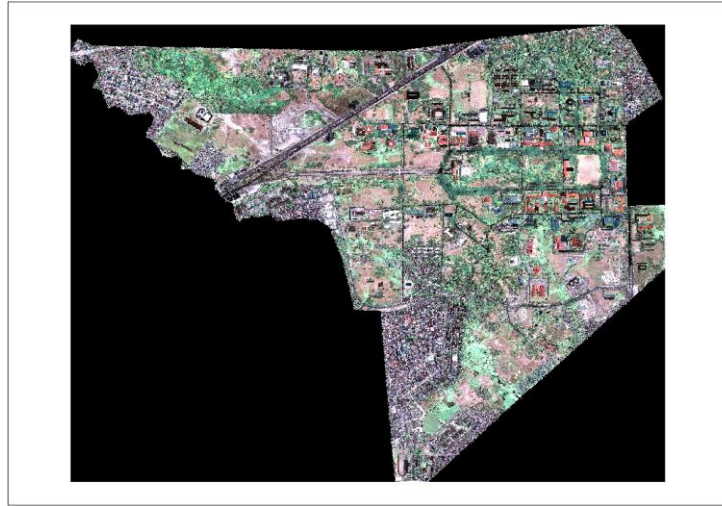
Figure 1 - UP Diliman Campus.

Two hundred and twenty species of trees can be found on campus. Of these, 121 are exotic; 83 are indigenous while 16 are endemic. (Sotalbo, 2001) A tree inventory conducted in 1982 by the then Campus Landscaping Office and Arboretum recorded a total of 64,469 plants. The locations of these trees were also indicated on a map. Unfortunately, the records of this inventory were destroyed by a fire that gutted the former Campus Planning, Development and Maintenance Office in 1996.

The trees in UP campus provide wide array of benefits to the community, from cleaning the air and reinforcing the soil, to providing shade and enhancing the aesthetic value of the area. Many groups, both from inside and outside the university, have shown interest in the diversity of trees species in the campus. Efforts on keeping an inventory of the trees have long been undertaken. Conservationists likewise visit the campus to conduct native tree species identification.

Over the years, UP has lost many of its trees from natural calamities and human activities. In the case of UP Arboretum, informal settlers have invaded the area causing damage to the protected area. Developments in the campus also contributed to this loss.

More than keeping a list of trees and its characteristics, the greater need is to ensure that these trees remain protected, and that more trees are planted wherever necessary. The concern now is how the efforts on inventory and up keeping of trees can be aligned to serve more than one purpose.

With a spatial database and web GIS application, management of trees species in the campus can be better facilitated as it shall be based on accurate and up-to-date data and information. This application shall make use of the data, resources and technology, available from collaborating organizations. Likewise, with this in place, duplication of efforts can be avoided and data silos can be addressed.

3. MATERIALS AND METHODS

3.1 Materials

Relevant spatial datasets on urban trees from different sources, open-source geodatabase and web GIS software, other data acquisition tools, and appropriate hardware were utilized to come up with the prototype.

The spatial datasets include a tree inventory prepared by a group of UP graduate students on 2006 for their research "Tree Species Identification using Quickbird Satellite Image". Google Earth © imagery are also used as reference. For additional data input, mobile phones powered by Android ™ operating system (OS), are used to obtain tree locations and other attributes. This is made possible by the built-in Global Positioning System (GPS) and compass, and downloaded Smart Measure application.

Open-source geodatabase and web GIS software are used to integrate the available data and information, and develop a platform for a collaborative engagement on urban tree inventory and management. On the desktop side, the Quantum GIS software package was used to convert prepare the data for the datasets for database loading. GeoServer, PostGIS and GeoExplorer software packages were utilized for the server setup. These software shall be used in creating a prototype facility that will provide for interactive and dynamic mapping of urban trees, and in the future, a tool for collaborative spatial database development.

