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Use of geographic information systems at Gifft Hill School, St. John, U.S. Virgin Islands

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Use of geographic information systems at Gifft Hill School, St. John, U.S. Virgin Islands

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ABSTRACT

Board members, administrators, and faculty at Gifft Hill School, St. John, U.S. Virgin Islands, required a method for recording, organizing, and communicating information about the property and facilities on the school grounds. This information will be used while planning and managing facilities expansion. In addition to these physical attributes of the property and facilities Iowa State University desired a way of recording growing conditions to inform the design and manage of a school garden program. Geographic information systems (GIS) were evaluated as a possible solution to managing this spatially variable information. Using ArcGIS, Global Positioning System (GPS), data available from government agencies, and data collected on-site, we built a GIS for Gifft Hill School. In 2010, we collected and mapped environmental variation at candidate locations for school gardens. By mapping land cover and current and planned buildings, we determined the most suitable locations for initial school gardens using ArcGIS model builder and calculated site areas for budgeting purposes. We combined GIS and GPS to plan a trail through dense vegetation between the two Gifft Hill School campuses. The use of GIS to collect and manage information about the site and facilities has been successful in initial planning and construction activities.

CHAPTER 1. INTRODUCTION

Thesis Organization

Chapter 2 presents a manuscript titled Informed Site Planning Using Geographic Information Systems to Map Environmental Conditions, Infrastructure, and Facilities, which will be submitted for publication in HortTechnology. This manuscript describes problems with information availability at Gifft Hill School, U.S. Virgin Islands and examples of our efforts to solve these problems through the use of geographic information systems (GIS). Kevin Duerfeldt collected, analyzed, and interpreted the raw data. Dr. Michael Reinert planned the project and provided guidance during data collection, analysis, interpretation, and writing of this manuscript.

General Introduction

Gifft Hill School, St. John, U.S. Virgin Islands is a private kindergarten through twelfth grade school and is the only high school on the island. St. John is a remote Caribbean island in the Lesser Antilles (Ch 2. Fig. 1). This island is removed from many conveniences that we take for granted. This creates both physical and social challenges to living and working on island. We observed the island has little fresh water other than what is collected from roofs and stored in cisterns. Utilities are unreliable; it is not uncommon for electricity or Internet services to be interrupted multiple times during a week. Groceries are expensive and of unreliable quality and supply, for example while visiting in 2010 we found watermelon cost 18 dollars apiece. While working on the island during the summer of 2010, we learned that produce must be purchased and consumed quickly after being received by grocery stores to avoid spoiling. Statistics provided by The Annie E. Casey Foundation give evidence of social problems on St. John. Of children in the Virgin Islands, 55% are raised in single-parent homes, whereas the U.S. national average is 32%. Seventeen percent of teens between the ages of 16 and 19 are neither enrolled in school nor working, which is more than twice the national average of 8%. Thirty-four percent of children in the Virgin Islands live in poverty, nearly twice the U.S. national average of 18% (Kids Count Databook, 2010).

To address some of these physical and social problems, a mutual benefactor of Iowa State University and Gifft Hill School provided a gift to Iowa State University that allowed the two schools to develop a service learning and school garden program. This program, called EARTH (Education And Resiliency Through Horticulture), was designed to integrate horticulture and environmental science into the curriculum at Gifft Hill School and improve perceptions of agriculture among students of Gifft Hill School. The EARTH Program is constructing and managing gardens and other facilities that are both aesthetically pleasing and educational. These facilities provide a leaning environment for students and fresh fruits and vegetables for the school lunch program. The development of gardening programs to change attitudes and behaviors is supported in the literature. For example, school garden programs have been shown to increase students' preferences for eating fruits and vegetables (Lineberger et al., 2000) and to increase science achievement and positive classroom behavior among students (Klemmer et al., 2005; Blair, 2009).

While planning the program and the construction of initial facilities, we recognized several gaps in our knowledge of the site and problematic growing conditions on St. John. These problems include absence of information about the property, its boundaries, and manmade structures; shallow, rocky soils; intense wind and solar radiation; extreme wet and dry seasons; highly erodible soils; unstable slopes created during previous construction; and eroded soil causing sedimentation in Fish bay, negatively affecting marine ecosystems downstream of the school.

