WORCESTER POLYTECHNIC INSTITUTE

Urban Tree Mapping

An Interdisciplinary Qualifying Project Report: Submitted to the Faculty Advisors:

Robert Krueger

Renata Konrad

In partial fulfillment of the
Degree of Bachelor of Science & Bachelor of Arts

by:

Anna Costello
ascostello@wpi.edu

Brandon Grace
brandong@wpi.edu

William Seibold
wdseibold@wpi.edu

Matthew Wzorek
mwzorek@wpi.com

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Abstract

The Asian longhorned beetle eradication program required a replicable and systematic approach to collecting data and managing Worcester's urban forest. We developed software linkages to allow multiple organizations to collaborate and record each replanted tree in a centralized database. To prove the feasibility of our approach, we collected data for approximately 525 trees and populated a flexible web-based database application that we designed. Organizations with unique data requirements can synthesize tree records and establish a single tree inventory.

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Introduction

The Asian longhorned beetle is an invasive pest that arrived in the United States from Asia concealed in solid wood packing material (APHIS Factsheet, 2008). Introduced to the United States in 1996, the Asian longhorned beetle has shown its destructive force by infesting and destroying many urban forests across the nation, including New York, New Jersey, and Illinois. In each of these previous infestations the beetle was contained and caused no further damage to outlying forest because of natural barriers and the rapid response of officials to implement eradication programs. The first step of these eradication programs includes the inspection of any potentially infested trees. ALB-positive and immediately surrounding trees were removed, chipped, and burned in order to control the spread.

On August 1, 2008, an Asian longhorned beetle infestation was discovered in Worcester, Massachusetts. It is believed to have been introduced 10-15 years prior to the first sighting. The eradication effort that followed the discovery included a quarantine in the city of Worcester and the towns of West Boylston, Boylston, Holden, and Shrewsbury (Santos, 2009). The outbreak of the ALB in Worcester, Massachusetts posed an increased threat relative to other outbreaks due to its geographic location. “The city sits at the southern edge of the great Northern hardwood forest, millions of contiguous acres stretching to Canada and the Great Lakes” (Aslop, 2009). If the ALB ever spread beyond Worcester, millions of acres of trees could potentially be infested across the nation.

Approximately 25,000 trees were removed, with the greatest concentration of removal occurring in the Burncoat and Greendale areas. These neighborhoods are located near the Saint-Gobain factory, which is believed to be the epicenter of the infestation. The residents of these neighborhoods witnessed the loss of ecological services to the individual household and the community after the ALB-infected trees were removed. These services affect energy savings, wind breaks, soil containment, storm water runoff, noise reduction, and the habitat for many species of wildlife. In addition, urban trees contribute to the overall appeal of a neighborhood through aesthetically pleasing environments.

In these now tree-barren neighborhoods, residents have begun to realize the extent of the benefits that their trees had provided. To try to reclaim these benefits, three organizations have become involved in the replanting effort and management effort. The Department of

Conservation and Recreation, the Worcester Tree Initiative and the City of Worcester have attempted to reclaim these lost benefits by planting trees through various channels.

Our goal was to assist these organizations by developing and initiating a sustainable process for collecting, mapping, and sharing data for each replanted tree. We created protocols for collecting data, field tested our methodology, and proved that our process is feasible and can be continued by others. We developed a set of tools that the organizations can use to manage their replanted trees. We used a GIS mapping program, ArcMap, to create a map of the locations of approximately 525 replanted trees in the Greendale and Burncoat areas. The collected data was also used to populate a Dabble DB application that we designed. Our project will aid the three organizations in managing Worcester's urban forest. This report describes the knowledge and information needed to complete this process.

Background Information

According to "Assessing Ecosystem Service Values Provided by Urban Trees"(Sima et al., 2010), more than $600,000 in monetary value will be lost each year due to the removal of approximately 8,600 trees from the Greendale and Burncoat areas. Replanting programs have been created to attempt to reclaim the economic value provided by urban trees. It is not well-known that there are three organizations involved in reaching this goal. The purpose of our project was to develop the capacity for these organizations to be able to achieve their task through the use of various software programs and management tools.

Previous Replanting Efforts

The Asian longhorned beetle (ALB) has sparked a major tree removal and replanting effort to restore the urban tree cover to the city, but this is not the first replanting effort in Worcester's history. Two major replanting efforts were conducted after the hurricane of 1938 and the tornado of 1953. In September of 1938, a Category 5 hurricane made its way towards New England. This hurricane downgraded to a Category 3 when it made landfall, but was still responsible for widespread damage to the environment. In June of 1953, an F4-F5 tornado tore across Central Massachusetts and Worcester, devastating everything in its path, including a large portion of the city's tree population. To help restore the urban tree cover as quickly as possible, foresters decided to plant many hardwoods. The tree of choice was the Norway Maple because they grow relatively quickly and are known for their toughness in urban environments (Shakespere, 2003). This was a good idea at the time, but now the tree itself is considered an invasive species as well as the main food source for the Asian longhorned beetle. The lack of biodiversity of tree species in Worcester posed a huge threat with the introduction of the ALB. The current replanting organizations have considered the long-term effects of the infestation and made recommendations to plant a variety of trees that are resistant to the Asian longhorned beetle.

Asian Longhorned Beetle

The Asian longhorned beetle is a particularly large beetle ranging from 0.75 to 1.25 inches long. The main portion of the body is black and glossy with white spots. The long antennae are also black and have horizontal white stripes. Typically, the adult beetles are seen from late spring to fall, depending on the climate. Larvae survive the winter by living inside host trees, which are typically hardwoods. The female ALB will chew into the bark of the host tree and lay 35-90 eggs. The larvae will then feed on the innards of the tree during the fall and winter months, cutting into the tree’s vascular system (Plant Protection and Quarantine, 2007). During the spring months, the ALB emerges through exit holes, which allow foresters to positively identify infested trees (Introduced Species summay project, 2004).

The naturally slow-spreading ALB has the potential to infest a large area due to human transportation. With the ALB larva living inside trees during the winter months, humans can easily transport the beetle unknowingly in firewood. In addition to human involvement, the ALB can fly up to distances of 400 yards. Because the ALB spreads quietly, it can cause significant damage before it is detected. Consequently, the damage and costs associated with infestations are very high, “Damage from infestations in Illinois, New Jersey, and New York has resulted in the removal of more than 30,000 trees and costs to State and Federal governments in excess of $269 million since the discovery of the infestations in 1996” (APHIS Factsheet, 2008). If the infestation spreads nationwide, it is estimated that it will cause $41 billion in losses in the lumber, maple syrup, nursery, and tourism industries.

Asian Longhorned Beetle Infestation in Worcester

In August of 2008, the State of Massachusetts and the Animal and Plant Health Inspection Service (APHIS) enacted a quarantine on certain portions of Worcester in response to an ALB sighting. Soon after the ALB sighting, a business notice from APHIS, DCR, and the City of Worcester explained that “Residents and businesses are prohibited from moving or transferring ALB regulated materials (including firewood […], live beetles, and wood, logs, stumps, roots, branches, leaves, and green lumber from ALB host trees) from the regulated area” (Markham, Sullivan, & O'Brien, 2008). The quarantined area has changed multiple times to include areas with newly discovered infestations. As of September 24, 2009, it covers 74 square miles, including the City of Worcester, the town of West Boylston, and portions of the towns of Boylston, Holden, and Shrewsbury.

In order to stop the ALB spread in Worcester, APHIS and the State of Massachusetts’ DCR created an eradication program to remove thousands of trees from high-risk areas. “The preferred eradication method for Massachusetts includes survey to discover infested trees, the removal of infested trees, and chemical treatment of host trees within a ½ mile.” (Massachusetts

Asian Longhorned Beetle Cooperative Eradication Program: Massachusetts Environmental Assessment) Since Oct. 1, 2008, the Massachusetts ALB eradication program has surveyed more than 212,000 trees (USDA Animal and Plant Health Inspection Service, 2009). Field workers sent to visually inspect the trees began in the Greendale neighborhood and spread outward to gauge the spread. Peter Nystedt, a resident of the Greendale area, explained in an e-mail the inspection process he observed.

> "Trees on our own street were inspected multiple times by crews of no less than three people each and findings were entered on preprinted forms that the crews carried around on clipboards … Smoke jumpers were brought in to climb and assess the canopies of every susceptible tree in the infested area. …I observed the climbing of trees by smoke jumpers to inspect the canopies of trees, the only true way to assess a tree for infestation. All susceptible trees had to be climbed by smokejumpers to do this assessment. Trees were marked by the smokejumpers with various colored spray paint. Placards were attached to some trees in an effort to alert and notify concerned individuals regarding tree infestation status" (Nystedt, 2010).

Since the removal process began in August 2008, over 25,000 trees have been removed from the Greendale and Burncoat neighborhoods (Sima et al., 2010). Image 1, and Image 2, below, provide an idea of how much damage the ALB caused in these neighborhoods.

Image 1. Granville Avenue before tree removal.

Image 2.Granville Avenue after tree removel in association with the ALB eradication program.

Benefits of Urban Forests

With the introduction of the Asian longhorned beetle and removal of thousands of trees from Worcester, Massachusetts, the benefits provided by these urban trees have been lost. The specific benefits of urban forests have been well-documented through computational analysis and studies of the community's residents. By recognizing the service values that trees provide, educated individuals and organizations can focus on rebuilding an optimized urban forest. These benefits will be discussed by topic.

Social Value

Urban forests contribute to the general well-being of people in a variety of ways. Trees create more desirable environments while reducing crime and stress levels (Dwyer, 1992). The provided shade has been linked to reduced cancer risk due to less UV radiation. Urban trees have also been shown to reduce noise and promote community involvement (Dwyer, 1992).

Environmental Value

Urban forests provide habitats for wildlife (Dwyer, 1992) and lead to improved biodiversity. "Urban forest structure, defined by the size, species composition, and location of urban trees, is typically expressed as a percentage of tree canopy cover over a city, and is an indicator of the contributions of the urban forest" (Dwyer, 1999). Quantifiable effects on communities include: lower local air temperatures (McPherson, 2003), reduced air pollution (Hilton, 2008), carbon storage (Hilton, 2008), stormwater reduction (Hilton, 2008), and improved water quality(Hilton, 2008). The loss of urban trees can have a devastating effect on communities because trees provide environmental services at a much cheaper rate than the alternative.

Economic Value

Urban forests provide many services that contribute to cost savings for individuals and communities. Oftentimes, the extent of these services is not fully realized until the trees are removed. For example, the removal of trees from neighborhoods leads to decreased shade coverage for buildings. Consequently, cooling costs in the summer will increase for the individual and might force him or her to purchase blinds. The services provided by forests are necessary for the community, but even a small quantity of trees can be advantageous for individual tree stewards. Although there are many contributing factors to household energy usage, proper planning can maximize the benefits of tree canopy. For example, the direction and distance of trees relative to buildings strongly affects its energy usage for cooling needs. Trees planted within 12.2m of the east and west sides of buildings can directly lead to energy savings through additional shade. "Changes in energy use from existing shade ranged from -21 to -24% for cooling" (Simpson, 2002). Other economic impacts include increased real estate values and local economic development (Dwyer, 1992).

To illustrate the economic value lost from these removed trees, Table 1 and Figure 1 show the number of trees removed per species. At the bottom of Table 1, the grand total presents the total number of trees removed in the Greendale and Burncoat communities (Sima et al., 2010).

Table 1. Population summary of trees removed in the Greendale and Burncoat areas of Worcester, MA from December 2008 to April 2009.

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Population Summary of All Trees

2/17/2010

	DBH Class (in)									
Species	0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	>42	Total Standard Error
Broadleaf Deciduous Large (BDL)										
Norway maple	689	827	700	383	288	135	47	16	5	3,090
White poplar	277	336	172	40	13	14	1	0	1	854
Elm	88	207	179	46	10	11	2	1	2	546
Ash	72	151	136	66	20	13	4	0	3	465
White ash	3	24	27	26	13	5	1	2	1	102
BDL OTHER	32	74	59	41	37	28	17	13	10	311
Total	**1,161**	**1,619**	**1,273**	**602**	**381**	**206**	**72**	**32**	**22**	**5,368 (±NaN)**
Broadleaf Deciduous Medium (BDM)										
Maple	470	778	447	164	107	44	18	5	4	2,037
Birch	116	284	125	19	10	4	0	1	0	559
Red maple	37	62	86	54	35	22	5	6	4	311
Black Maple	64	84	30	9	2	2	2	1	0	194
Gray birch	34	24	23	3	1	1	0	0	0	86
BDM OTHER	1	8	7	4	2	2	0	0	1	25
Total	**722**	**1,240**	**718**	**253**	**157**	**75**	**25**	**13**	**9**	**3,212 (±NaN)**
Broadleaf Deciduous Small (BDS)										
BDS OTHER	1	4	5	2	0	1	0	0	0	13
Total	**1**	**4**	**5**	**2**	**0**	**1**	**0**	**0**	**0**	**13 (±NaN)**
Grand Total	**1,884**	**2,863**	**1,996**	**857**	**538**	**282**	**97**	**45**	**31**	**8,593 (±0)**

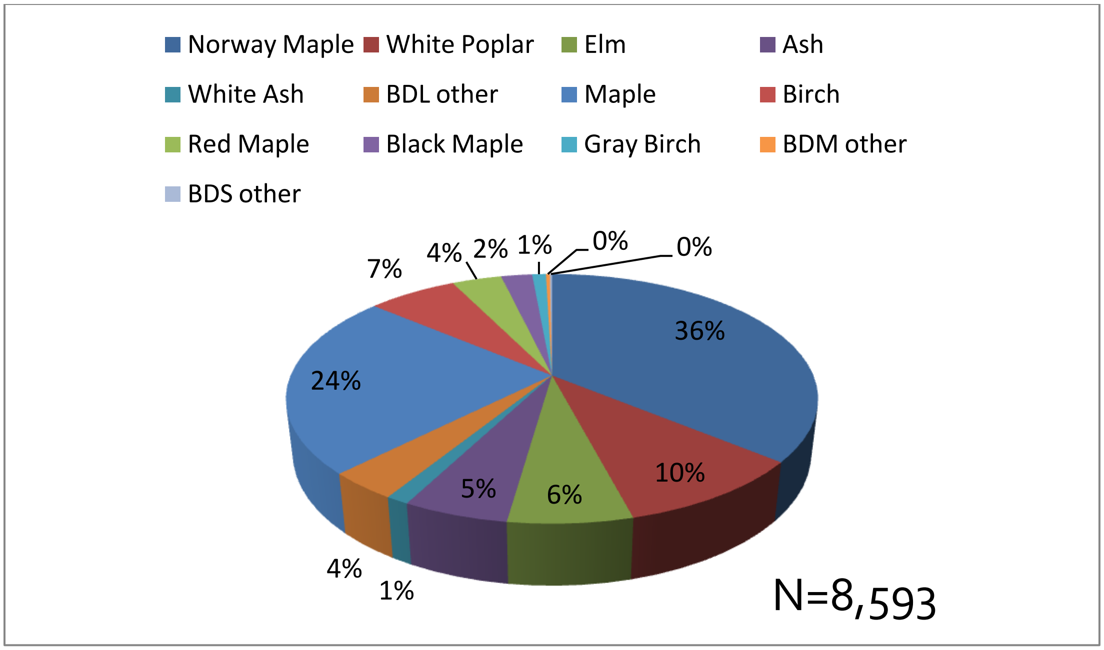

Figure 1. Removed Trees by Species in the Greendale and Burncoat areas of Worcester, MA from December 2008 to April 2009.

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Table 2 and Figure 2 show the monetary value of trees that were removed from Greendale and Burncoat. By removing 8,593 trees from these neighborhoods, the city loses $628,178 in service values that were once provided by these trees (Sima et al, 2010).

Table 2. Total annual benefits of all removed trees by species ($) in the Greendale and Burncoat areas of Worcester, MA from December 2008 to April 2009.

Worcester

Total Annual Benefits of All Trees By Species ($)

2/23/2010

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error	% of Total $
Norway maple	99,897	2,943	17,746	15,717	79,592	215,895	(±0)	34.4
Maple	49,974	1,364	8,589	7,317	40,373	107,617	(±0)	17.1
White poplar	30,703	529	4,214	3,132	40,679	79,257	(±0)	12.6
Birch	10,421	204	1,613	1,942	20,403	34,583	(±0)	5.5
Elm	15,447	371	2,611	2,717	27,913	49,059	(±0)	7.8
Ash	17,171	331	2,989	2,824	15,114	38,429	(±0)	6.1
Red maple	13,947	262	2,436	2,735	10,637	30,017	(±0)	4.8
Black Maple	3,411	67	548	652	7,041	11,719	(±0)	1.9
White ash	5,738	119	1,046	1,006	3,775	11,684	(±0)	1.9
Gray birch	1,492	29	233	273	3,144	5,172	(±0)	0.8
OTHER STREET TREI	19,912	455	3,496	4,029	16,856	44,747	(±0)	7.1
Citywide Total	268,114	6,673	45,521	42,343	265,527	628,178	(±0)	100.0

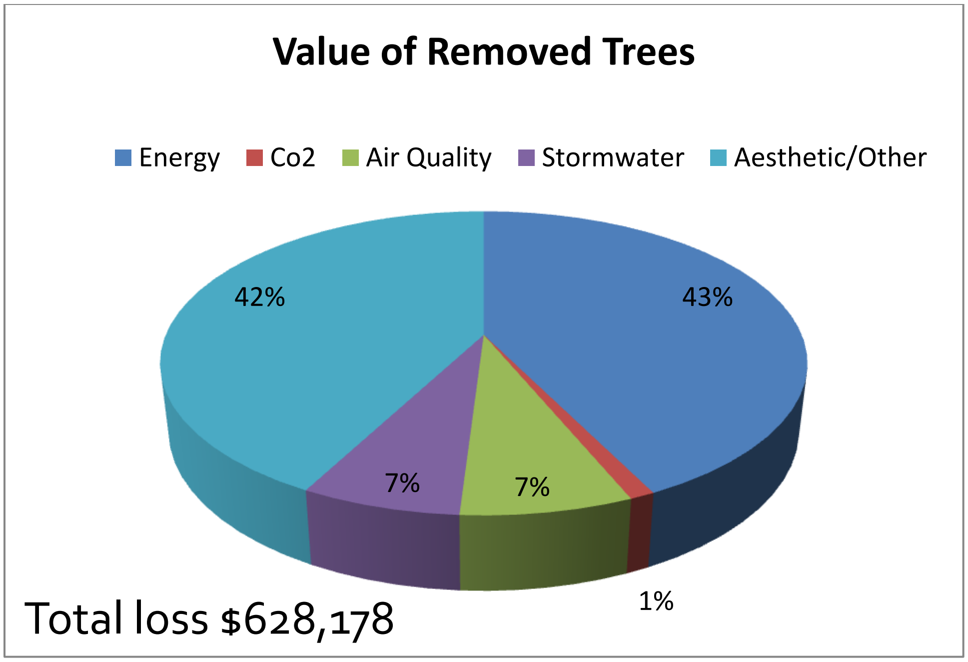


Figure 2. Value of removed trees in the Greendale and Burncoat areas of Worcester, MA from December 2008 to April 2009.

Urban Forest Management

New research is continuously available that supports the importance of urban forestry, but the difficulty rests with the planning process for urban development. GIS is an invaluable tool for applying efficient practices to a large-scale environment. "These spatial analyses and inventories provide current, comprehensive information vital to open-space decision-making and identify opportunities for a coordinated effort to guide urban development in a manner that will take advantage of all the social and ecological functions available from the urban forest" (Dwyer, 1999). With the assistance of GIS, urban planners can effectively and efficiently meet a variety of the public's needs while simultaneously promoting the preservation of urban forests.

In practice, managing the replanting of thousands of trees is complex. To further complicate the replanting process in Worcester, many organizations with differing agendas are involved in replanting the Worcester area. As policy makers come to terms with the extent of the changes brought upon the city by the Asian longhorned beetle, more monetary resources will be allocated to eradication programs in addition to replanting efforts. This creates a resource management problem as the programs grow over time. Our project attempted to alleviate this problem by providing management tools for three organizations.