3.2. Methodology

Figure 2 shows the components and stages of implementation of the study. Activities to be undertaken include spatial database design, data acquisition, database build-up, web GIS set-up and installation, and developing methods for collaboration. Each activity has corresponding outputs which will be integrated to achieve the objectives of the study.
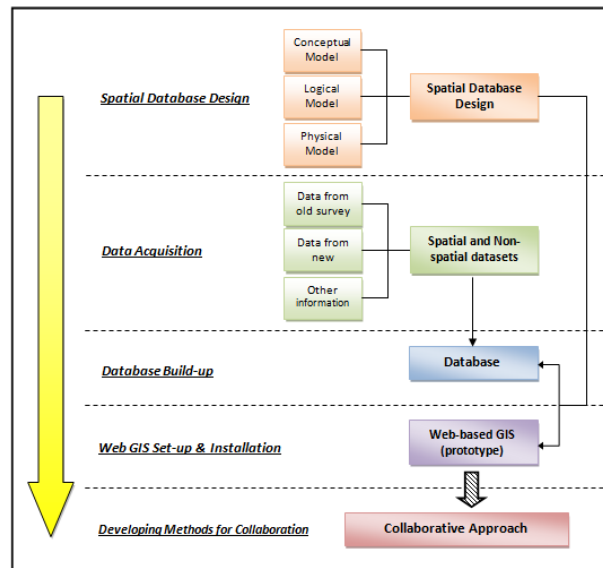

Figure 2 - Study Components and Stages of Implementation.

3.2.1 Spatial Database Design

A conceptual model is designed based on the objectives of the study. The entities and attributes are defined and the entity-relationship diagram is drawn. From this, the logical model or the schema is created. The entities and attributes identified are taken into consideration during data acquisition. For the physical model, the programs and platforms to be used in developing the database and setting up the web GIS are identified.

The spatial database design shall be applied during the database build-up and web GIS set-up and installation.

3.2.2 Data Acquisition

For this research, two sets of tree inventory data are used as the base information. The first set is acquired from archive data of past research. Said data were gathered using traditional survey methods. The local coordinates were then converted to global coordinates (WGS84) using QGIS' coordinate conversion tools. Field validation is undertaken to ensure accuracy and appropriateness of data.

The second set is acquired recently using available mobile phone technology applications particularly the Smart Measure application running in Android OS. Actual field observations were undertaken using mobile phones as data gathering tool. Coordinate conversion was not necessary as the as the Android app already uses global coordinates. The procedures implemented are discussed in the appendix.

Other information and related literature are also used as reference for better understanding of the subject and obtaining ideas for the collaborative aspect being proposed.

3.2.3 Database Build-up

The datasets acquired and verified are integrated into the PostGIS structure. Data from the 2006 survey are transformed accordingly and entered directly to the database. Data from the recent field survey are likewise processed and uploaded to the database. In the future, tree data shall be added to the database by file input or through GeoExplorer's web interface.

3.2.4 Web GIS set-up and installation

Figure 3 the three-tier deployment system architecture which is adopted for the Web GIS set-up. (Eckerson, 1995)
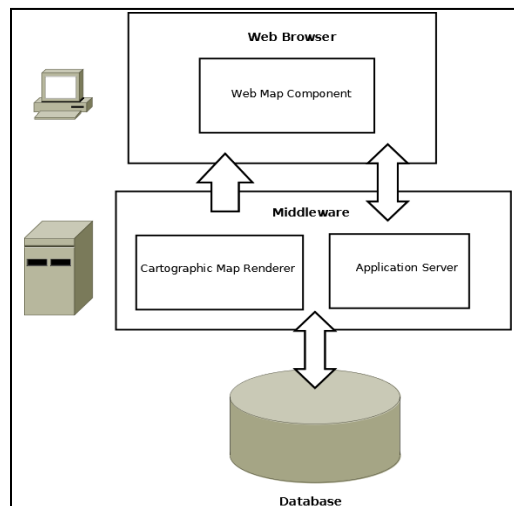

Figure 3 –Three-tier web deployment architecture. (Eckerson, 1995)

The system shall have a web map component, a middleware and a spatial database. The web map component allows access to the data with just a web browser. The middleware reads data from the database and applies styling rules and outputs map images. This provides also the programming framework for custom applications. The spatial database provides random access to large data sets, query processing that understands spatial relationships, and transactional integrity during concurrent editing.