To understand these problems, we collected information about property characteristics such as property lines, topography, and ground cover using publically available datasets from the United States Geological Survey and the Natural Resources Conservation Service. The locations of existing and planned buildings, driveways, parking areas, and entrances were collected using a GeoXT GPS unit (Trimble Navigation Limited, Sunnyvale, CA) and site plans provided by the Gifft Hill School Board and georeferenced to the site. We began environmental monitoring by installing a Davis weather station at Gifft Hill School and by taking similar measurements using hand held data loggers with sensors for temperature, humidity, and wind velocity. We collected soil samples and had soil fertility and geotechnical engineering tests completed. We used all of this information to create a geographic information system (GIS) that can be used to analyze and communicate site information to board members of Gifft Hill School. Our GIS will save the school time and money by allowing board members to make informed decisions as they continue development of the property.

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CHAPTER 2. INFORMED SITE PLANNING USING GEOGRAPHIC INFORMATION SYSTEMS TO MAP ENVIRONMENTAL CONDITIONS, INFRASTRUCTURE, AND FACILITIES

Modified from a paper submitted for publication in HortTechnology

Kevin R. Duerfeldt and Michael E. Reinert

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ABSTRACT. Board members, administrators, and faculty at Gifft Hill School, St. John, U.S. Virgin Islands, required a method for recording, organizing, and communicating information about the property and facilities on the school grounds. This information will be used while planning and managing facilities expansion. In addition to these physical attributes of the property and facilities Iowa State University desired a way of recording growing conditions to inform the design and manage of a school garden program. Geographic information systems (GIS) were evaluated as a possible solution to managing this spatially variable information. Using ArcGIS, Global Positioning System (GPS), data available from government

agencies, and data collected on-site, we built a GIS for Gifft Hill School. In 2010, we collected and mapped environmental variation at candidate locations for school gardens. By mapping land cover and current and planned buildings, we determined the most suitable locations for initial school gardens using ArcGIS model builder and calculated site areas for budgeting purposes. We combined GIS and GPS to plan a trail through dense vegetation between the two Gifft Hill School campuses. The use of GIS to collect and manage information about the site and facilities has been successful in initial planning and construction activities

Introduction

Gifft Hill School is a private kindergarten through twelfth-grade school on the island of St. John, U.S. Virgin Islands (Fig. 1). In 2010, the school approached the Iowa State University Department of Horticulture through a mutual benefactor to develop a collaborative service-learning and school garden program. This program, now the EARTH program (Education And Resiliency Through Horticulture), is centered on teaching horticulture and natural sciences in their middle school. One of the goals of the EARTH program is to construct school gardens that produce fruits and vegetables for the school-lunch program. Through the addition of gardening to the curriculum and fresh produce to the lunch program the EARTH Program hopes to ameliorate social challenges found on St. John. These challenges include: one, the high cost and low quality of produce shipped to the island; two, unhealthy, fried diets; three, student’s environmental science self efficacy; and four, sustainability of life on St. John. These challenges were communicated to us by faculty at Gifft Hill School and observed by researchers during initial visits. During initial discussions, it became apparent that a lack of recorded site information posed challenges for the program. To move forward in developing the property, information such as topography, property lines, locations of current facilities, distances between facilities, and site area were needed to make decisions. To properly design and manage the planned gardens, temperature, light intensity, humidity, wind velocity and direction, soil fertility, and physical characteristics of the soil also needed to be recorded and available for use. Geographic information systems (GIS) was chosen as a means to capture, manage, and communicate this spatially variable information and solve the information availability problem at Gifft Hill School.

GIS is "a system for capturing, storing, checking, manipulating, analyzing and displaying data which are spatially referenced to the Earth" (Department of the Environment, 1987). GIS maps are analogous to maps drawn on clear cellophane layers that can be overlaid to compare spatial relationships between two or more data sets. Computer-based GIS were developed in the late 1960's and evolved from the fields of cartography and spatial analysis (Coppock and Rhind, 1991). The two types of GIS are vector and raster, and both use a combination of maps and tables to store and display information. Vector GIS stores discrete data such as data collection sites, trails, and buildings as points, lines, and polygons. Raster GIS uses grid cells to create surfaces from continuous data such as elevation or soil fertility. Tabular data are composed of features in rows, and attributes of features in columns.