Assisting the Organizations Involved in Resource Management

Worcester Tree Initiative

The Worcester Tree Initiative (WTI) is a private, non-profit, outreach group created in January of 2009 to help combat the damage caused by the ALB infestation. During the summer and fall months of their first year, the WTI held a number of tree workshops that taught community members about proper tree planting and care techniques. In their first year, the WTI gave away roughly 1300 trees to tree stewards. Participants were asked to fill out a contact sheet and tree species request form in exchange for a tree. A record for each tree, including information about the tree and the steward, was later put into an Excel database. In addition to community giveaway workshops, the WTI also held plantings at public schools, teaching students and faculty about tree care and its importance. An important part of the WTI's mission is to promote tree stewardship and to empower individuals in replanting their communities.

Department of Conservation and Recreation

Another organization helping with the replanting effort is the Massachusetts Department of Conservation and Recreation. The DCR received $4.5 million in stimulus money for the replanting efforts in Worcester. This is the fourth largest federal grant in recent funding from the American and Reinvestment Act (Fox, 2009). The DCR uses this money to replant trees on public land and on private properties.

City of Worcester Forestry Service

A third organization involved with the replanting efforts is the City of Worcester Forestry Service. The Forestry Service is primarily responsible for street tree management. Working with the USDA and the DCR, the City of Worcester Forestry Service has helped with the eradication of the Asian longhorned beetle.

Due to all the removed and replanted trees in Worcester, these three organizations needed a systematic way to organize and collect this data. To help them with this problem they needed us to create a central database that all of the organizations can access. With this database, the organizations will be able to collaborate and work together in an effort to replant Worcester's urban tree cover.

Management Tools

Tree Inventories

Developing a tree inventory was an important first step in our project. “A tree inventory is the gathering of accurate information on the health and diversity of the community forest” (Ricard). These inventories are used more and more by urban communities in order to plan for long term land use. Tree inventories can provide a great benefit to the communities and their local governments. These benefits can include the assessment of a tree management program, determination of the total value of a community’s resources, better work efficiency, and instilment of greater public interest and education.

Urban trees are more difficult and time-costly to evaluate than conventional forests because they provide more benefits (i.e., conventional forests provide mostly wood fiber, where urban trees provide a range of ecological services) (Wood J. P., 1999). Thus to evaluate the uses and benefits of trees, data must be collected at the “tree” scale. Street tree surveys, sample surveys, and computerized systems all contribute to the data needed for these analyses.

Street tree surveys require one to examine several different factors. The specific type of information will vary on the survey type, but generally, the majority of the information is consistent regardless of project specifics. This data is composed of: species, size, physical condition, damage or injury, management/maintenance needs, tree location, site characteristics, parking restrictions, and other information (Smiley & Baker, 1988). This data can be broken down into two types, Transitory and Permanent. Transitory information includes characteristics that can change, like “Pruning needs of a tree or a specific trees conditions” (Wood, 1999). Permanent information deals with the location of trees and the individual species. In our case, we are only collecting permanent data of tree location and species. We decided to only collect geospatial data and species information for the tree inventory, because it is more useful as an archive tool to the Worcester Tree Initiative.

Tree inventories can also provide a great resource to the public and their communities. Many people know little about the trees in their communities, but show some interest in learning about them (Wood, 1999). By having a general database illustrated on a map, the public can learn a great deal. “The data can show residents about the benefits, tree conditions, costs of urban trees, and the entire urban forest system” (Wood, 1999). Community members can use this graphical representation and information to understand why certain trees need to be removed, and become educated on the best species to plant (Long, Moxley, & Megalos, 2008). Citizens can be educated on why it is important to manage trees and the benefits that can be taken from tree inventories.

Geographic Information Systems

To accomplish our objective of creating a useful map for the WTI, we must conduct a detailed tree inventory to verify location and species of trees. With the data that is received from this inventory, we can implement it into the GIS and create detailed maps that can be used by our sponsors. The inventory can be used to plan for future replanting efforts and to maintain relationships with stewards.

Geographic Information Systems (GIS) use georeferenced (location based) data to visually represent the dataset, which allows users to better understand and solve problems. GIS can be defined as "A system for capturing, storing, checking, integrating, manipulating, analyzing, and displaying data which are spatially referenced to the earth" (Bateman, 2003). Data can be collected and integrated from multiple sources, which can increase the overall accuracy of the results. The GIS manipulates the data and displays a layered map that represents the aggregate of the collected data. Essentially, each tree on the map represents the specific physical location of each tree. Mapping the pattern of urban forests and land usage makes it feasible to explore opportunities for tree planting initiatives within an urban environment. In addition, the GIS can use the referenced data and mathematically "Performs various statistical analyses, produces maps, calculates benefits based on specific site conditions, and generates a summary report" (Hilton, 2008). The resulting output can quantitatively demonstrate the ecological benefits of trees in a given location, which is useful for informing the public of the importance of urban forests. Some software systems are capable of converting these benefits into cost dollar savings. This is a valuable tool because it provides a standardized quantity that can be compared to current or alternative solutions. GIS can be used by decision makers to gain a better perspective on a current situation through the use of a visual aid.

The Geographic Information System Process

GIS offers many advantages over paper maps, allowing users to find correlations between sets of data not usually seen concurrently. Separate layers of spatial data can be put onto a single map using GIS. Types of spatial data that are relevant to urban foresters can be roads, slope, soil quality, commercial or residential zoning, tree position, tree species, tree health, tree age, tree cover, zoological species composition, potential for protection status, wind speed, infrared heat readings, air pollution, stormwater runoff, population, economic status, and land-use(Nicholls, 2001) (Pauleit & Duhme, 2000) (Wood, 1999). This information can be used to draw far more conclusions than could be drawn from a paper map. From this information, urban foresters could decide where new trees should be planted, what areas should be protected, and what benefits are being gathered.

The process for entering data into a geodatabase requires a front-end input system that contains the data fields. Tablet PCs with specialized software are commonly used, allowing users to take the tablet to the tree sites. We used Geolink as the data input software on the tablets. Essentially, the user creates tables and associated attributes in this software and then populates the data in the field. At each tree site, some of the attributes must be manually entered (such as the street and house number), but the software automatically appends other attributes to each record. The GPS latitude and longitude coordinates are received via Bluetooth and, in addition to date and time, included for each record. The output from this front-end software is in the form of a geospatial data table, and it can be exported and viewed on a map or in database format.

GIS software is the natural evolution of the modern database, combining the functionality of a standard database management system (DBMS) with a platform to perform analysis and visually display data. Although the linear process is consistent for each application of GIS, the decision-making procedure must consider the needs of the organization. The following diagram (Figure 3) illustrates the applied approach for creating a GIS, and each step will be further discussed in detail.

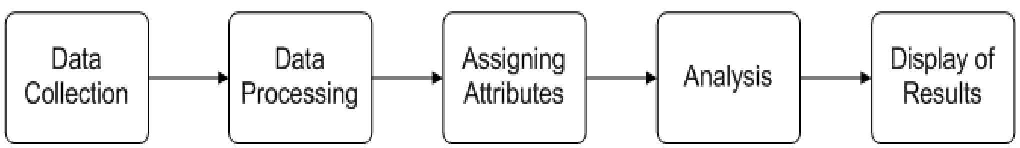


Figure 3. GIS procedure diagram.

It is important to note that each step in the process should be analyzed before the GIS can be implemented. The information requirements of the users must be determined, "The database design process must be completed before any data can be placed into the database and before the DBMS can function as expected to support an organization's or agency's applications" (Montgomery, 1993). Spatial data can be collected from multiple sources, including sketch maps and GPS readings. Data processing involves removing the uncertainty of handheld GPS units, which is approximately 5 meters. Each data point can be visually corrected at the tree site as data is collected. Alternatively, tree locations can be corrected by overlaying the coordinates on a visual map of the area and identifying misplaced trees. (For example, a tree that appears to be in the middle of a street would be relocated to a nearby sidewalk, if appropriate.) Attributes are assigned to each tree record as needed for the users' analysis requirements. The GIS analysis of the data can be qualitative or quantitative. According to Peggy Middaugh of the Worcester Tree Initiative, one of the greatest replanting challenges is the identification of planting locations (Middaugh, 2009). A visual representation of candidate planting sites would be invaluable because of the organizations' limited resources. GIS displays the results in a format that organizations can more easily use; a map is substantially more useful to our sponsors than a tree database on its own.

GIS software can be applied with various levels of complexity. The Worcester Tree Initiative can use basic GIS software to map the locations of its stewards' trees. Data from multiple data collection sessions can be combined to illustrate the distribution of trees and aid the WTI in tracking the health and location of each steward tree. Sophisticated GIS decision-making analysis can be applied to collected data. The geography of the area, including its slope and terrain, affects the health of the trees and the ecological services they provide.

The contextual information regarding the current situation in Worcester made it apparent that our project could help the organizations manage the replanting efforts more efficiently. Multiple organizations are involved in replanting thousands of trees in Worcester, and we saw firsthand that collaboration between the groups is lacking. A more systematic approach to the replanting process and the creation of a centralized tree inventory will encourage more cooperation between organizations. We developed specific objectives to address the needs and concerns of the organizations we worked with.

Methodology

In order to help the WTI, DCR, and City of Worcester Forestry Service manage urban forests, we needed to systematically create a database that could organize all the data. This would allow all three organizations to collaborate and work together and manage the tree resources in the city. In order to create this database and ensure our projects sustainability there were a couple of steps we needed to complete:

1. Conduct a Needs Assessment
2. Locate and Acquire Data
3. Develop & Field Test Proof of Concept
4. Develop Manual

By completing these four objectives we were able to successfully design a database useful for the three organizations, record over 525 trees (both street trees and WTI trees), and develop a manual that will be useful for WTI volunteers tracking tree health.

Objective 1: Conduct a Needs Assessment

The first step of our project was to indentify the specific needs of the WTI, DCR, and the City of Worcester Forestry Service. To accomplish this, we held stakeholder interviews consisting of both small and large focus groups. We met with Peggy Middaugh from the WTI, Eric Seaborn and Alan Snow from the DCR, and Brian Breveleri from the City's Forestry Service. In these focus groups we discussed what exactly each sponsor was expecting from us, and what we were expecting from them. Getting all the organizations to meet at once was a particularly challenging task, but they provided a great deal of insight into the implementation of our project. A main topic of discussion was identifying the data fields that each organization wanted in the final database. The DCR and City of Worcester wanted to collect more data for each tree than the WTI. This needed to be considered when creating the data input forms in Geolink. The below table, Table 3, shows the fields that are unique to each organization.

Table 3. Fields requested by the WTI, DCR, and the City of Worcester Forestry Program to include in final database.

WTI	DCR	City of Worcester
ID	ID	
Street	Street	Street
Species	Species	Species
Location	Location	Location
Prop_Num	Prop_Num	Prop_Num
	Funding	Funding
Date	Date	Date
Notes	Notes	Notes
Latitude	Latitude	Latitude
Longitude	Longitude	Longitude
Caliper	Caliper	Caliper
	Cond	Cond
	CondNotes	CondNotes
	PropDam	PropDam
	DamNote	DamNote
	Mulch	Mulch
	Unit	Unit
	Stakes	Stakes
	PlantDepth	PlantDepth
	Time	Time
	Moisture	
	EQ_Access	EQ_Access
	Irrigation	Irrigation
	Participating	Participating
	Permission	Permission
	Setback	Setback

Once these fields were established, we were able to start thinking about the database. This database had to be designed so the multiple organizations could input their own sets of data. After showing the organizations the compiled list of fields and design for the database, each organization realized the potential that this project entailed.

Objective 2: Locate & Acquire Data

After we identified the necessary fields for our data collection, our next step was to acquire the data, hardware, and software necessary to complete our project. In order to find the locations of the WTI trees, we were provided with the WTI's Excel database. This database contained records of every WTI tree given away during the 2009 planting season. In order to collect street tree locations for the City, we obtained a map of the Burncoat and Greendale area and a list of the tree species for each road the City had replanted on. These two sets of information from the WTI and City allowed us to identify our study area for our project.

To satisfy our software needs the City and DCR provided us with tablet computers loaded with Geolink and GIS layers. These tablets allowed us to collect the tree locations and export the data into individual spreadsheets for each logging session. To help us become familiar with Geolink, Mollie Freilicher from the DCR provided us with a tutorial session. She showed us the proper way to set up and use Geolink to record tree locations. This was very helpful and allowed us to become proficient with the Geolink program.

Once we were comfortable with using the tablet and Geolink we needed to look at the database and maps we received. The WTI's Excel database was the largest database we worked with, containing nearly 1,060 entries. Each tree entry included information in a number of fields, many of which were not necessary to our project. As part of the planning process, the Excel spreadsheet was imported into Microsoft Access. We performed queries on the data which allowed us to efficiently organize the specific fields needed for data collection (tree species, address, house number, location, and notes) while excluding the unnecessary fields.

The WTI's Excel database had very inconsistent data which needed to be cleaned to allow for easier data management. The street names and species entries needed to be corrected and unified to make the data easier to work with. Creating data uniformity within the species field was important for future stages of the project. We needed to determine a single generally-accepted species name for each type of tree in order to create the picklist (drop-down menu) on the Geolink tablet. Establishing data standards at this stage ensured that the collected data would be uniform.

Objective 3: Develop & Field Test Proof of Concept

Our third objective incorporated many aspects of our project, as we implemented the processes that we previously designed. We became familiar with multiple software programs and created user interfaces and linkages between them. The large-scale data collection effort required us to develop protocols for managing data. The WTI's relationship with its stewards remains vital, and we needed to approach the situation carefully by developing a protocol for interacting with residents. Our processes were uniquely developed in response to the needs of the organizations and the current situation in Worcester. We documented our methods to ensure that end-users of various backgrounds, from volunteers to professional foresters, can collect data with Geolink and import the data into a Dabble DB application. A sound methodology was important to ensure best practices were followed.

Developed Customized User Interfaces

Once we had our data cleaned and our fields collected from each organization, we were able to set up Geolink. Geolink acts as the front-end for the database, utilizing a pre-created form that contains all of the necessary fields. We created three "tabs" (Image 3) and associated forms (Image 4, Image 5, Image 6) that were used depending on the situation at the collection site.

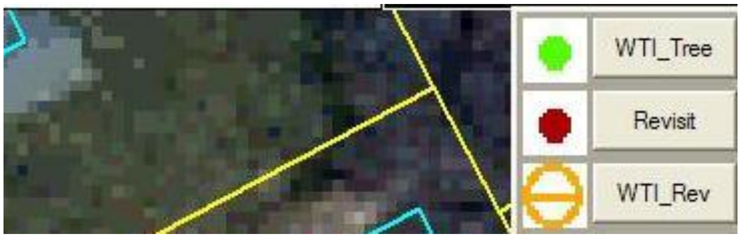


Image 3. Screenshot of Geolink tabs: "WTI_Tree", "Revisit", and "WTI_Revisit".

The "WTI_Tree" tab (Image 4) was used for the majority of the recorded trees, and contains the following attributes: ID, Street, Property Number, Species, Location, Notes, Latitude, Longitude, and Date. After locating the tree, the Geolink user placed a symbol on the tablet's map to represent its position. The street and property number were manually entered in addition to the identified species of tree and its location relative to the building (front yard, back yard, street, left side, or right side). The date was automatically recorded, in addition to the GPS coordinates received via Bluetooth unit. The other two tabs were used for alternative purposes.

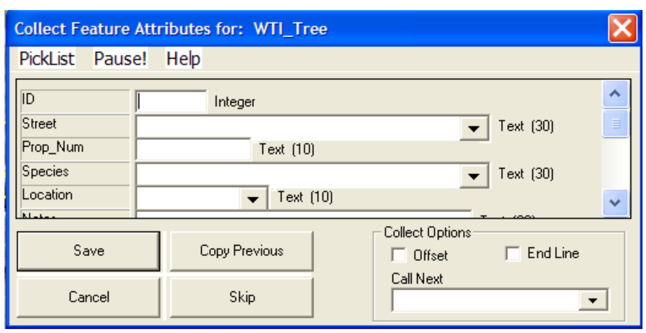


Image 4. Screenshot of "WTI_Tree" feature attributes box in Geolink.

The "WTI_Revisit" tab (Image 5) was used to indicate trees that required further inspection by the Worcester Tree Initiative. The only attributes required for this tab are the street, property number, and reason why the WTI needs to become involved. This tab was used when the tree species could not be identified or if the tree could not be located.

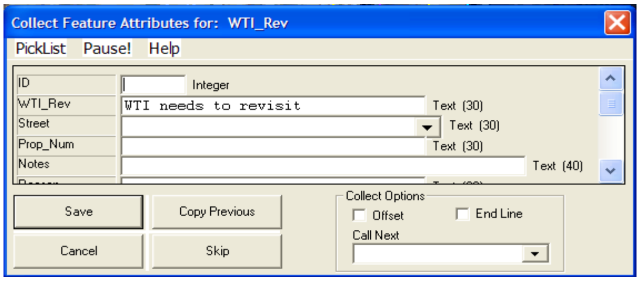


Image 5. Screenshot of "WTI_Revisit" feature attributes box in Geolink.

The third tab, "Revisit", (Image 6) was used when we did not have visual access to the tree from the street. In addition to the street and property number, this table also includes attributes used to describe the problem. For example, if the property owners were not home and the tree was planted behind the house, we would need to contact the owner and attempt to come back at a later date.

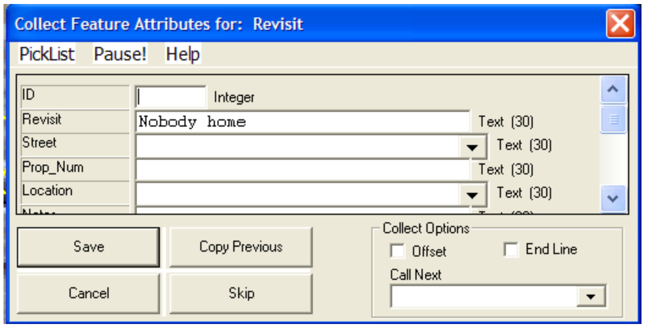


Image 6. Screenshot of "Revisit" feature attributes box in Geolink.

Created Protocols for Logging WTI Trees

The WTI's goal of verifying the planting of stewards' trees while upholding a relationship with owners required us to create specific protocols. We collaborated with the WTI to determine how to gain access to trees planted in homeowners' backyards. In order to maintain an accurate database for the WTI, we created a classification system for each planting site with Geolink.

Data Collection

Before beginning actual data collection, we conducted multiple test runs to ensure that we had sound data collection protocols. In some instances we needed to test the Geolink software, so we were able to conduct the test runs at our office. One of the most difficult aspects of data collection was the management of vast amounts of data. After multiple test runs, we settled on what we believed to be the most efficient process for data collection. The group member in the passenger seat acted as the database manager and navigator, using a map and list of WTI tree addresses from the WTI database to determine the route. Group members three and four, in the back seat, concentrated on inputting the data into Geolink. Group member #3 recorded the observed location of the tree into Geolink using the tablet PC and input the tree information, provided by member #4, from the WTI database. As each visible tree was recorded into Geolink, the entry was deleted from a copy of the WTI database by the navigator. If the tree was not visible from the road, it was marked as “Revisit” in Geolink and the record was highlighted in the WTI database. As each street was completed, the navigator marked it off with a highlighter on the map.

Multiple control systems were established to ensure that each site was accurately labeled. First, the copy of the WTI database was updated by removing each successful tree sighting. Trees entries marked with the “Revisit” tab were highlighted in the database. Second, this list could be verified by viewing the Geolink data. Combining every “Revisit.dbf” file produced a comprehensive list of street addresses that needed to be returned to. This same process was repeated with the “WTI_Revisit” files. This allowed us to create and deliver a list of street addresses that the WTI would use to contact the owners.

Interacting with Residents

Many of the WTI trees were not visible from the street, so we needed to devise a solution to obtain this data. It was important for us to respect the privacy of the WTI stewards with backyard trees to maintain the positive relationships created between the stewards and the WTI at the tree give-aways. Working with Peggy Middaugh, Director of the WTI, we learned that at the give-aways, recipients were informed of WTI’s intention to monitor tree health over the next few years. She concluded that the stewards’ formal agreement with the WTI would allow us access to the tree. As a formal measure, we worked with Peggy to produce a letter that we later delivered to those addresses marked “Revisit”. Its purpose was to remind them of the WTI’s plans and inform them about our project and intentions (See *Appendix A- Letter to WTI Residents*).