Open-source programs which correspond to each component in the system architecture are utilized. The web map component used is the GeoExplorer, a spatial data viewer. The middleware is the GeoServer, an application server. Lastly the spatial database used is the PostGIS. The use of these programs foregoes high development costs and reinvention of readily available resources.

3.2.5 Developing Methods for Collaboration

The methods and proposed arrangements for collaborationare drafted based on the findings from the different stages of implementation, and other related programs and engagements. This incorporates options and preferences for input of additional data and information, and data accuracy among others. It also defines the provisions for data warehousing, sharing and updating. The output would be recommendations for executing a sound collaborative approach in developing further the urban trees spatial database.

4. DISCUSSION

4.1 Spatial Database Design

The spatial database design is done in three stages. First is the conceptual modelling. The entities, relationships and enterprise rules are identified. The entity-relationship (ER) diagram is created accordingly.

The entities identified are as follows:

1. Tree - this entity refers to a specific tree in the inventory. This is represented by a point in the spatial database
2. Species - this entity refers to a species of tree in the inventory. This would normally be an attribute of tree but is given its separate table for more flexibility and so that other species-specific information like family name and common name and distribution can be added.
3. Visit- this refers to a data collection field work. This provides information on the schedule of tree visits.
4. Tree-Visit- This is the intersection of the entities tree and visit. Tree attributes such as height, diameter and other time bound values are incorporated in this relationship.

The ER diagram showing the relationships and cardinality of each entity is shown in Figure 4.
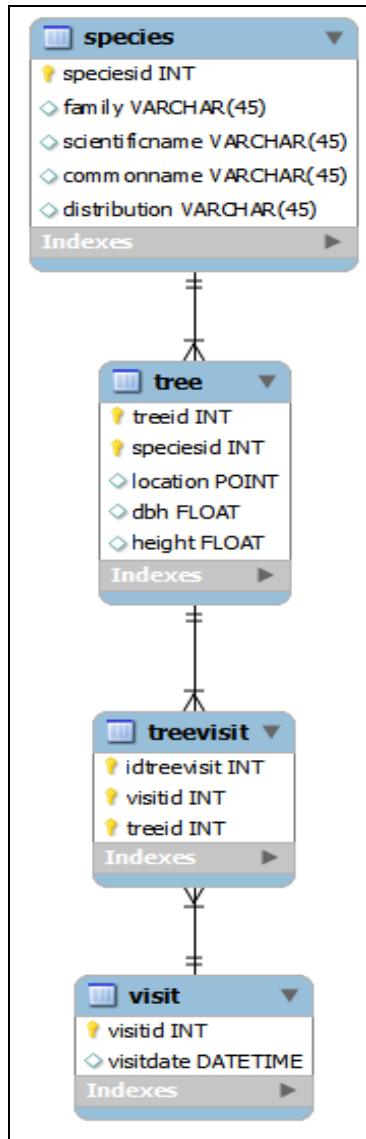
Figure 4. ER Diagram

A tree belongs to one and only one species. A visit can be scheduled regularly for monitoring of trees. For each visit, attributes of a tree shall be collected and stored in the database.

The second stage of spatial database design is the logical modelling. In this stage the schema or skeleton table for each entity and relationships and corresponding data dictionary are defined. The results of logical modelling are shown in the following tables.