The use of GIS in precision agriculture is well documented through case studies. The National Research Council (1997) defined precision agriculture as “a management strategy that uses information technology to bring data from multiple sources to bear on decisions associated with crop production.” Using this definition, our efforts to plan and manage teaching and production gardens at Gifft Hill School using GIS qualify as precision agriculture, even though they are not on a commercial scale. The objectives of precision agriculture are to increase efficiency of time, energy, and chemical inputs, to improve product quality and to protect the environment (Roberson, 2000). Several examples of how GIS has been used in precision agriculture include mapping slope in commercial blueberry fields (Zaman et al., 2010), precision placement of fertilizer applications by guiding variable rate applicators in citrus orchards (Schumann, 2010), and selecting trees for agroforestry (Ellis et al., 2000).

We have three objectives for this research. First, collect and organize pertinent information needed for the planning, design, construction, and management of facilities and gardens at Gifft Hill School. Second, use GIS to assist Gift Hill School with planning and construction of facilities. Third, produce an example of GIS used successfully, at scales smaller than those for which it is typically applied.

Materials and Methods

Study site

GIFFT HILL SCHOOL. Gifft Hill School is a private kindergarten through twelfth grade school located on the island of St. John, U.S. VI, 18°19'51"N, 64°46'19"W. It was established as a preschool in 1978 and merged with Coral Bay School in 2004. This was the first time students were able to receive a seamless primary and secondary education on St. John. The school's property is six hectares and contains the lower campus, which houses the elementary school; the upper campus, which houses the middle and high schools; and areas of undeveloped vegetation (Fig. 2). Students and faculty at the school include a diverse mix of race, family income level, and cultural background.

Site selection

POTENTIAL GARDEN LOCATIONS. We monitored the environment at four locations determined to be the most suitable for initial school gardens. These locations were chosen using model builder in ArcGIS (ESRI, Redlands, CA). We created a model that identified suitable locations based on proximity to classrooms and current land use or cover (Fig. 2, Fig. 3). This model used geoprocessing tools to analyze a map of current land use and locations of property lines, buildings, and a drainage way. Only open, forest, and additional areas were selected. "Open" refers to flat areas cleared of woody vegetation, "forest" includes areas that are steep and covered in dense vegetation, and "additional" areas include sidewalks, entrances, and concrete gathering spaces. The maximum distance allowed from classrooms changed with ground cover to acknowledge the differences in difficulty moving through steep areas of dense vegetation compared with flat open areas. We allowed this model to consider sites at distances of up to 150 m from a classroom to be chosen for open and additional areas, and 50 m for forested areas. These distances are intended to allow sufficient time for students and faculty to walk between gardens and classrooms, without spending excessive class time doing so. A drainage way enters the property between the main building and soccer field. This drainage way is buffered nine meters; disturbing the vegetation in this area during construction practices is discouraged. This suggestion is in accordance with guidelines for sustainable development promoted by the Coral Bay Community Council (2006). This buffer is intended to prevent eroded soils from causing sedimentation in local bays. The Coral Bay Community Council is a nongovernmental organization that allows residents to participate in future commercial and residential development and coordinates storm water mitigation, erosion, and sedimentation research on the island.

PLANNED TRAIL. We integrated GIS and Global Positioning System (GPS) to plan a trail connecting the upper campus, which houses the middle and high schools, to the lower campus, which houses the elementary school (Fig. 2). Using georeferenced plans for the property and topography lines obtained from the Coral Bay Community Council, we planned a route for a trail that balanced distance and change in elevation. We then uploaded the coordinates of the planned trail onto a GeoXT GPS unit (Trimble Navigation Limited, Sunnyvale, CA). This allowed us to navigate through the forest, clearing the proposed trail.