The letter briefly explained our role as WPI students and our involvement with the WTI. It also described the credentials we would provide to homeowners if needed; a WTI T-shirt and our WPI identification cards. Because consent to backyard access was implied, it was crucial for us to provide multiple contact methods that stewards could use to voice any concerns. The letter clearly presented the WTI’s phone number, our group e-mail alias, and our advisor’s e-mail address. The few stewards who refused access, as well as those with backyard fences or other obstructions, were excluded from data collection or marked as a "WTI_Revisit". Those who did not voice opposition were assumed to be in agreement with our proposed actions. We were able to enter their backyards with the tablet PC and successfully collect the data.

Field Testing Our Concept

It was extremely time-consuming to collect data for the WTI trees. Fieldwork was conducted nearly every day for three weeks and required more time than anticipated due to multiple factors. Visible WTI trees from the street were quickly entered into Geolink without leaving the car, but many trees were planted in the backyard, hidden from view, or simply weren't planted. Of the 340 visited WTI trees, about 150 were initially marked as "Revisit" and the WTI-approved notice was placed on the front door. After finishing the data collection for all visible trees we returned to the revisit sites. Sufficient notice had been given to the stewards and we were able to enter the backyards of homeowners without fences. By having visual access to all of the property, we could definitively label each tree. The portable tablet was used to record the position of each identified tree. The "WTI_Revisit" tab was used if the WTI would need to contact the owner. Trees that were still in the pot, couldn't be correctly identified, or didn't exist were marked as "WTI_Revisit". Approximately 65 addresses were marked as "WTI_Revisit" and given to the WTI in the form of a database. These trees, in addition to the trees planted outside the Greendale and Burncoat area, will need to be located and collected by the WTI.

Data collection for the Forestry Service's street trees was simple and expeditious. Brian Breveleri, Director of the City of Worcester Forestry Service, requested that we collect data for approximately 250 street trees in the Greendale and Burncoat areas, centered around Bay State Road, Clark Street, Burncoat Street, and West Boylston Street. We received a newly configured tablet with Geolink from the Forestry Service. The street trees could be quickly located and entered into Geolink at a much faster rate than the WTI trees. The Forestry Service was aware of the time constraints placed on us, and we were only required to input each street tree's species and location into Geolink. The simplicity of data collection for street trees allowed us to collect more than 100 trees per hour.

Design Database

Each of the three organizations had different needs and goals for data collection. The WTI would primarily use our collected data to maintain its relationships with tree stewards. Each steward received a free tree in exchange for attending a planting seminar. The WTI needed a way to track the health of the tree and stay in touch with stewards. The stewards signed a formal agreement with the WTI that explained what was expected of them. The $50 trees were essentially an investment into the future, and stewards would need to fulfill their side of the agreement by caring for the tree. Additionally, the WTI wanted to promote tree stewardship for individuals and communities. The online database would satisfy the WTI's goals by linking each tree to its physical location, owner, and contact information. Most of the WTI trees were planted by individual stewards, and the data will be collected by volunteers. The DCR and Forestry Service planted their own trees and therefore had different data needs.

The decision to use Dabble DB as a database strongly influenced the setup of Geolink on each organization's tablets. Although each organization was using a different configuration of Geolink, the structure of Dabble DB allows for multiple data sources to be easily integrated into a single database. The "Latitude" attribute for each record was chosen to serve as the unique identifier, or Primary Key, for the database. Geolink records the Latitude position as either a 9 or 10 digit decimal, which essentially ensures that it will be unique among other records. As data is imported into the Dabble DB application, the software uses Latitude to determine if each record already exists. If the Latitude value is unique (not present in the database), then a new record is created. If the Latitude is present, then the record is updated with the new information.

The data needs of the organizations are constantly evolving. Dabble DB allows users to dynamically manipulate the attributes (columns) as needed. This will be invaluable for an organization, such as the WTI, that plans on expanding its data collection in the future to include additional information for each tree. If the WTI collects data to track the health of each individual tree, they only need to input the Latitude position and the additional attributes, and Dabble DB will update the record. Image 7 displays this step of the importing process.

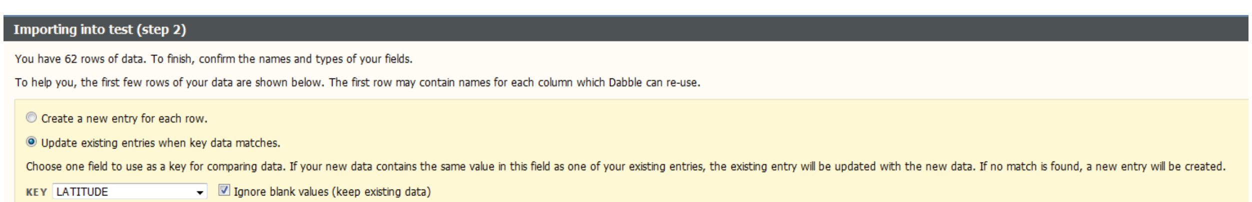


Image 7. Updating information in Dabble DB.

Objective 4: Develop Manual

The last and perhaps most important process was to create a manual to ensure the sustainability of our project. We wanted to make sure that once we were gone, the three stakeholders would be able to successfully replicate our best data collection practices and easily transfer the data to the shared online database. In the manual, we explained in detail how to collect data with Geolink and how to transfer data to the online Dabble DB database (See attached *Appendix B- Manual*). To ensure the format would be easy for the end users to follow, we modeled the structure of our manual off proven successful manuals.

Findings

We found that developing linkages between software programs created a set of tools that will aid the organizations in managing their urban forests. The three organizations have unique data needs, data collection procedures, and personnel. We designed and field tested protocols for collecting and managing vast amounts of data. Each organization can use its own Geolink configuration to collect the data that is most useful. The data from three sources can be synthesized into a single tree database. We designed a web database using Dabble DB that can accommodate the varying and evolving needs of the three organizations involved in replanting thousands of trees. Our tools will aid these organizations in working toward a common goal: better urban forest management.

Proof of Concept

Our results demonstrate that our systematic approach to collect data for approximately 525 trees was successful. The collected data can be visually represented in a GIS mapping program. ArcMap was used to create a composite map consisting of multiple GIS layers and our collected data. The shapefiles from Geolink are collectively imported into ArcMap to produce a more intuitive visual representation of the data. Using the background GIS layers from the DCR and MassGIS, we created maps of the WTI trees and Forestry Service street trees in the Burncoat and Greendale areas. This will allow organizations to see the distribution of trees and plan future replanting efforts. Future volunteers and groups will be able to see all of the trees on a certain street. This management tool can be used to improve the efficiency of data collection and management of one of the most important resources- time.

ArcMap

The below images (Image 8 and Image 9) are maps of the study area in Greendale and Burncoat. The green circles represent WTI trees that were visible from the street. The orange circles represent addresses where the tree couldn not be visually located from the road. Approximately one-half of the WTI trees needed to be returned to at a later date to collect data. The second map displays the aggregated data from every logging session (276 WTI trees).

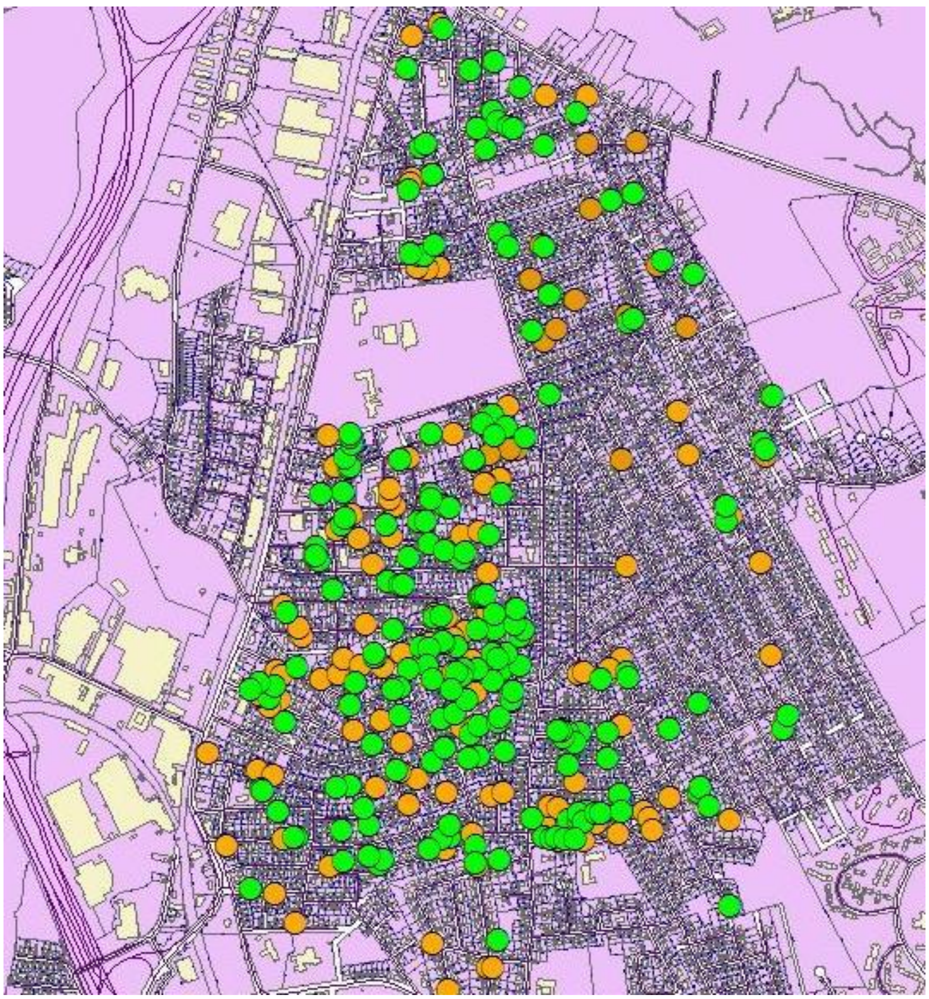


Image 8. ArcGIS output of WTI trees in Burncoat and Greendale represented by green circles. Orange circles represent sites marked with the "Revisit" tab in Geolink.

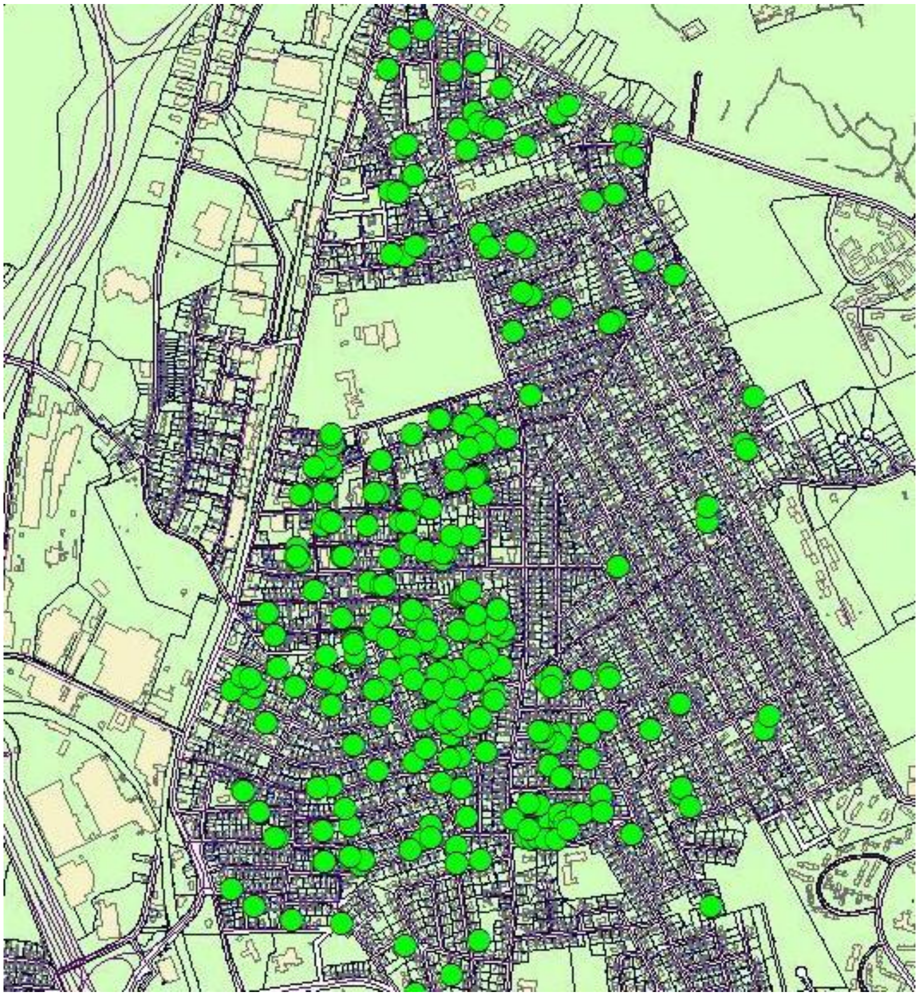


Image 9. ArcGIS output of all WTI trees in Burncoat and Greendale represented by green circles.

Our group found these maps to be extremely useful for managing our data collection. Similarly, the WTI and other organizations can use the maps to manage organizational resources. On the macro level, the visual representation provides a tool for decision-makers to plan for future data collection. Visiting hundreds or thousands of replanted tree sites inherently requires a large amount of time. The map can be adjusted to accommodate the needs of the organizations. The below image, Image 9, represents a map of the WTI trees in the Burncoat area. The populated streets on the bottom of the map are Thorndyke Road and Monterey Road.

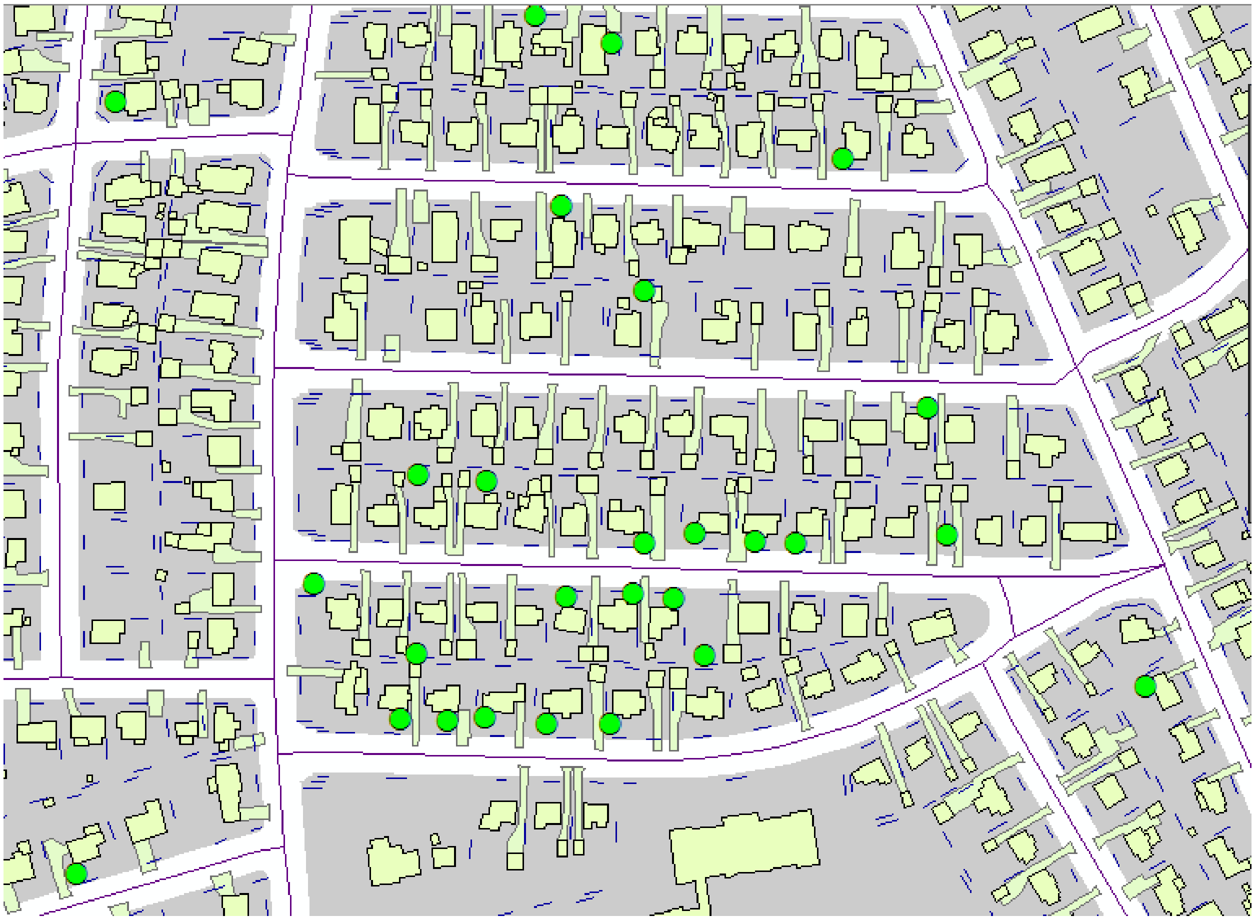


Image 10. A close-up of a section of Image 8.

A map of a smaller area will be useful for planning data collection sessions conducted by volunteers. We conducted data collection for WTI trees by using a database with each tree identified by street address and species. The WTI intends to track the health of the stewards' trees over the next three years. The visual representation provided by ArcMap will allow data collectors to quickly see the quantity and location of the trees on each street. This map provides only the location of each tree. The same dataset was used to populate a database that we designed to serve as a centralized repository for multiple organizations' replanted trees.

Dabble DB

We designed a database application using Dabble DB, which is a web-based database platform. Each of the three organizations required different data fields for each collected tree record. The structure of Dabble DB facilitates the diverse needs of the three organizations. As the quantity of data changes over time to meet organizational goals, the database can be easily adapted to include more fields. The multi-user online database can be accessed from any computer with web access. Data collection for thousands of trees will be a collaborative effort on the part of many organizations and volunteers. The end-users of the database come from different backgrounds and technical abilities, however the Dabble DB application is relatively simple to use.

The Dabble DB platform simplifies many of the technical aspects of maintaining a database. The database supports multiple access levels: “Read only”, “Read and write”, and “Read, write and build” (Help and support for Dabble users, 2010). This enables the volunteer-driven WTI to track the health of thousands of trees in a decentralized manner. It is more efficient for a large quantity of people to aid in the data collection in order to update the database. One of the inherent concerns for a web-based application is data backup, but Dabble DB provides a solution for this. “Dabble DB includes two primary backup tools. The first is a downloadable ZIP file containing all of the data. The second is the ability to restore the database to various "snapshot" points from the last 30 days. Both are accessible from the Backup and history tab of the admin page, accessible to Admin users” (Help and support for Dabble users, 2010). Relative to standard relational databases, Dabble DB is more intuitive and end-user friendly.

Importing data into the Dabble DB database is as simple as copying and pasting records from an Excel spreadsheet into a window on the Dabble DB website. Viewing and manipulating the layout of the database is done through the creation of a new “view”. The database isn’t altered, “Views are “non-destructive”. What that means is that changing what you see in the view has no effect on the data itself. Views allow you to organize the same data in multiple ways, all while keeping the data structure itself intact” (Help and support for Dabble users, 2010). Users who are unfamiliar with the format of Dabble DB don’t have to worry about deleting entries or altering the database in any way. The use of views enables users to view the data in the desired format, save the view, and share it with others. A view might show only the street, address, species, and location of the record if that is all that is needed. Filters can be applied to narrow the results down to a certain street, as seen below.