Tree Table:

Attributes and Data Type	Description
Tree-ID (Integer)	Unique key identifier for entity 'Tree'
Geometry Column (object)	Indicates the geometry type for the entity 'Tree'
Species-ID (Integer)	Unique key identifier for entity 'Species'
DBH (Double)	Diameter at breast height
Height (Double)	Refers to the height of the entity 'Tree'

Species Table:

Attributes and Data Type	Description
Species-ID (Integer)	Unique key identifier for entity 'Species'
Family (String)	Specifies the family the 'Species' belongs to
Scientific Name (String)	Scientific name of each 'Species'
Common Name (String)	Common name of each 'Species'
Distribution	Indicates whether the 'Species' is endemic, indigenous or exotic

Visit Table:

Attributes and Data Type	Description
Visit-ID (Integer)	Unique key identifier for entity 'Visits'
VisitDate (Integer)	Specifies the date and time of visit (yyyymmddtttt)

Tree-Visit Relationship Table:

Attributes	Description
Tree Visit ID	Unique key identifier for the combination of 'Tree' and 'Visit'
Tree-ID (Integer)	Unique key identifier for entity 'Tree'
Visit-ID (Integer)	Unique key identifier for entity 'Visit'

The last stage of spatial database design is the physical modelling. The appropriate physical databases, applications and other programs to implement the spatial database design are identified. For this study, open-source programs are used. These are the PostGIS, GeoServer and GeoExplorer. Functionalities of said programs can cater to the requirements of the prototype spatial database and web GIS application.

4.2 Data Acquisition

Spatial datasets acquired are comprised of archived data from past research and new set of data from recent survey.

The tree data in the archived dataset is acquired using conventional survey where total station is used to get side shots and record location of trees. The locations of trees are stored in local coordinate system. These are converted and projected to WGS '84 to be consistent with the recently acquired data. Tree attributes are also included in the database of the previous survey.

The new set of data is acquired using Android-powered mobile phone with installed SmartMeasure application, and built-in compass and GPS. The SmartMeasure application is calibrated first prior to actual field testing. Observations are tabulated and appropriate coordinate conversions and accuracy assessment are performed. The resulting data are plotted in Google Fusion Tables for visualization. Full discussion of the methodology on using the mobile technology application and processing of results can be found in the appendix.

The developed methodology can be easily executed by ordinary users with a minimum requirement of Android device and internet. There is a good fit on the relative location of observed trees, however, the accuracy can still be improved with the use of a GPS with a higher specified accuracy i.e. at least mapping grade GPS.

The associated attributes for the new set of trees observed are identified by a forester.

The two sets of data acquired comprise the initial datasets to be integrated to the prototype spatial database and web-GIS application.

It should be noted that other modes of data acquisition can also be utilized to further populate the spatial database. These include among others, use of existing street maps and available satellite image, ground identification and measurement using tape measures, compass, total stations, GPS and other instruments, and other sophisticated methods such as aerial photo interpretation and remote sensing. These modes are not presented in detail in this research but can still be considered valid once data integrity is confirmed.

4.3 Database Build-up

The data points from the two initial datasets were loaded to ArcMap using the import XY tool. The plotted points where then exported to the shape file format. The shape file was then loaded to the PostGIS database using the PGAdmin utilities shp2pgsl tool. This converts the shape files spatial and non spatial data to tables in the PostGIS database. Figures 5 and 6 show the interface of the database created.
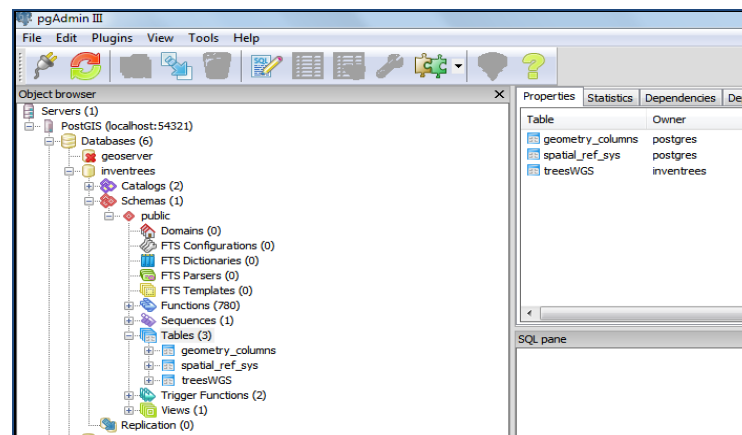