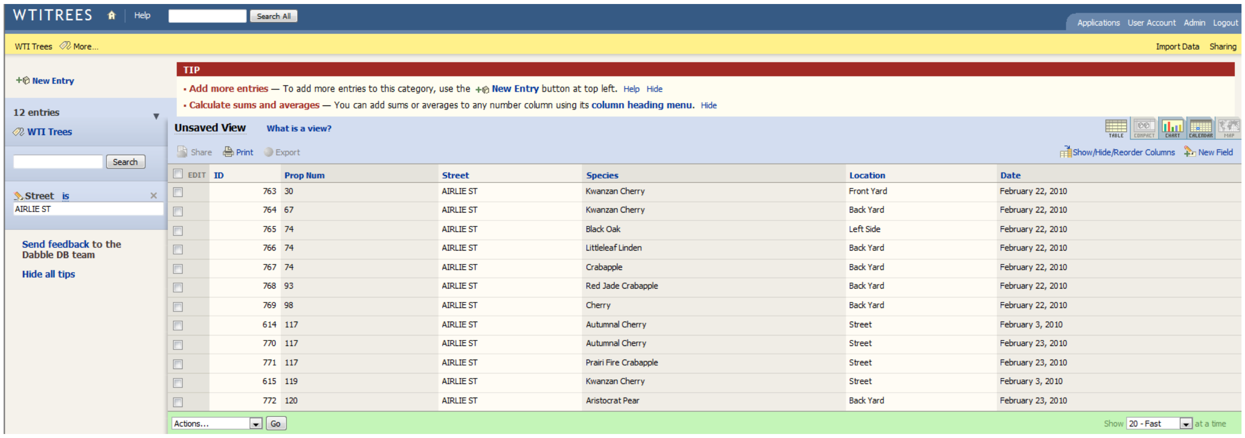


Image 11. Screenshot of the online WTI database using Dabble DB.

Each tree was recorded as one of five locations with respect to the house: Street, Front Yard, Left Side, Right Side, or Back Yard. The location can be used as a filter to manage collecting data for trees. In the below image, trees are grouped by street, and trees that were located in the Back Yard aren't displayed ("Location is not Back Yard").

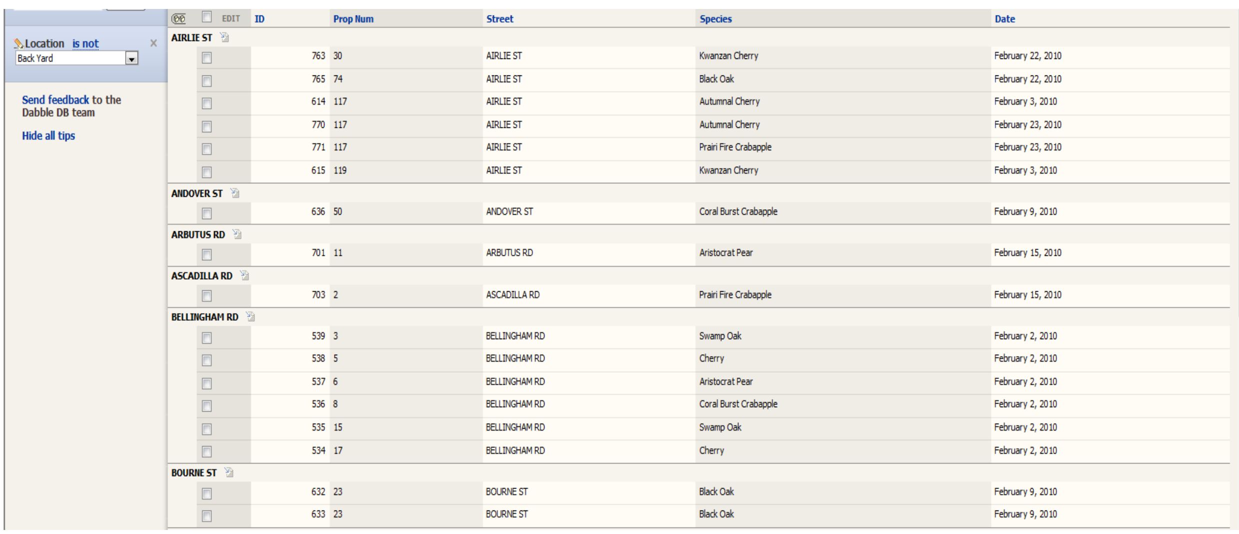
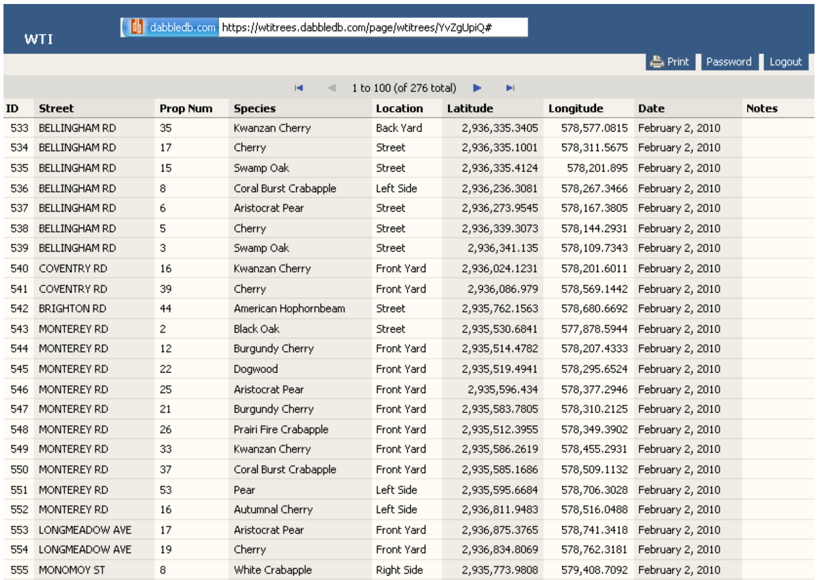


Image 12. Displays ability to exclude certain data and organize data in different ways.

The Dabble DB database can share and export the data in multiple ways to aid the three organizations in creating a transparent tree inventory. The user-created views can be saved and easily shared with others as a web page via a permanent web address, as seen in the below image. The same display can alternatively be embedded into another web page with the provided HTML code. Alternatively, the view can be exported into a file, as seen in the below image (Image 13). "Below each option is the permanent, up-to-date URL to the data in the format of your choice. All export formats are always synchronized with your real data" (Help and support for Dabble users, 2010). Subscription formats, such as an RSS feed, can be used to notify users of data changes. The view can also be displayed as a web page on the Dabble DB website or dynamically integrated into a different web page (Image 14). If the Dabble DB application is configured to "Allow public access to exports", then any individual (including the public) can bookmark the web address and access the view.



ID	Street	Prop Num	Species	Location	Latitude	Longitude	Date	Notes
533	BELLINGHAM RD	35	Kwanzan Cherry	Back Yard	2,936,335.3405	578,577.0815	February 2, 2010	
534	BELLINGHAM RD	17	Cherry	Street	2,936,335.1001	578,311.5675	February 2, 2010	
535	BELLINGHAM RD	15	Swamp Oak	Street	2,936,335.4124	578,201.895	February 2, 2010	
536	BELLINGHAM RD	8	Coral Burst Crabapple	Left Side	2,936,236.3081	578,267.3466	February 2, 2010	
537	BELLINGHAM RD	6	Aristocrat Pear	Street	2,936,273.9545	578,167.3805	February 2, 2010	
538	BELLINGHAM RD	5	Cherry	Street	2,936,339.3073	578,144.2931	February 2, 2010	
539	BELLINGHAM RD	3	Swamp Oak	Street	2,936,341.135	578,109.7343	February 2, 2010	
540	COVENTRY RD	16	Kwanzan Cherry	Front Yard	2,936,024.1231	578,201.6011	February 2, 2010	
541	COVENTRY RD	39	Cherry	Front Yard	2,936,086.979	578,569.1442	February 2, 2010	
542	BRIGHTON RD	44	American Hophornbeam	Street	2,935,762.1563	578,680.6692	February 2, 2010	
543	MONTEREY RD	2	Black Oak	Street	2,935,530.6841	577,878.5944	February 2, 2010	
544	MONTEREY RD	12	Burgundy Cherry	Front Yard	2,935,514.4782	578,207.4333	February 2, 2010	
545	MONTEREY RD	22	Dogwood	Front Yard	2,935,519.4941	578,295.6524	February 2, 2010	
546	MONTEREY RD	25	Aristocrat Pear	Front Yard	2,935,596.434	578,377.2946	February 2, 2010	
547	MONTEREY RD	21	Burgundy Cherry	Front Yard	2,935,583.7805	578,310.2125	February 2, 2010	
548	MONTEREY RD	26	Prairi Fire Crabapple	Front Yard	2,935,512.3955	578,349.3902	February 2, 2010	
549	MONTEREY RD	33	Kwanzan Cherry	Front Yard	2,935,586.2619	578,455.2931	February 2, 2010	
550	MONTEREY RD	37	Coral Burst Crabapple	Front Yard	2,935,585.1686	578,509.1132	February 2, 2010	
551	MONTEREY RD	53	Pear	Left Side	2,935,595.6684	578,706.3028	February 2, 2010	
552	MONTEREY RD	16	Autumnal Cherry	Left Side	2,936,811.9483	578,516.0488	February 2, 2010	
553	LONGMEADOW AVE	17	Aristocrat Pear	Front Yard	2,936,875.3765	578,741.3418	February 2, 2010	
554	LONGMEADOW AVE	19	Cherry	Front Yard	2,936,834.8069	578,762.3181	February 2, 2010	
555	MONOMOY ST	8	White Crabapple	Right Side	2,935,773.9808	579,408.7092	February 2, 2010	

Image 13. Dabble DB data displayed as web page.

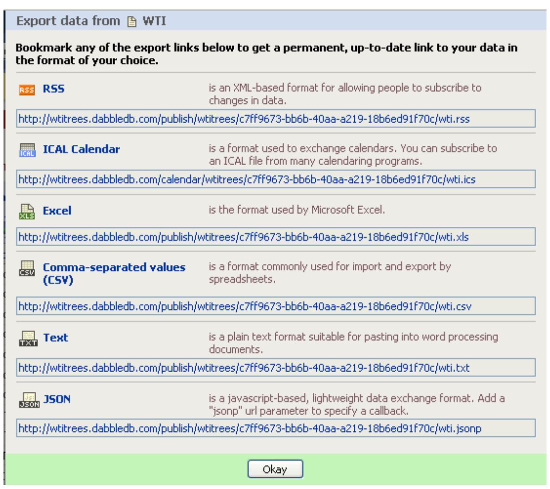


Image 14. The multiple export formats of Dabble DB.

Dabble DB contains one-click tools for analyzing the data. The calendar feature, as seen below (Image 15), can be used quickly visualize the dates that street addresses were visited.

Image 15. Data organized by date of collection using Dabble DB.

The data fields can be manipulated as needed to best help the organization. Only the relevant fields are displayed. The data can be grouped together by street, or the count of trees per street can be displayed in the form of a count or bar graph (**Error! Reference source not found.** and **Error! Reference source not found.**).

EDIT	ID	Street	Prop Num	Species	Location	Latitude	Longitude	Date	Notes
ACUSHNET AVE									
	557	ACUSHNET AVE	38	Kwanzan Cherry	Back Yard	2,936,598.4534	579,405.2711	February 2, 2010	
AIRLIE ST									
	614	AIRLIE ST	117	Autumnal Cherry	Street	2,937,382.7345	576,973.883	February 3, 2010	
	615	AIRLIE ST	119	Kwanzan Cherry	Street	2,937,409.1854	577,027.7344	February 3, 2010	
	763	AIRLIE ST	30	Kwanzan Cherry	Front Yard	2,937,226.6215	575,673.9871	February 22, 2010	
	764	AIRLIE ST	67	Kwanzan Cherry	Back Yard	2,937,384.5461	576,295.0285	February 22, 2010	
	765	AIRLIE ST	74	Black Oak	Left Side	2,937,207.0741	576,394.2039	February 22, 2010	
	766	AIRLIE ST	74	Littleleaf Linden	Back Yard	2,937,179.6843	576,404.7268	February 22, 2010	
	767	AIRLIE ST	74	Crabapple	Back Yard	2,937,146.811	576,405.6147	February 22, 2010	
	768	AIRLIE ST	93	Red Jade Crabapple	Back Yard	2,937,407.6534	576,657.9424	February 22, 2010	
	769	AIRLIE ST	98	Cherry	Back Yard	2,937,202.6365	576,718.6921	February 22, 2010	
	770	AIRLIE ST	117	Autumnal Cherry	Street	2,937,377.9436	576,968.2671	February 23, 2010	
	771	AIRLIE ST	117	Prairi Fire Crabapple	Street	2,937,471.9779	576,937.2389	February 23, 2010	
	772	AIRLIE ST	120	Aristocrat Pear	Back Yard	2,937,276.3729	577,082.5095	February 23, 2010	
ANDOVER ST									
	634	ANDOVER ST	37	Black Oak	Back Yard	2,935,798.7657	575,369.9806	February 9, 2010	
	635	ANDOVER ST	37	Red Oak	Back Yard	2,935,794.5196	575,390.3253	February 9, 2010	
	636	ANDOVER ST	50	Coral Burst Crabapple	Front Yard	2,935,606.7722	575,529.1646	February 9, 2010	
ARBUTUS RD									
	701	ARBUTUS RD	11	Aristocrat Pear	Left Side	2,940,038.218	577,871.0358	February 15, 2010	
	702	ARBUTUS RD	40	Aristocrat Pear	Back Yard	2,940,139.7113	578,808.1665	February 15, 2010	
	787	ARBUTUS RD	38	Aristocrat Pear	Back Yard	2,940,109.519	578,767.8147	February 23, 2010	
ASCADILLA RD									
	703	ASCADILLA RD	2	Prairi Fire Crabapple	Front Yard	2,939,444.4964	578,033.7713	February 15, 2010	
BAY STATE RD									
	791	BAY STATE RD	116	Kwanzan Cherry	Back Yard	2,935,397.9363	578,964.5447	February 23, 2010	
	797	BAY STATE RD	8	American Linden	Back Yard	2,936,781.8663	578,194.6433	February 23, 2010	

Image 16. Data organized by street on Dabble DB.

Street	Count of WTI Trees
ACUSHNET AVE	1
AIRLIE ST	12
ANDOVER ST	3
ARBUTUS RD	3
ASCADILLA RD	1
BAY STATE RD	6
BELLINGHAM RD	7
BIRMINGHAM RD	1
BOURNE ST	2
BRANDON RD	1
BRIGHTON RD	2
BRISTOL ST	6
CASTINE ST	1
CATAUMET ST	1
CHATHAM VILLAGE RD	4
CHESHIRE RD	1
CHRISTINE ST	2
CLAFFEY AVE	2
CLARA ST	3
COLLINS ST	2
COVENTRY RD	2
CROYDON RD	2
CUMBERLAND ST	1
CUTTING AVE	3
DEEPDALE RD	1
DODGE AVE	1
DOROTHY AVE	5
DOYLE ST	1

Figure 4. Number of trees per street displayed in the form of a count using Dabble DB.

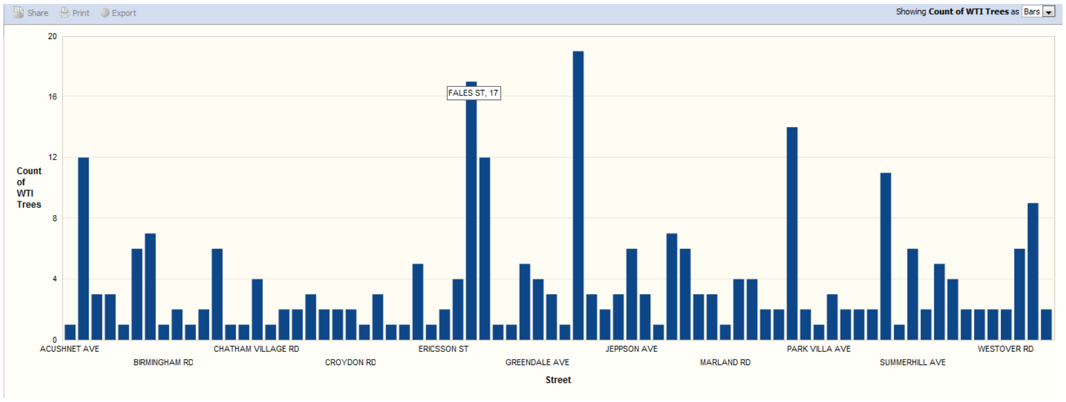


Figure 5. Number of trees per street displayed in the form of a bar graph using Dabble DB.

The Dabble DB application was primarily designed to store the data from multiple organizations. Each replanted tree in the Worcester area could potentially be mapped and imported into a centralized database. The basic analysis tools are very simple to use and can be used to manage large-scale data collection.

The database's flexible structure makes it adaptable for the evolving needs of the organizations. Accessing and updating data is simple, and the database is also scalable to account for an increased number of users, data fields, and tree records. Our database design will allow the three organizations to continue populating the database and adapt its format as needed.

Project Sustainability

We developed a replicable process for collecting data on replanted trees and storing the information in a centralized database. Although we populated the database with our collected data, ultimately the organizations will be responsible for continuing the tree inventory. We created a manual explaining our procedures and step-by-step instructions for collecting data with Geolink and importing the data into our Dabble DB application. The manual will allow each organization to continue collecting data on the replanted trees as they grow and as new trees are planted. By choosing Dabble DB as the database platform, our stakeholders will have the ability to adapt the database in response to changing data needs. The simplicity of Dabble DB made it an ideal choice for our stakeholders to use. Additionally, the database application can scale and adapt to accommodate any number of users (organizations), data fields, and tree records.

The manual we created will prove to be very valuable to the stakeholders in the future, especially the WTI. During the 2009 planting season, 1300 trees were provided by the WTI. One of the WTI's wishes is to be able to track the health of these trees over the next 3 years, the most important period in the trees' lives. To reach their goal of planting 30,000 trees in the next 5 years, the WTI will need to continue providing trees using a systematic process. Our manual will enable volunteers to replicate our best practices and protocols for managing data. An essential part of our project was to create a way for end-users of varying technical ability to replicate our methodology. People from various backgrounds, ranging from WTI's weekend volunteers to professional foresters, will be able to implement our procedures.

The true value of our database will become apparent when the three organizations start to use our work and build upon it. Each organization will utilize the database in a slightly different way according to its needs. WTI will use the database to stay in contact with the tree stewards who have planted WTI trees, to identify and make contact with people who took but did not plant a tree, and most importantly to track the health of the trees through the most vital stage of the young trees' lives. The other organizations will use the database to store a wider assortment of information than health status. As the database grows it can encompass more and more of Worcester's urban tree cover, until it becomes a comprehensive tree database.

Continuation of our Project

Our group created a systematic way for multiple organizations to work together toward a common goal; the management of replanted trees. The linkages between multiple software applications created a way for organizations with different needs to collaborate and seamlessly share information. Mapping the locations of replanted trees with GIS software can be expanded upon by performing GIS analysis of the local geography. The ecological services project group reported that each tree species provides different quantitative benefits (Sima et al., 2010). These benefits should be considered when individuals determine which tree species should be used in replanting efforts. Currently, tree species are largely chosen with aesthetics and personal preference as main criteria. The below chart (Figure 6) illustrates the disparity between ecological services provided by removed trees and replanted trees. The inner circle demonstrates that removed trees from the Burncoat and Greendale areas provided approximately equal service values in terms of aesthetics and energy savings. The outer circle represents the values provided by replanted trees. Approximately 87% of the value added by replanted trees is purely aesthetic.

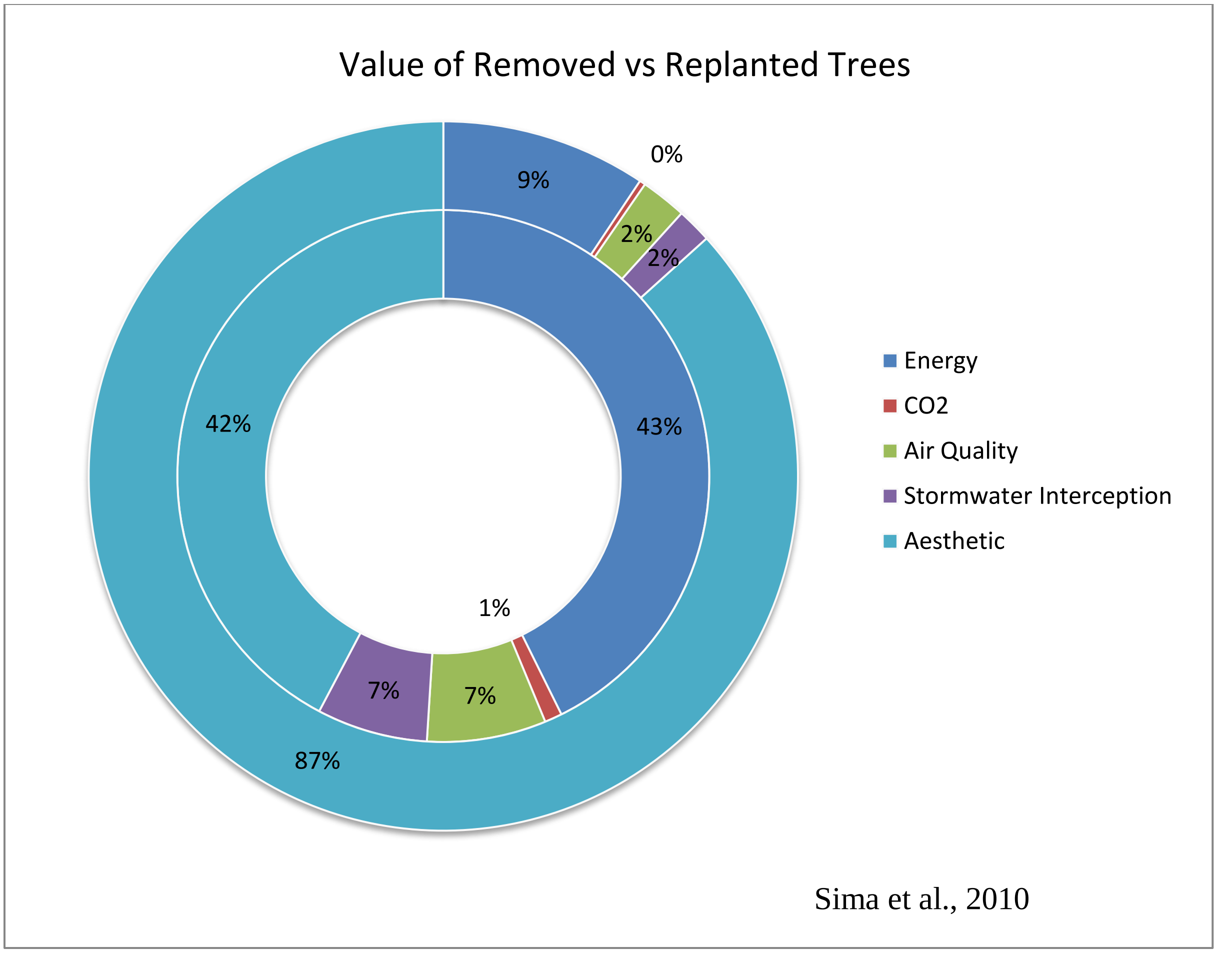


Figure 6. Value of removed trees vs. replanted trees in the Greendale and Burncoat areas of Worcester, MA.

In order to reclaim the social and monetary values gained through urban forests, the optimal species for each planting site should be considered. Our group's management tools can be used synergistically with the findings of the ecological services project group. Future IQP groups could work on a project to analytically determine a replanting solution that will most benefit the community.

Not all trees are created equally in terms of the ecological services they provide. State and local agencies should deterministically choose tree species based on the specific values they add to the community. The biodiversity of the urban forest should be considered, in order to gain a wide range of ecological services and also to contain possible invasive species from spreading in the future. Organizations that promote stewardship, such as the WTI, should attempt to give away as many trees as possible to community members. The data provided by the ecological services group proves that the ecological services are largely not considered by individuals. By educating the public about the importance of species selection, the values lost through the ALB eradication program can be reclaimed.

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Appendix A- Letter to WTI Residents

Rebuilding Worcester's Urban Forest

WORCESTER TREE Initiative

February 2010

Dear Residents,

We are a group of Worcester Polytechnic Institute students working with the Worcester Tree Initiative to map replanted trees in your neighborhood. This is part of our junior year project, which applies science and technology to a community project. Over the next few years the Worcester Tree Initiative intends to track the exact location and health of all the trees that were given away. The Worcester Tree Initiative will maintain a database of replanted trees and create a map of the tree locations.

We will start collecting our data in the month of February 2010 and may need to enter your yard for a few minutes to take our measurements. We can be identified by our WPI identification cards and Worcester Tree Initiative T-shirts.

If you do not want us to enter your yard, or have any other concerns, please contact the Worcester Tree Initiative at 508-752-1980.

You can also contact our group at ALBtreemapping@wpi.edu or our Professor at Krueger@wpi.edu

Thank you,

Bill Seibold | Brandon Grace | Anna Costello | Matthew Wzorek

WPI Students

Approved by,

Peggy Middaugh

WTI Project coordinator

WPI

Appendix B- Manual

GEOLINK®

The World's Leading GPS/GIS Software

Version 6.3.2.4

dabble db

Created By:

Brandon Grace

Bill Seibold

Anna Costello

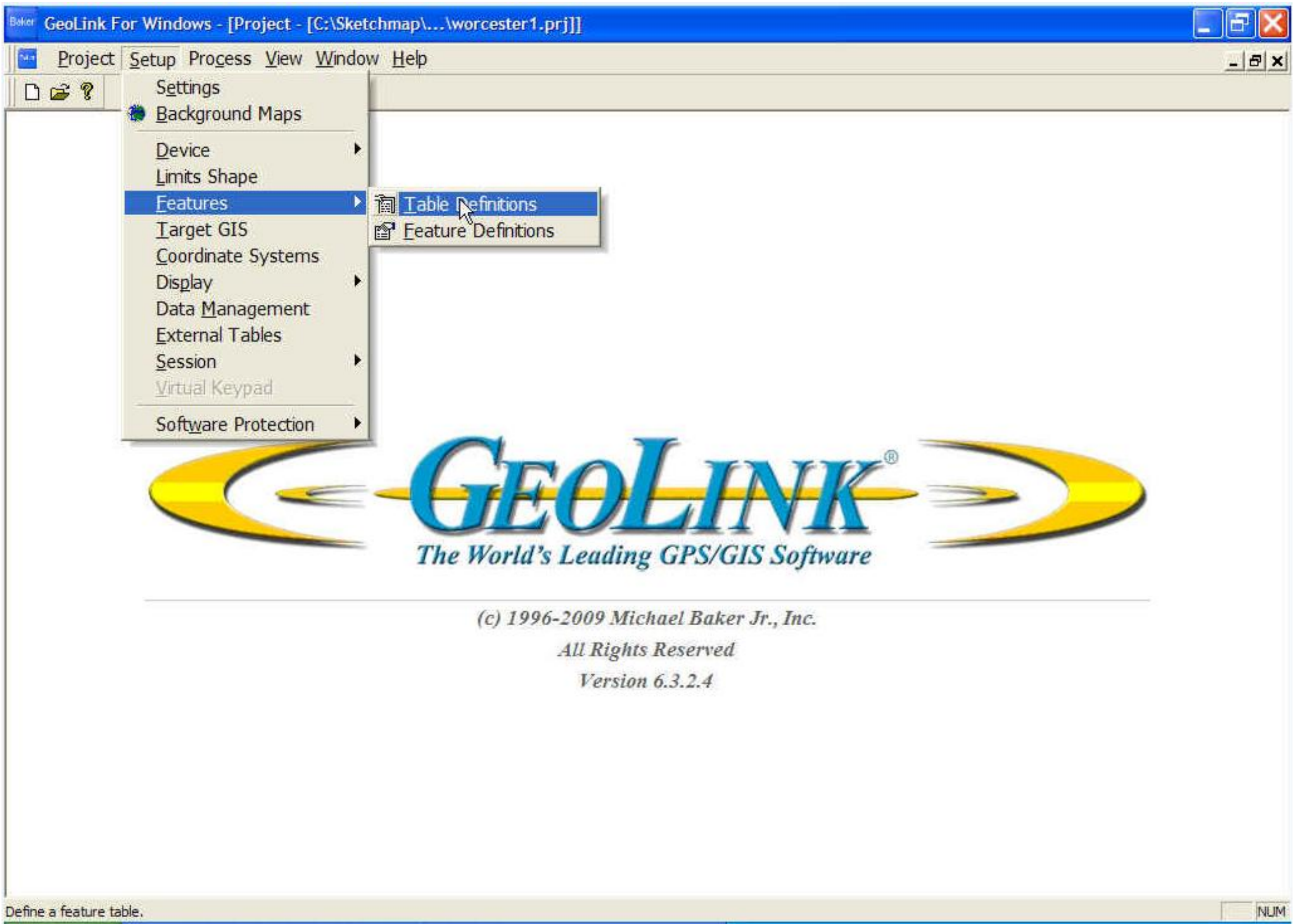
Matthew Wzorek

Inputting Data into Geolink

Geolink is a relatively straightforward program which can be used to track locations and information specific to an individual tree. In this manual we will show the procedure to collect the information and import the data into an online web database, Dabble DB. The first section will explain the procedure for collecting the data in Geolink. Included at the end of this section is a list of tips that can be helpful when collecting field data. The second section shows the procedure for importing the Geolink output into the Dabble DB application.

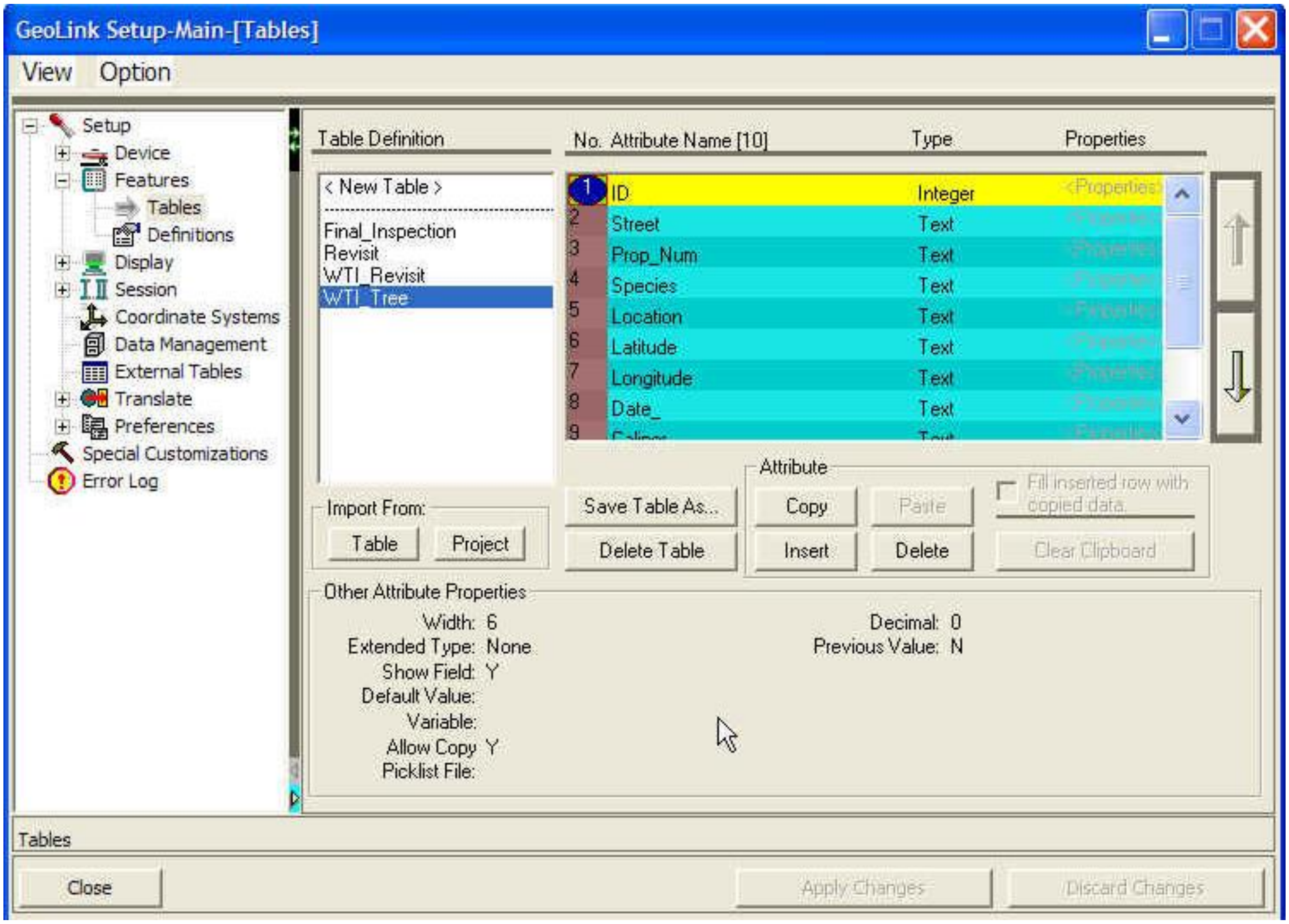
Step 1.

When you open up Geolink program the main screen will load the previous project. Click "OK" in the dialogue box. Next you can set up the fields if they are not provided for you. If the fields and tabs are already provided for you, then steps 2 and 3 may be skipped. If not provided, then continue with step 1. To do this you click on "Setup", "Features", and then "Table Definitions". Here you will be able to add any fields to the tabs you want to have in Geolink.



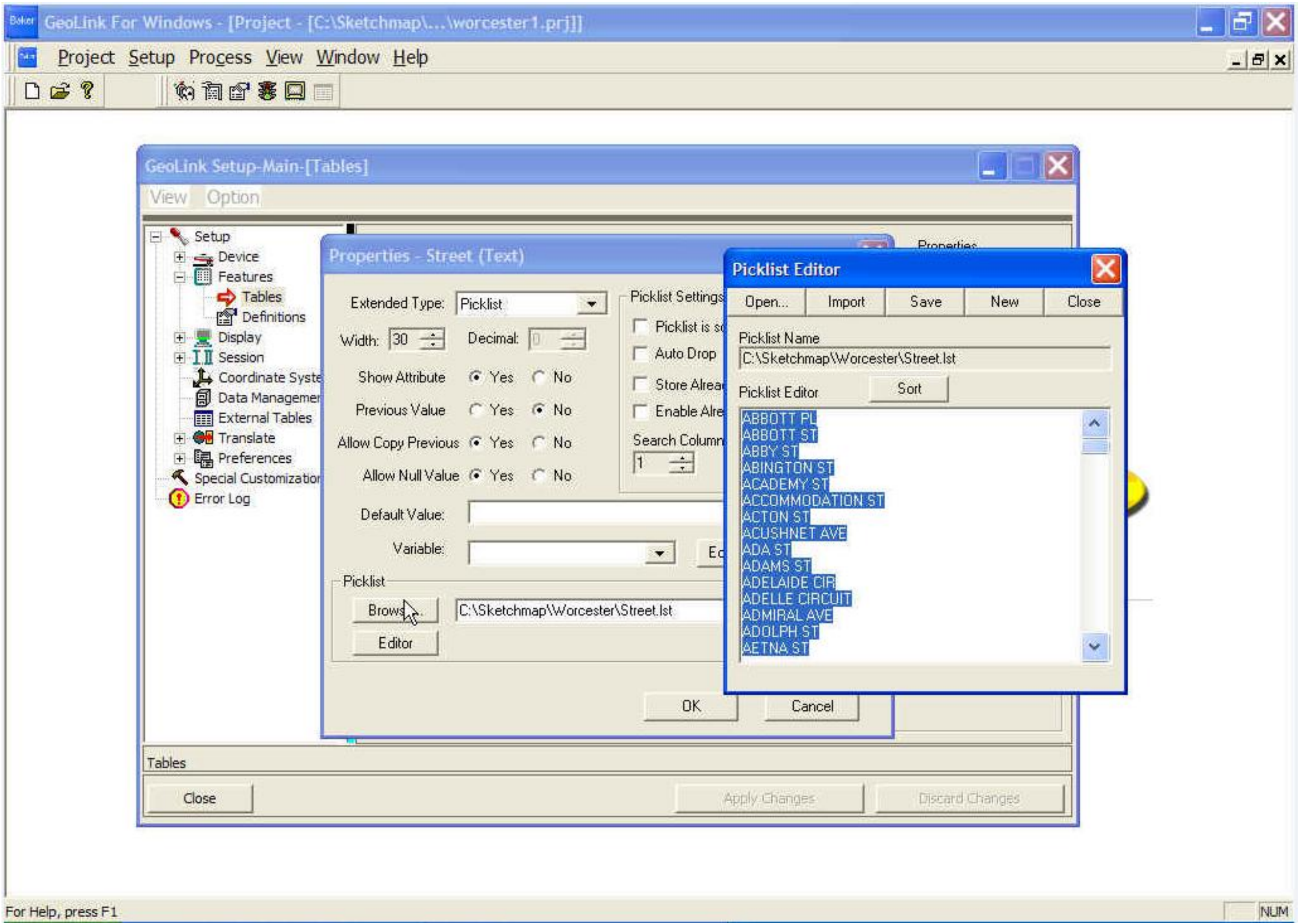
Step 2.

The below picture shows the fields that can be changed for each tab. You can add/remove tabs, fields, and adjust the order of the fields.



Step 3.

To add/remove to the picklist in each tab, you can click on the “properties” tab. For example, this picture shows list of tree species. You can manually add or remove any items you want in this list.

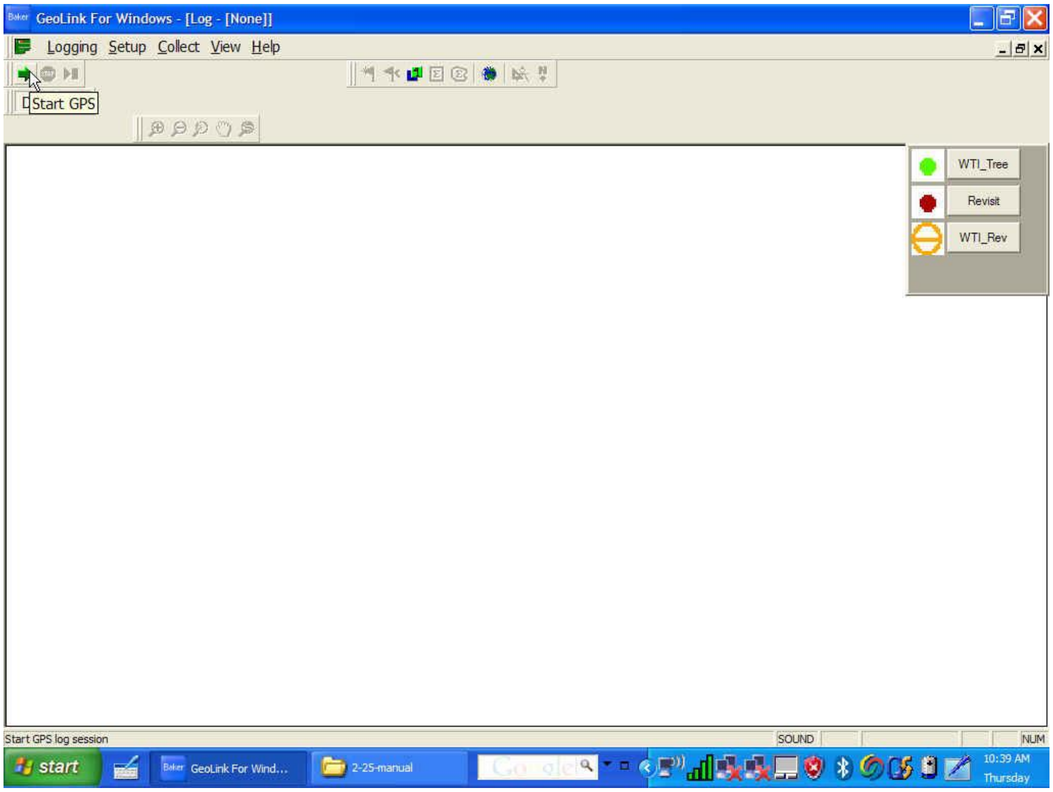


Step 4.

Once all the fields and picklist are complete you can start to log. Start the Geolink program. Click on the “Process” menu button, and then “Log”.