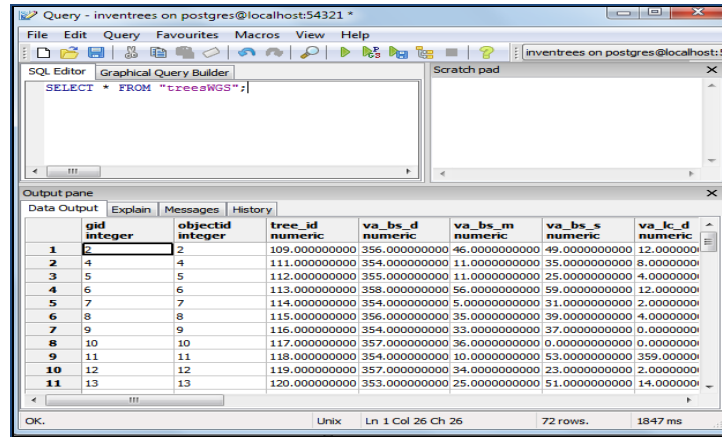**Figure 5** – Admin Interface.

Figure 6 – Query Interface

The created database supports data query as shown in Figure 6. Data query is used to retrieve data and information from the database depending on the user's objective or purpose. Sample data queries include selection based on species, tree conditions, and locations. Results of data queries can be used in planning and monitoring activities.

At the time of writing, query capability is limited to the database structure. Integration to the web GIS interface shall be facilitated in the future

4.4 Web GIS

The GeoExplorer client was customized to load the trees layer at start up. It was also set to focus on the extents of the Academic Oval as that was the area where the sample trees are located.

User access control was implemented in Geoserver. This allows the system to categorize users based on roles and permissions.

Types of users

The prototype web GIS was designed to accommodate three types of users as shown in Figure 7. They are, in the order of increasing privilege:

1. Anonymous
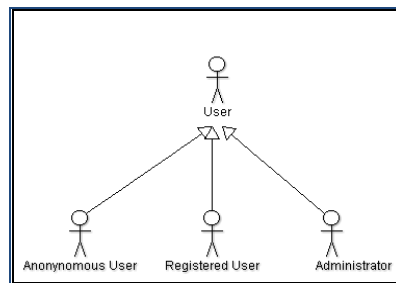2. Registered / collaborator
3. Admin

Figure 7 – Types of Users.

   The anonymous users have no editing privileges. They can only view the page and browse around. Registered user/ collaborators are more trusted users and hence, have more privileges. They can add as well as edit trees. The administrators are special privileged collaborators that can manage other users in addition to their tree editing privileges. The use case diagram in Figure 8 summarizes the privileges of the different user types.
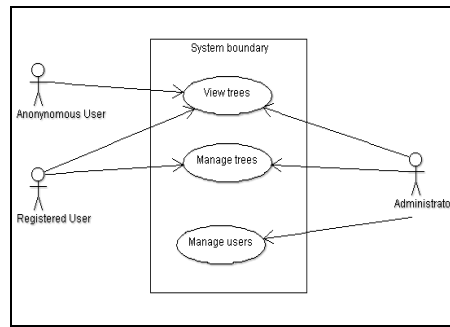