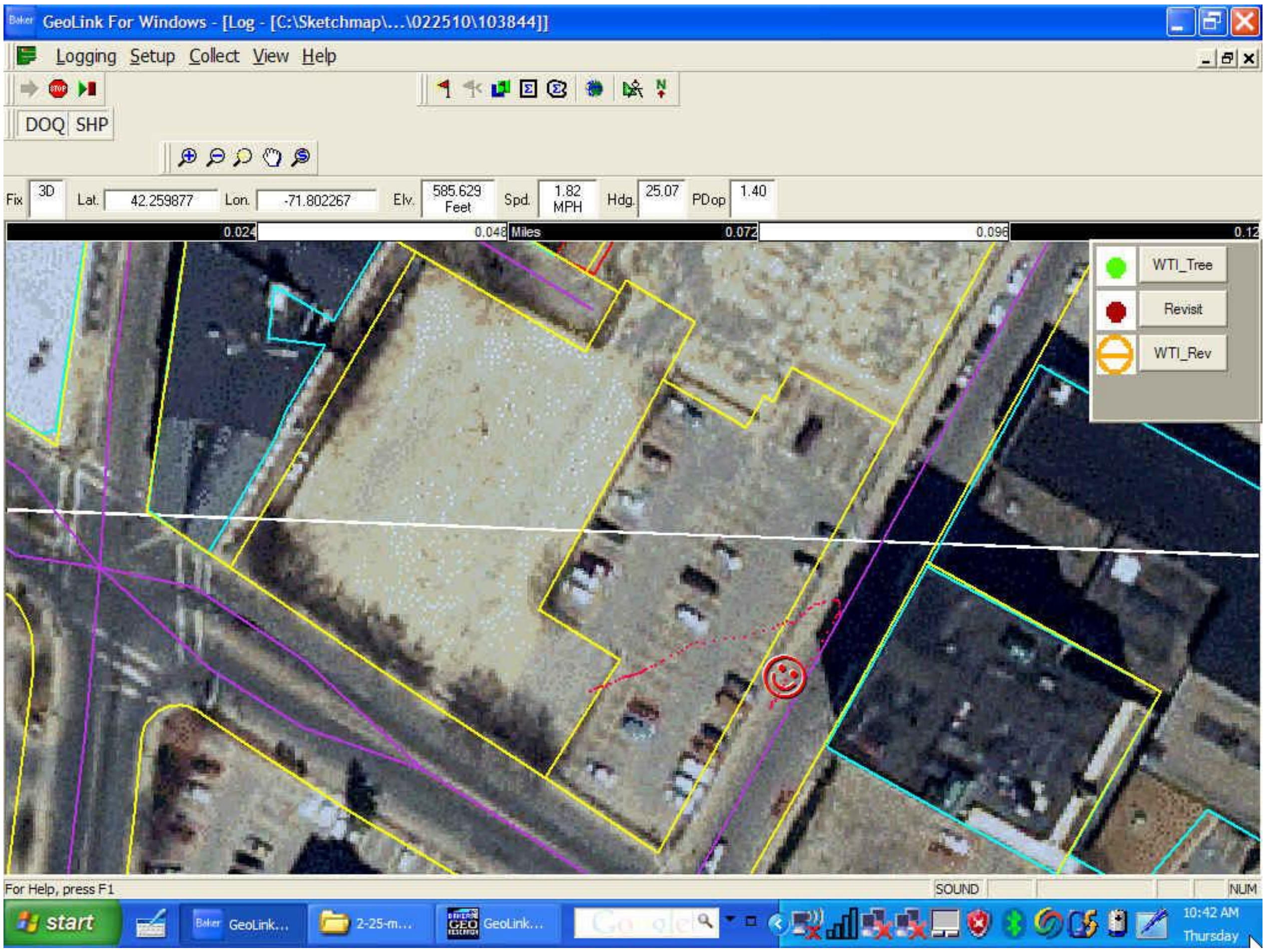
Step 5.

Bluetooth is a wireless technology that allows a separate unit to communicate with the tablet computer. Turn the Bluetooth GPS unit on, if needed. The Bluetooth unit must be located outside or near a window in order to record GPS readings. It may not work in buildings or in heavy cover. Also if the Bluetooth GPS unit is not within approximately 5 feet of the tablet pc it will not be able to connect. Click the green arrow in the upper left corner to begin logging. Select "Log with GPS" if prompted and click "OK".



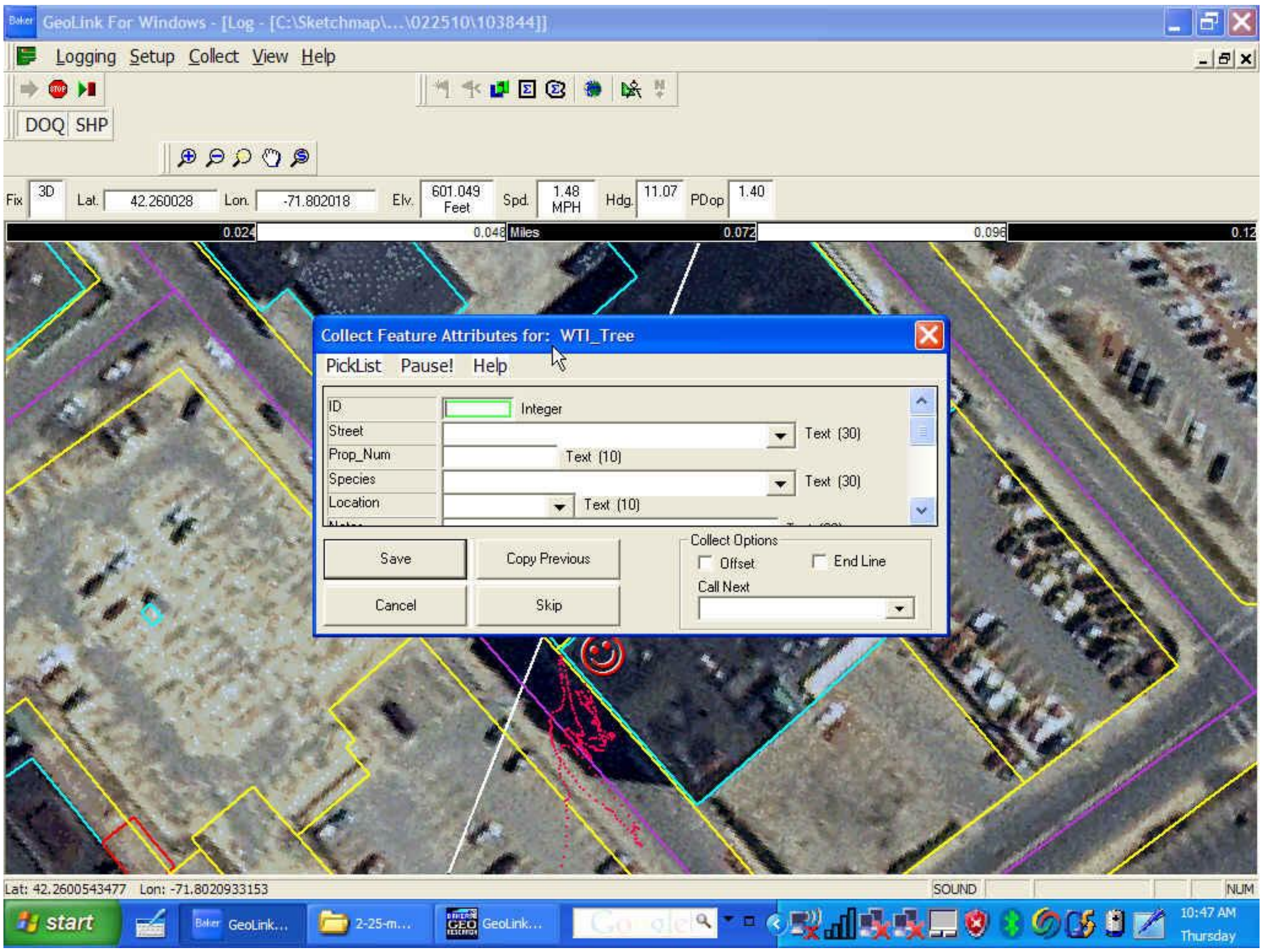
Step 6.

The software might take a few seconds to initialize the GPS. When the "Fix" displays "3D" in the upper left corner, you may begin collecting data.



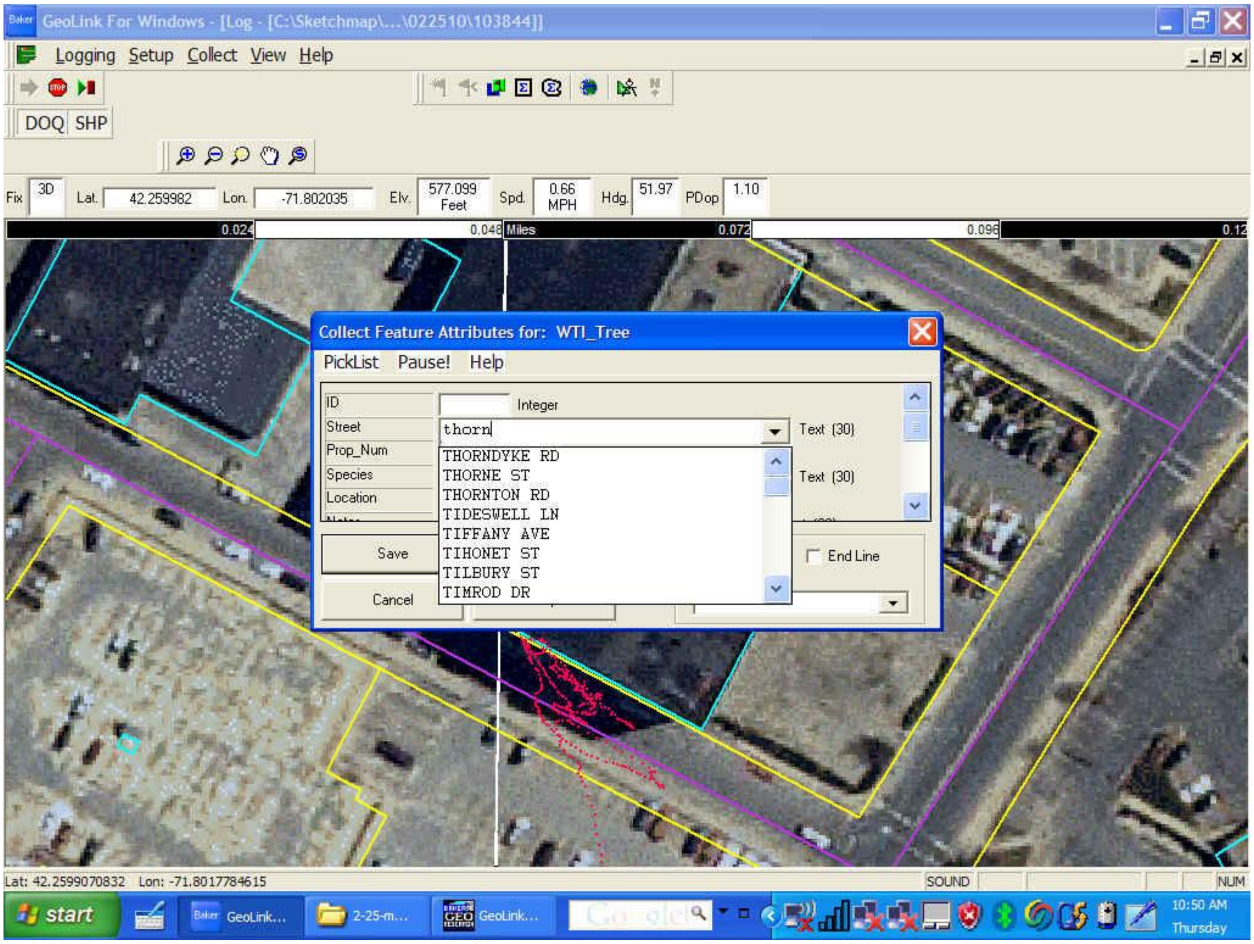
Step 7.

Click on the appropriate tab to record the data. For example, click the "WTI_Tree" tab in the upper right corner of Geolink. Place the stylus on the map to mark the tree and select "End Sketch" when prompted.



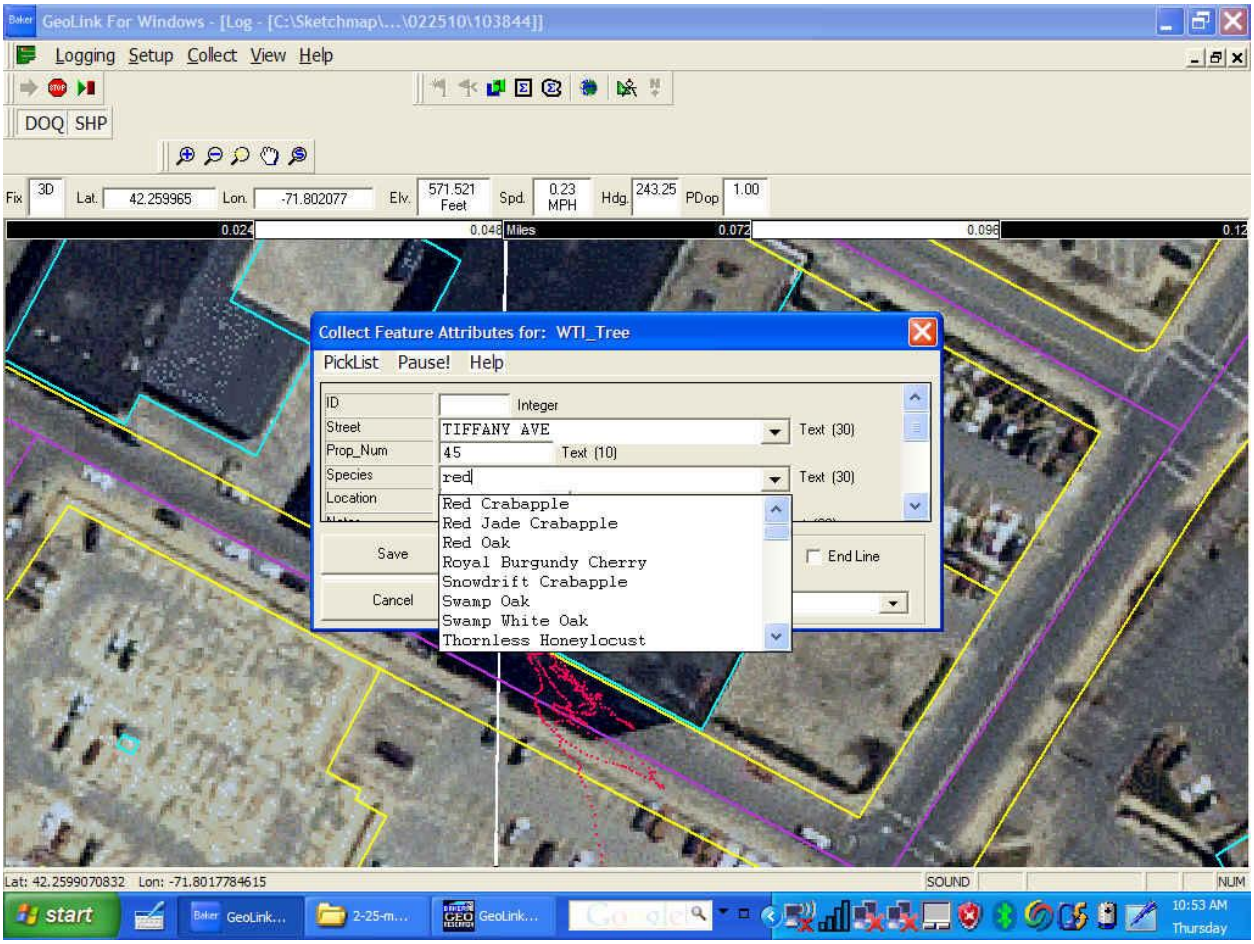
Step 8.

A dialogue box labeled “Collect Feature Attributes for: WTI_Tree” will appear. Press tab or click in the “Street” picklist box. The street name can be browsed to, or the first few letters of the street can be entered and then the street results will be narrowed.



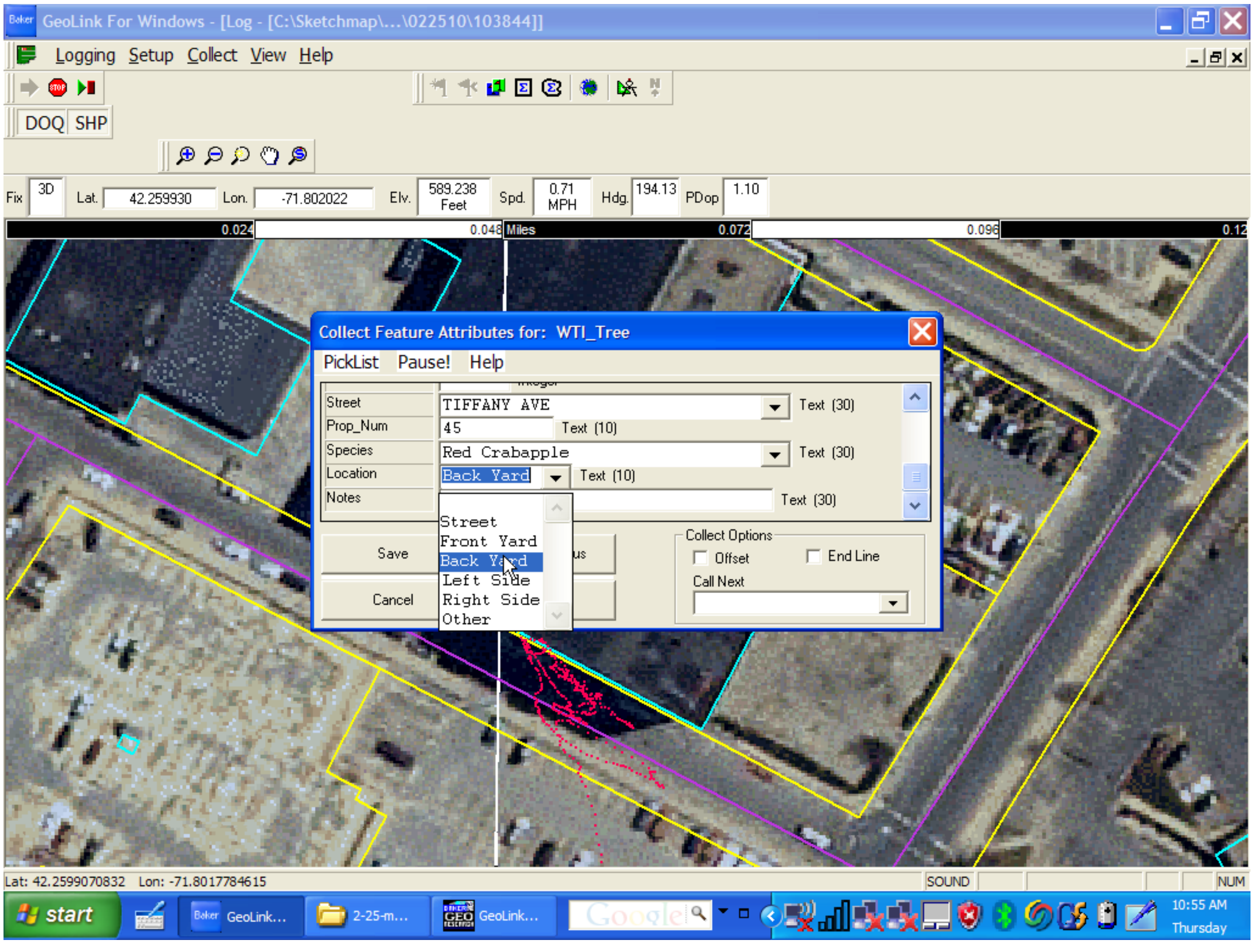
Step 9.

Enter the property number in the “Prop_Num” field. The “Species” picklist is similar to the “Street” field. The first few letters of the species can be entered to narrow the results.



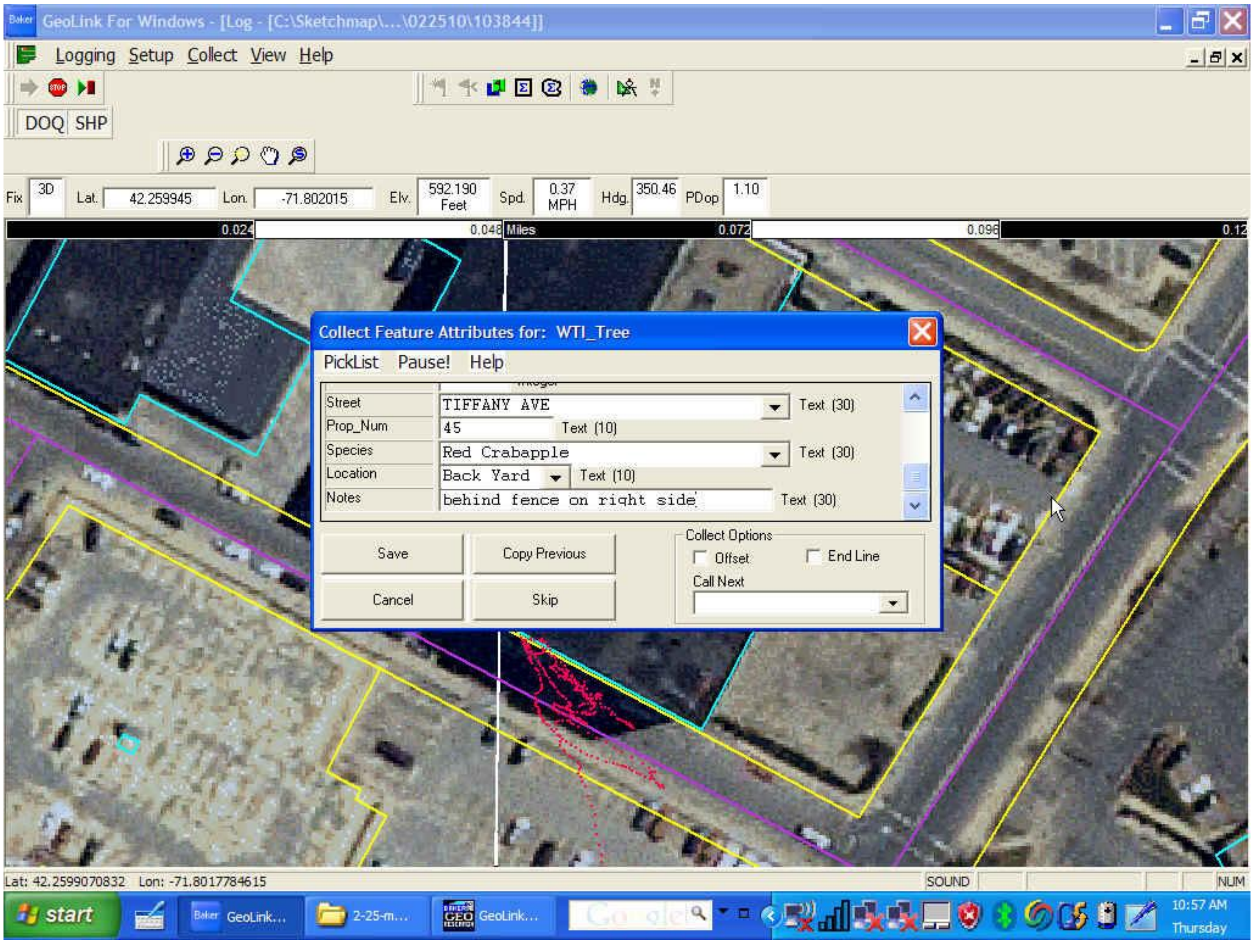
Step 10.

The Location field is also a picklist. Click the downward arrow to list the locations and select the appropriate entry.



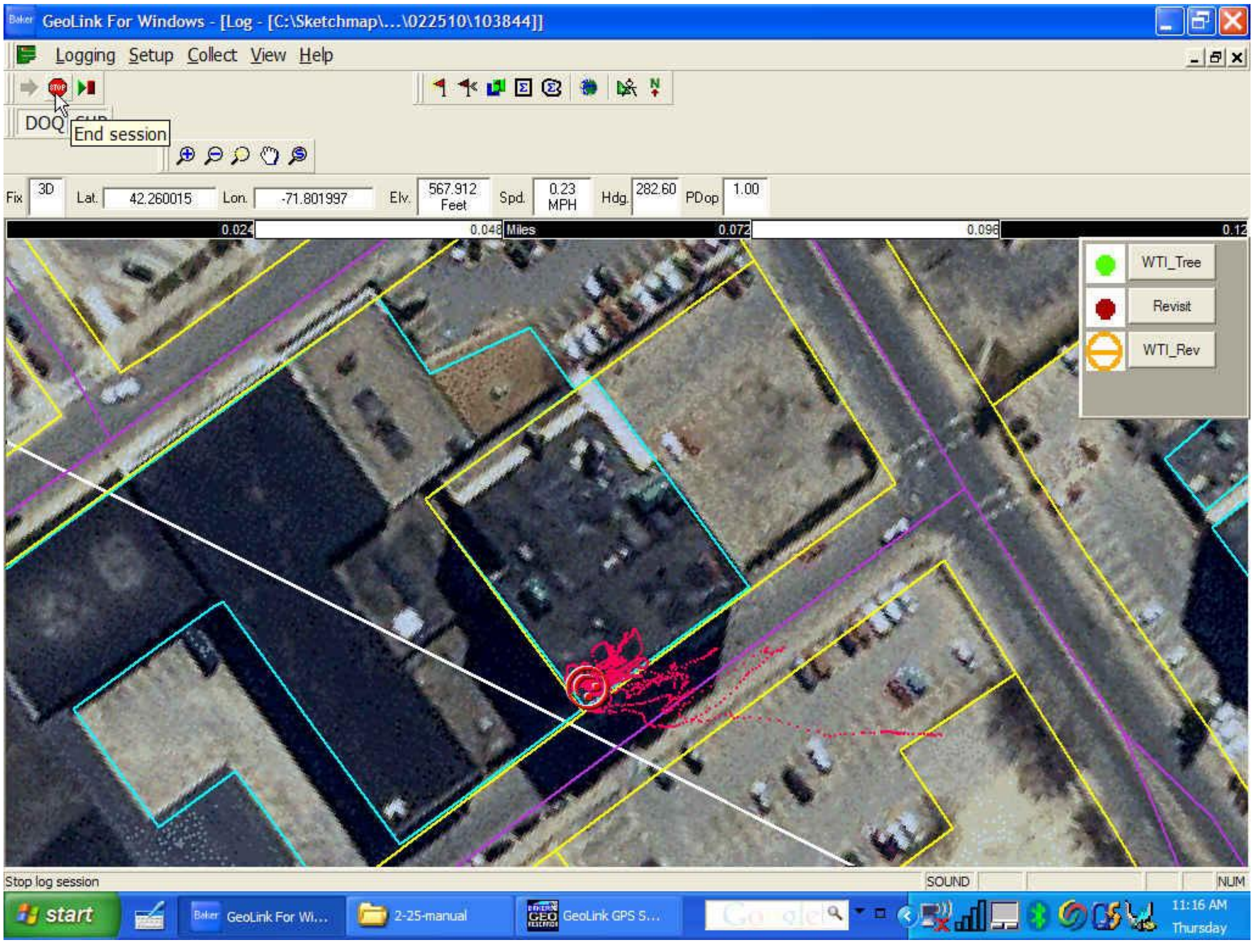
Step 11.

The “Notes” field is used to describe any relevant information about the tree or street address. After verifying that the inputted information is correct, click the “Save” button. Geolink will return to the background image and update the location to reflect any changes in movement.



Step 12.

When you are ready to end the logging session, click the red "STOP" sign in the upper left and click "OK".



Step 13.

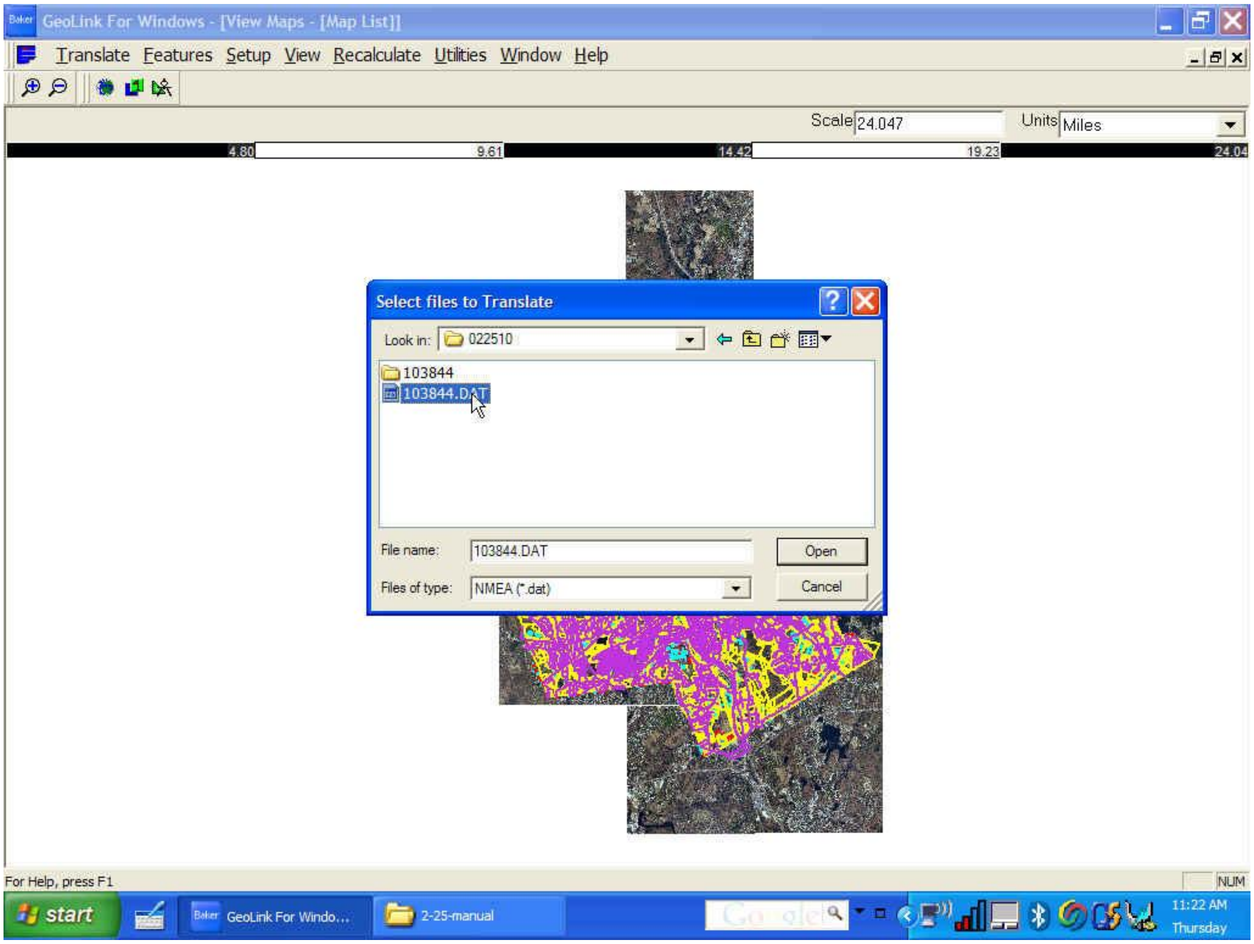
It is recommended to translate the files after each session. Click the “Process” menu at the top and select “Translate”.

Step 14.

Wait for the background images to finish loading, this might take a few seconds. Click the "Translate" menu in the upper left corner and then click "Select Files".

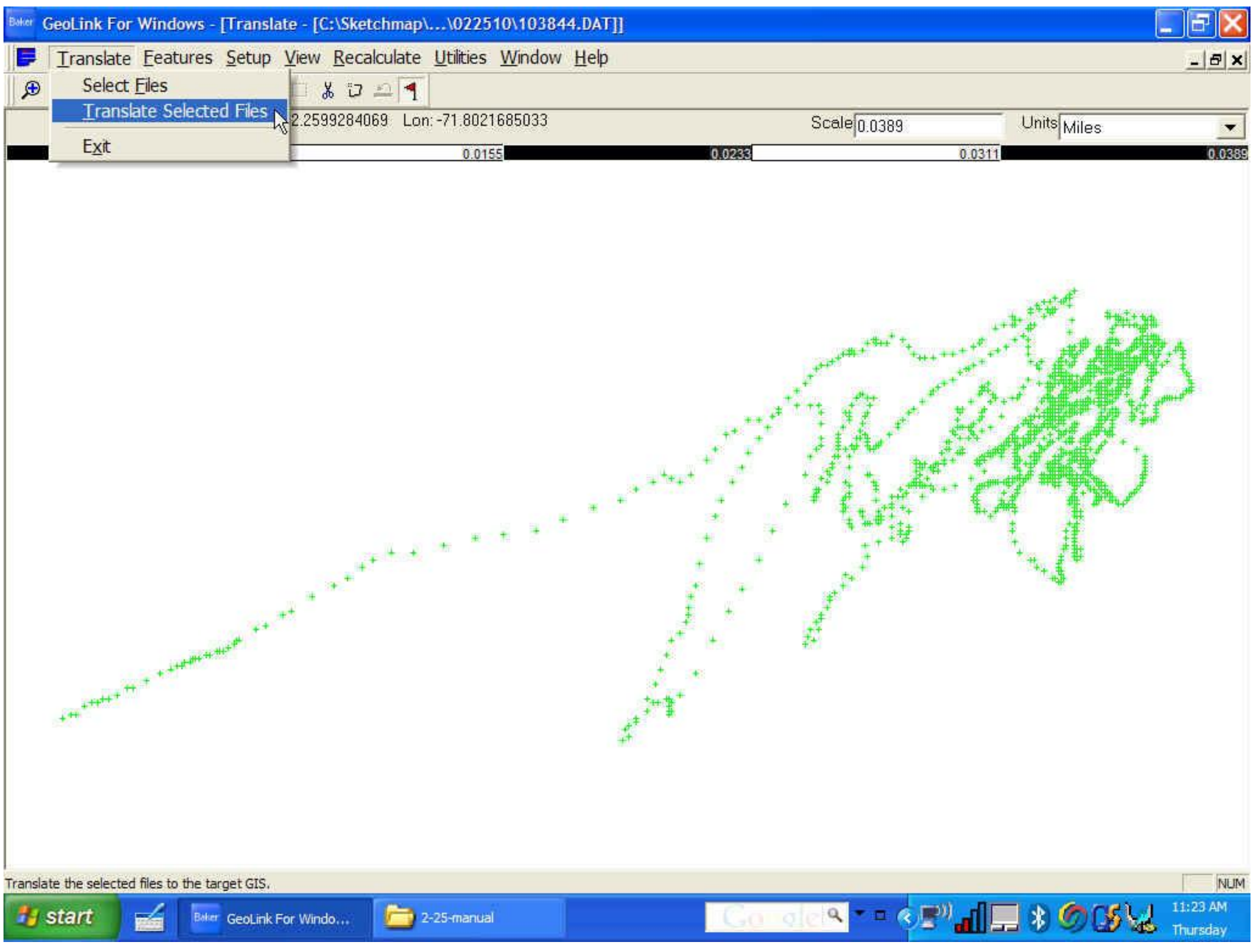
Step 15.

Browse to the “Log” folder within the project directory. Most likely, you will need to click “Up One Level” and then enter the folder corresponding to the current date. Select the .DAT file that corresponds with the time that logging was initiated. Click “Open”.



Step 16.

Depending on the amount of data collected, Geolink might take a few seconds to prepare the files. Click on “Translate” in the upper left corner and select “Translate Selected Files”. The “Translate Statistics File” dialogue box will display some information about the log file, including the number of trees collected as “Point features collected:”. Click “Close”. Turn off the Bluetooth GPS unit if needed. The Geolink output files can now be imported into a spreadsheet or Dabble DB.



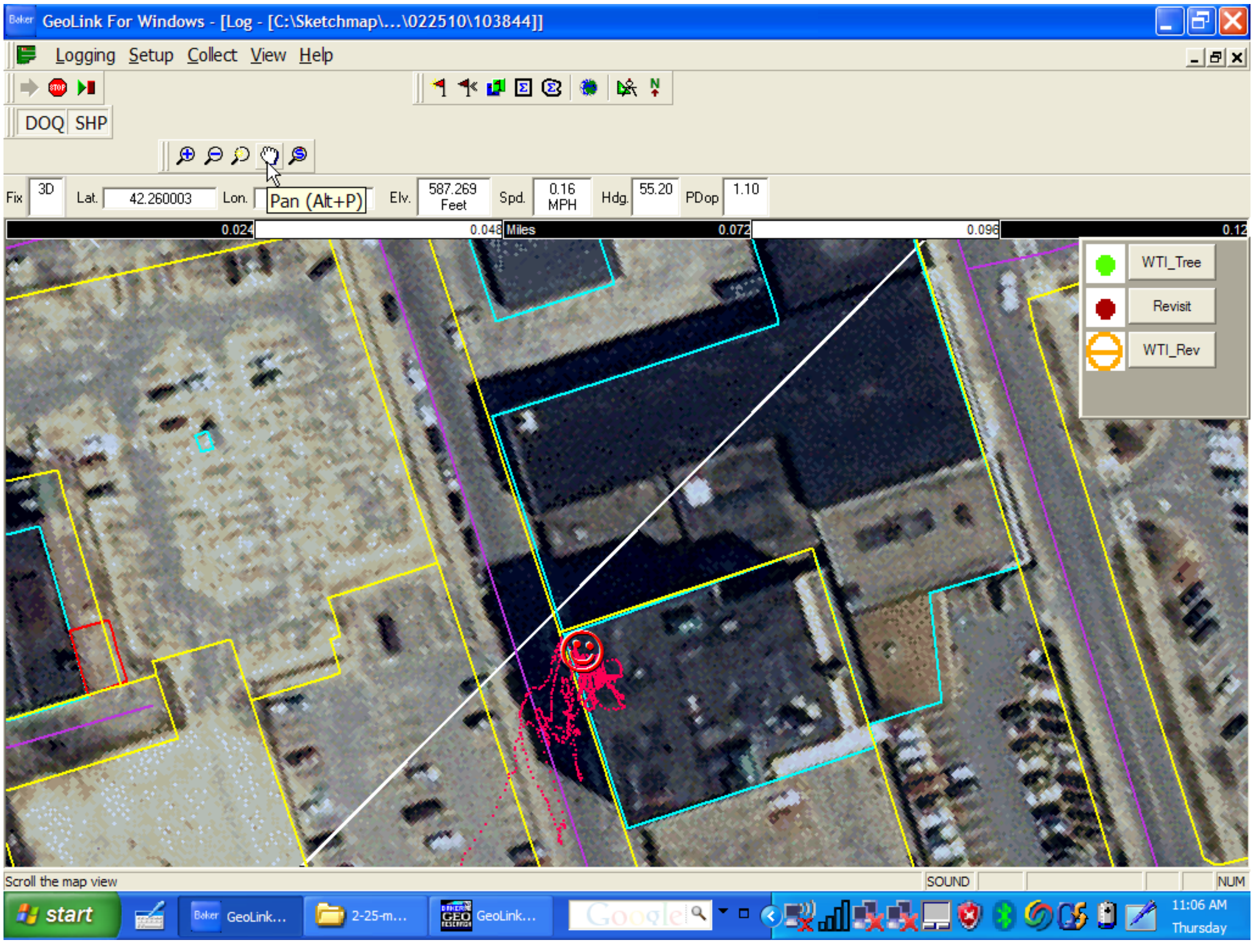
Tips for Geolink

After the tab is clicked, you cannot click a different tab and place the stylus on the map to enter data in the second tab. Suppose the "WTI_Tree" tab is chosen, but the user would like to use the "Revisit" tab. Place the stylus anywhere on the map, click "End Sketch", and then close the dialogue box by clicking the "X" in the upper right.

If the background images aren't displaying, try clicking the "DOQ" and "SHP" buttons twice each in the upper left corner of Geolink. This should refresh the background.

The "Copy Previous" button can be used to save a great deal of time. A few of the data fields remain constant and don't need to be entered each time. This might include the Street, Species, and Location fields. Note that "Copy Previous" copies the data entries from the previous use of that tab. For example, suppose the first address on a new street is marked as "Revisit". Using the "WTI_Tree" tab for the second address and clicking "Copy Previous" will not correctly copy the "Street" entry from the previous record.

If the graphic representing the current GPS location is missing from the screen, try clicking the "Pan" button twice or use the shortcut (Alt + P) twice.