Figure 8 – Use Case Diagrams

   Collaborators and administrators need to login (see Fig 9) so that the system can authenticate them and grant them their extra privileges. Once authenticated, the user can then access the editing tools (Fig 10). Anonymous users don't have access to such tools and can only view the data (Fig 11).
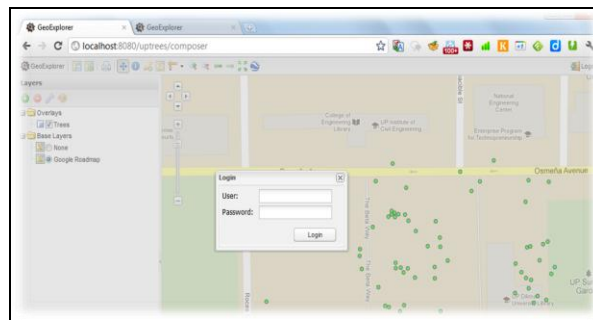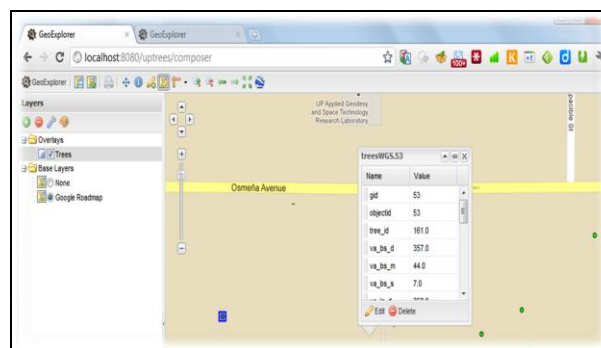

Figure 9 – User login screen

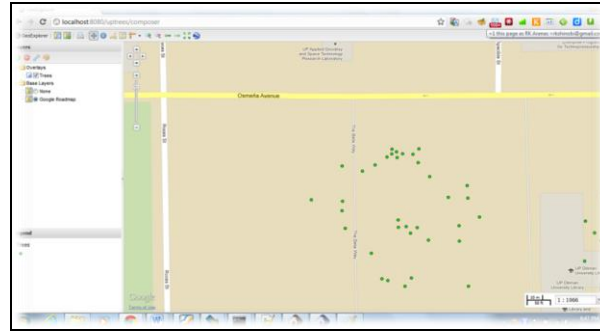**Figure 10** – Sample editing session

Figure 11 – General user view

4.5 Collaborative Aspect

This section discusses the factors to be considered and recommendations for successful full-scale implementation of a collaborative urban tree spatial database and web GIS application.

4.5.1 Institutional Arrangements

Initiatives for implementing this kind of engagement should include coordination with interested parties and individuals, forging agreements and laying out concrete goals and objectives. Expectations, requirements and contributions of each entity should be taken into consideration. Local communities should be encouraged to take part in this engagement. Responsibilities of respective organizations in all aspect of the undertaking must be clearly defined. This way, benefits to the respective organizations and the community would be completely realized.

4.5.2 Data

Data acquisition and management are among the major concerns in this undertaking. One of the objectives of this collaborative engagement is to have an accurate and up-to-date spatial database of tree making use of available data and resources of participating organizations and individuals. Available spatial datasets from each unit must be collected, normalized and validated. All these should be integrated to a spatial database and web GIS for easy access. Additional tree data can be submitted through the Tree Web GIS facility developed.

Data integrity must be ensured at all times. To do this, validation of every point submitted must be undertaken prior to acceptance and inclusion to the database. Considering the several methods of tree data collection, categorization should be done according to methods used and consequently data accuracy. To provide opportunity to those who want to participate, the facility should be accessible to the public with some restrictions.

The concerns on data warehousing, custody and management should be addressed through written policies and guidelines agreed upon by member institutions.

4.5.3 Technology

As much as possible open source technologies should be utilized to limit the cost of development and avoid technology bias. It should be noted that as the size of the database increases, the requirements and specifications will also increase. This should be considered during the planning and implementation stages.

5. CONCLUSION

Through the use of modern technology i.e. mobile and web technology, we were able to come up with an initial database and a web IS front-end for a web-enabled collaborative tree inventory of use in UP Diliman. By utilizing free and open source software, we were able to easily build the prototype from existing components at zero monetary cost.

Moreover, latest developments in mobile technology i.e. GPS technology, Android OS and Smart Measure app in the market enables us to propose a viable option for updating our tree database. Data integration from different field observations is facilitated by the initial spatial database model as proposed in this research.

6. REFERENCES

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