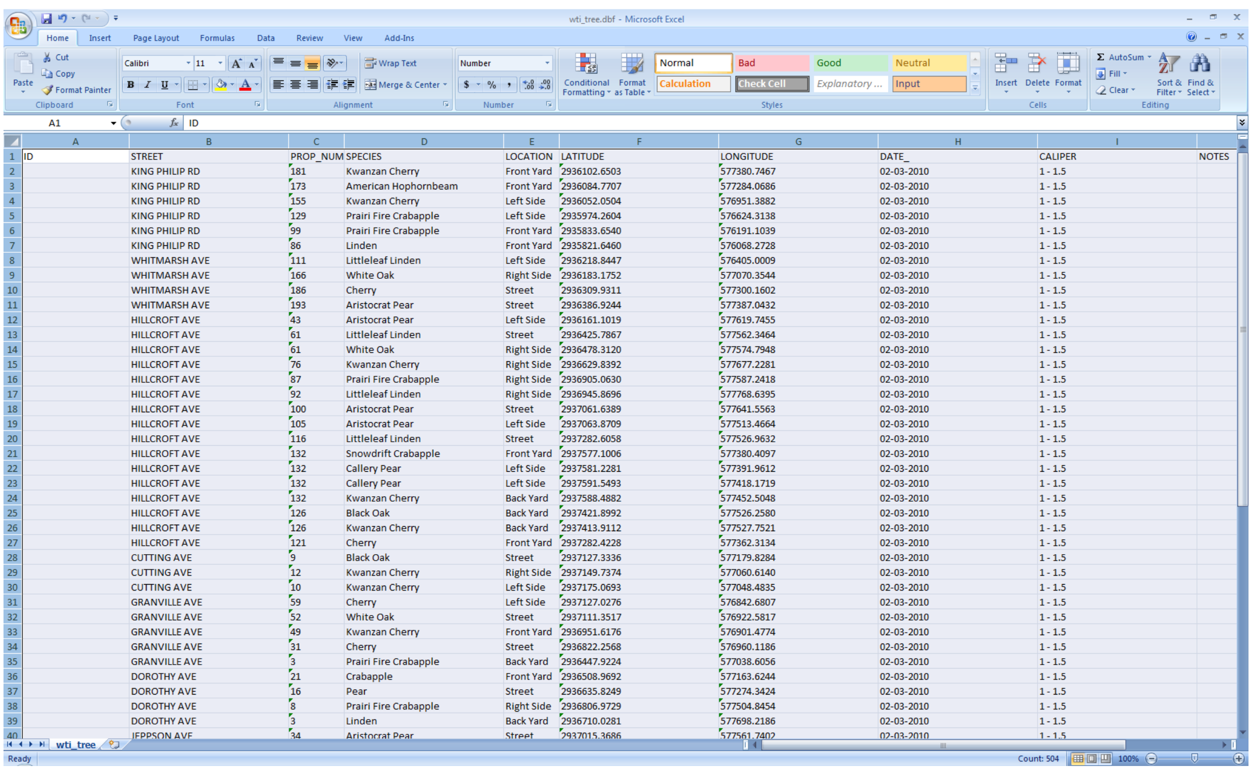


The "Notes" field should be used to store any corrections. If a record with incomplete or incorrect data is saved, then the easiest remedy is to select the same tab and place the stylus in the correct position again. Select "Copy Previous" and make the appropriate changes. In the "Notes" field, something similar to "Delete other 41" will allow the user to delete the other record after it is imported into Excel.

Importing into Dabble DB

The Geolink output is stored in date-stamped directories within "C:\Sketchmap\Worcester_WTI\Translte". Each tab in Geolink corresponds with a database table (.dbf file extension) that contains all of the records. In this example, the tab was named "WTI_Tree" and the corresponding database file from the logging session is "wti_tree.dbf". Open the Geolink output file in Microsoft Excel or an alternative spreadsheet application.

At this point, the data should be verified to ensure that it is consistent and accurate before proceeding. Errors from the data entry phase (Geolink) should be corrected. Our group used the "Notes" attribute in the field to manage data and fix any incorrectly entered records. Once the data is cleaned and manipulated in Excel as needed, it can be imported into dabble db. "Select all" by clicking the cell above the "1" of the first row, and then copy this data to clipboard (ctrl + c).


wti_tree.dbf - Microsoft Excel

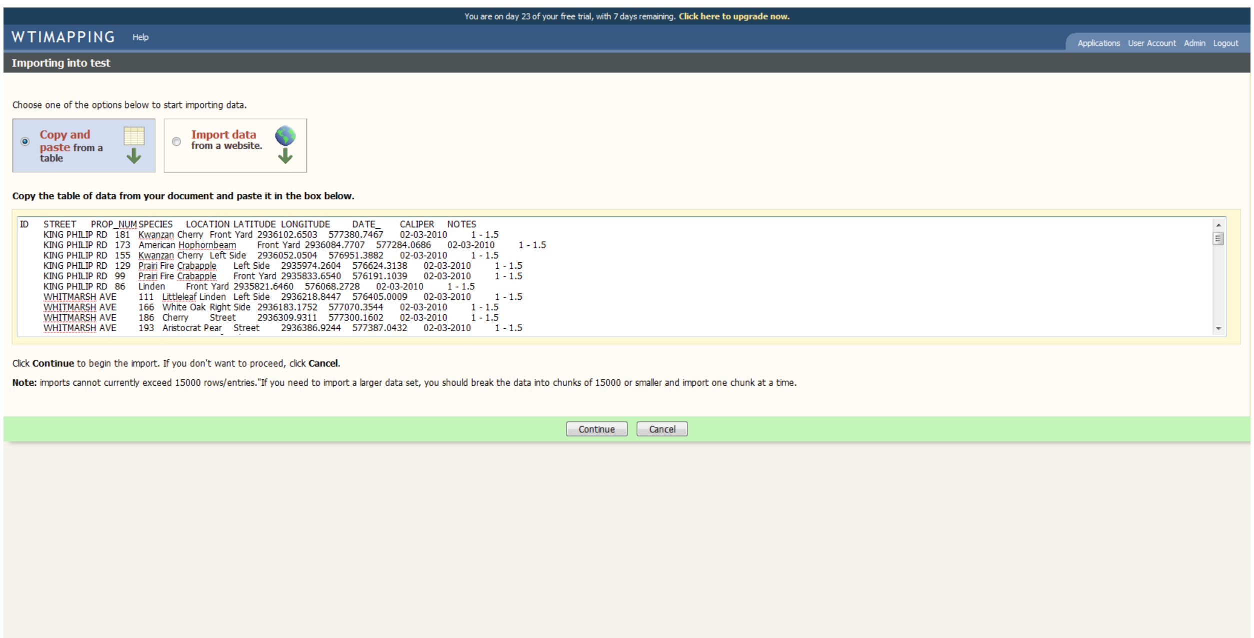
	A	B	C	D	E	F	G	H	I
1	ID	STREET	PROP_NUM	SPECIES	LOCATION	LATITUDE	LONGITUDE	DATE_	CALIPER	NOTES
2		KING PHILIP RD	181	Kwanzan Cherry	Front Yard	2936102.6503	577380.7467	02-03-2010	1 - 1.5
3		KING PHILIP RD	173	American Hophornbeam	Front Yard	2936084.7707	577284.0686	02-03-2010	1 - 1.5
4		KING PHILIP RD	155	Kwanzan Cherry	Left Side	2936052.0504	576951.3882	02-03-2010	1 - 1.5
5		KING PHILIP RD	129	Prairi Fire Crabapple	Left Side	2935974.2604	576624.3138	02-03-2010	1 - 1.5
6		KING PHILIP RD	99	Prairi Fire Crabapple	Front Yard	2935833.6540	576191.1039	02-03-2010	1 - 1.5
7		KING PHILIP RD	86	Linden	Front Yard	2935821.6460	576068.2728	02-03-2010	1 - 1.5
8		WHITMARSH AVE	111	Littleleaf Linden	Left Side	2936218.8447	576405.0009	02-03-2010	1 - 1.5
9		WHITMARSH AVE	166	White Oak	Right Side	2936183.1752	577070.3544	02-03-2010	1 - 1.5
10		WHITMARSH AVE	186	Cherry	Street	2936309.9311	577300.1602	02-03-2010	1 - 1.5
11		WHITMARSH AVE	193	Aristocrat Pear	Street	2936386.9244	577387.0432	02-03-2010	1 - 1.5
12		HILLCROFT AVE	43	Aristocrat Pear	Left Side	2936161.1019	577619.7455	02-03-2010	1 - 1.5
13		HILLCROFT AVE	61	Littleleaf Linden	Street	2936425.7867	577562.3464	02-03-2010	1 - 1.5
14		HILLCROFT AVE	61	White Oak	Right Side	2936478.3120	577574.7948	02-03-2010	1 - 1.5
15		HILLCROFT AVE	76	Kwanzan Cherry	Right Side	2936629.8392	577677.2281	02-03-2010	1 - 1.5
16		HILLCROFT AVE	87	Prairi Fire Crabapple	Right Side	2936905.0630	577587.2418	02-03-2010	1 - 1.5
17		HILLCROFT AVE	92	Littleleaf Linden	Right Side	2936945.8696	577768.6395	02-03-2010	1 - 1.5
18		HILLCROFT AVE	100	Aristocrat Pear	Street	2937061.6389	577641.5563	02-03-2010	1 - 1.5
19		HILLCROFT AVE	105	Aristocrat Pear	Left Side	2937063.8709	577513.4664	02-03-2010	1 - 1.5
20		HILLCROFT AVE	116	Littleleaf Linden	Street	2937282.6058	577526.9632	02-03-2010	1 - 1.5
21		HILLCROFT AVE	132	Snowdrift Crabapple	Front Yard	2937577.1006	577380.4097	02-03-2010	1 - 1.5
22		HILLCROFT AVE	132	Callery Pear	Left Side	2937581.2281	577391.9612	02-03-2010	1 - 1.5
23		HILLCROFT AVE	132	Callery Pear	Left Side	2937591.5493	577418.1719	02-03-2010	1 - 1.5
24		HILLCROFT AVE	132	Kwanzan Cherry	Back Yard	2937588.4882	577452.5048	02-03-2010	1 - 1.5
25		HILLCROFT AVE	126	Black Oak	Back Yard	2937421.8992	577526.2580	02-03-2010	1 - 1.5
26		HILLCROFT AVE	126	Kwanzan Cherry	Back Yard	2937413.9112	577527.7521	02-03-2010	1 - 1.5
27		HILLCROFT AVE	121	Cherry	Front Yard	2937282.4228	577362.3134	02-03-2010	1 - 1.5
28		CUTTING AVE	9	Black Oak	Street	2937127.3336	577179.8284	02-03-2010	1 - 1.5
29		CUTTING AVE	12	Kwanzan Cherry	Right Side	2937149.7374	577060.6140	02-03-2010	1 - 1.5
30		CUTTING AVE	10	Kwanzan Cherry	Left Side	2937175.0693	577048.4835	02-03-2010	1 - 1.5
31		GRANVILLE AVE	59	Cherry	Left Side	2937127.0276	576842.6807	02-03-2010	1 - 1.5
32		GRANVILLE AVE	52	White Oak	Street	2937111.3517	576922.5817	02-03-2010	1 - 1.5
33		GRANVILLE AVE	49	Kwanzan Cherry	Front Yard	2936951.6176	576901.4774	02-03-2010	1 - 1.5
34		GRANVILLE AVE	31	Cherry	Street	2936822.2568	576960.1186	02-03-2010	1 - 1.5
35		GRANVILLE AVE	3	Prairi Fire Crabapple	Back Yard	2936447.9224	577038.6056	02-03-2010	1 - 1.5
36		DOROTHY AVE	21	Crabapple	Front Yard	2936508.9692	577163.6244	02-03-2010	1 - 1.5
37		DOROTHY AVE	16	Pear	Street	2936635.8249	577274.3424	02-03-2010	1 - 1.5
38		DOROTHY AVE	8	Prairi Fire Crabapple	Right Side	2936806.9729	577504.8454	02-03-2010	1 - 1.5
39		DOROTHY AVE	3	Linden	Back Yard	2936710.0281	577698.2186	02-03-2010	1 - 1.5
40		JEPPSON AVE	34	Aristocrat Pear	Street	2937015.3686	577561.7402	02-03-2010	1 - 1.5

wti_tree

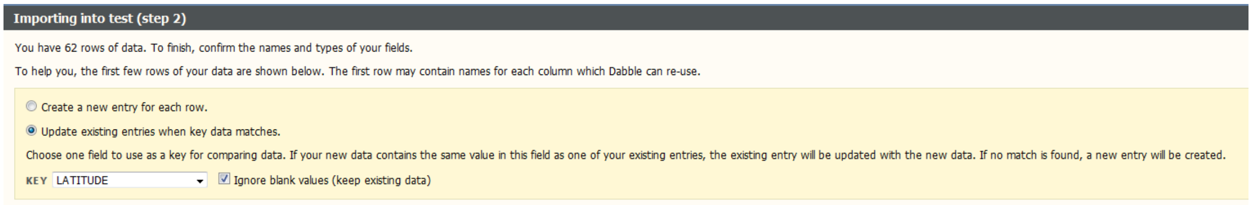
Ready Count: 504 100%

Next, use an internet browser and login to the dabble db application. Click “Import Data” in the upper right corner. On the next web page, select which category you would like to import into, using the dropdown menu, and click on the “Import” button.

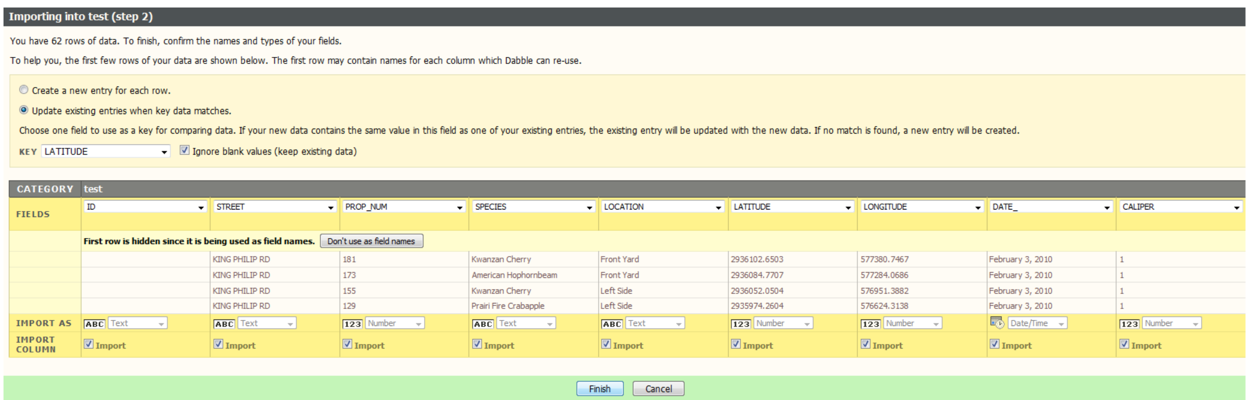
Paste the spreadsheet data (ctrl + v) into the box and click “Continue”.



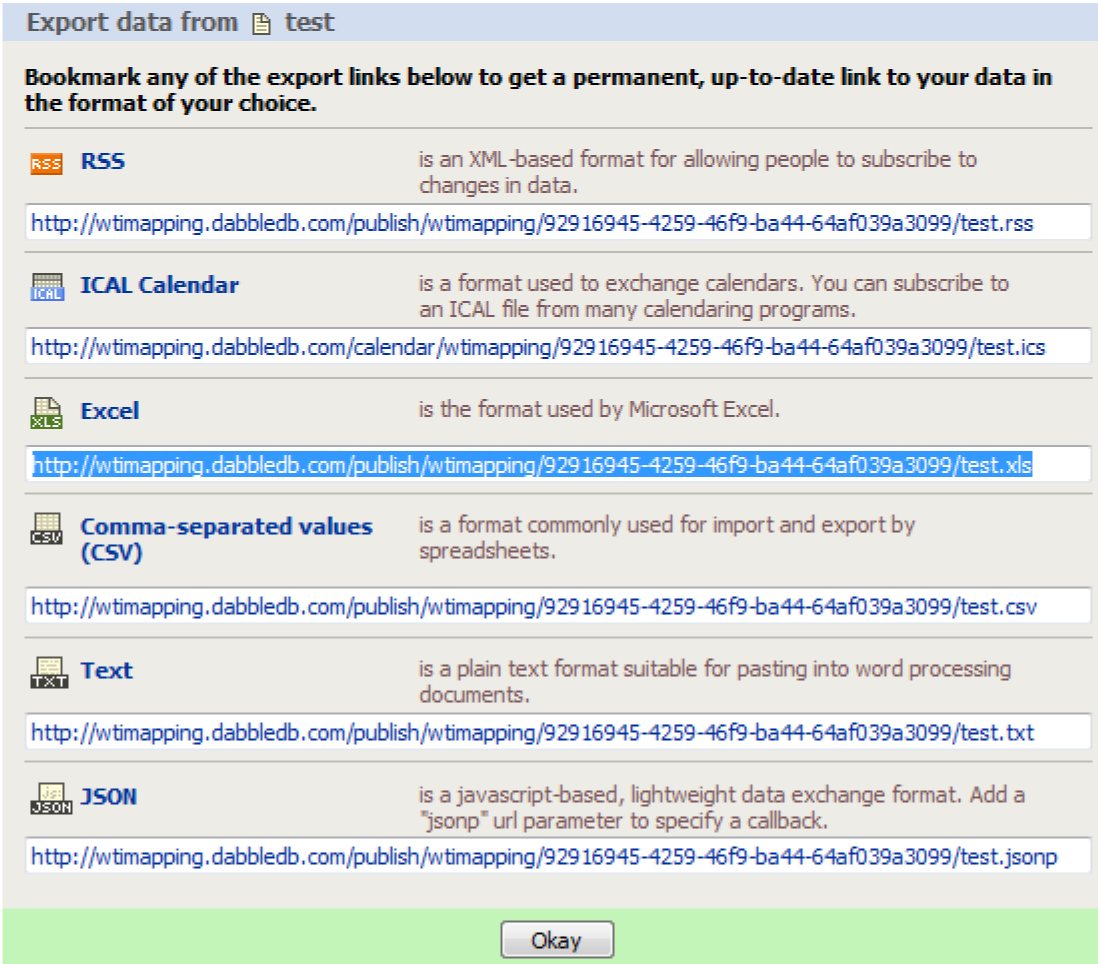
There are two radio buttons at the top of the next web page. Select “Update existing entries when key data matches”. Next to “KEY”, select “LATITUDE” and check the checkbox labeled “Ignore blank values (keep existing data)”.



Verify that the field names are correct and the data type is set correctly. Dabble DB generally analyzes the data type correctly, but the date field can be imported as either “Date/Time” or “Text” depending on user preferences, for example. Click the “Finish” button.



The data has been imported into the database. To export the database view into Excel format, click the “Export” button. Save the view if needed. Dabble DB provides a web address for each file format.


Export data from test
Bookmark any of the export links below to get a permanent, up-to-date link to your data in the format of your choice.
RSS
is an XML-based format for allowing people to subscribe to changes in data.
http://wtimapping.dabbledb.com/publish/wtimapping/92916945-4259-46f9-ba44-64af039a3099/test.rss
ICAL Calendar
is a format used to exchange calendars. You can subscribe to an ICAL file from many calendaring programs.
http://wtimapping.dabbledb.com/calendar/wtimapping/92916945-4259-46f9-ba44-64af039a3099/test.ics
Excel
is the format used by Microsoft Excel.
http://wtimapping.dabbledb.com/publish/wtimapping/92916945-4259-46f9-ba44-64af039a3099/test.xls
Comma-separated values (CSV)
is a format commonly used for import and export by spreadsheets.
http://wtimapping.dabbledb.com/publish/wtimapping/92916945-4259-46f9-ba44-64af039a3099/test.csv
Text
is a plain text format suitable for pasting into word processing documents.
http://wtimapping.dabbledb.com/publish/wtimapping/92916945-4259-46f9-ba44-64af039a3099/test.txt
JSON
is a javascript-based, lightweight data exchange format. Add a "jsonp" url parameter to specify a callback.
http://wtimapping.dabbledb.com/publish/wtimapping/92916945-4259-46f9-ba44-64af039a3099/test.jsonp
Okay