Data collection and analysis

SPATIAL DATA. Table 1 describes all the layers, and their sources, that we used in ArcGIS (ESRI, Redlands, CA). Initial spatial data were supplied by governmental and nongovernmental agencies through online servers and personal communications with agency officials. Current structures were digitized using aerial images. Plans for future construction were scanned, georeferenced, and digitized. All files were downloaded in, created in, or converted to U.S. State Plane Coordinate System, Puerto Rico U.S. Virgin Islands. This is a Cartesian coordinate system used in place of longitude and latitude for assigning locations on maps. We also used North American Datum 1983 to translate locations from a flat map to positions on the ellipsoid earth.

ENVIRONMENTAL MONITORING. Environmental data were collected using a Davis weather station (Davis Instruments, Hayward, CA); PASCO SPARK, a mobile learning device and data logger with plug-in sensors (PASCO, Roseville, CA); and Oakfield soil probe (Oakfield Apparatus, Inc., Oakfield, WI). Equipment was chosen based on two criteria: ability to provide precise and accurate data for site planning, and ease of implementation in a classroom setting.

The Davis weather station was installed permanently on the lower field (Fig. 5) and continuously records conditions in five-minute intervals. The integrated sensor suite includes a rain collector, temperature and humidity sensors, and an anemometer. Additional sensors to measure solar radiation, soil temperature, and soil moisture were added to the integrated sensor suite. We also measured weather conditions daily using the PASCO SPARK. This mobile, handheld unit was chosen based on its design for a kindergarten through twelfth grade science curriculum. It includes predesigned lab assignments suitable for use in the classrooms after this research is complete. The PASCO SPARK was used to take temperature, light intensity, and wind velocity measurements on the lower field (site 1), memorial basketball court (site 2), along the soccer field (site 3), and middle school outdoor classroom (site 4) (Fig. 5). We analyzed results using the PROC GLM procedure of the Statistical Analysis System software, (SAS, Version 9.2 SAS Institute Inc., Cary, NC).

SOIL FERTILITY. One composite soil fertility sample was collected from each of the four potential garden areas, classified as open by the site selection model. These open areas were the only accessible areas where in-ground production could be utilized. We used composite soil sampling techniques (Sawyer et al., 2003) (Fig. 5). Composite tests were shipped using guidelines and USDA/APHIS permits supplied by the Geotechnical Testing Lab, Iowa State University, Ames, IA. The Soil and Plant Analysis Lab, Iowa State University, Ames, IA, analyzed soil fertility using the Mehlich 3 method and also measured pH and percent organic matter.

Results

ENVIRONMENTAL MONITORING AND VARIATION. Environmental conditions likely to affect the production of horticultural crops varied within the property. Results of soil fertility analyses showed that amounts of many elements varied considerably between sites (Table 2). Soil interpretations and crop responses to fertilizer applications have not been published for St. John. Using recommendations for other areas we determined that these alkaline soils test between very low and optimum for phosphorus and between very low and low for potassium (Brandenberger et al. 2009). Wind velocity was the only weather condition tested that varied among sites (Fig 5.). Wind velocity at the memorial basketball court averaged 0.36 m/s where as wind velocity at the other three sites averaged 1.37 at the soccer field, 1.31 in the social area, and 1.2 m/s at the weather station.

LAND USE PLANNING. We successfully identified potential garden sites based on current land use and proximity to buildings using GIS. We used ArcGIS model builder to create a map showing possible locations for school gardens using a map of current land use and distances from the classrooms (Fig. 2, Fig.3, Fig. 4). Available areas were divided into three types: open, forest, and additional. Horticultural production could be added to additional areas through the use of foundation plantings and container gardens. Outputs from this model were used to calculate area available for school gardens (Table 3).

INFRASTRUCTURE PLANNING. GIS was used successfully to determine the optimal route for a trail connecting the two campuses at Gifft Hill School. We were able to navigate, clear, and mark this route using GPS (Fig. 6). We were able to determine the length of the trail using GIS and solicit estimates for construction from a local contractor.

Discussion

Environmental conditions likely to affect the production of horticultural crops varied across the property of Gifft Hill School, and this variation could be mapped in conjunction with current and planned facilities and infrastructure by using GIS. Furthermore, these maps were used to allocate land effectively for different purposes and plan future expansion and construction of new facilities.

Soil samples were tested to evaluate soils for the purpose of horticultural production. Although the unreplicated nature of the composite samples precluded statistical analysis, these preliminary data revealed some unusual edaphic conditions and varied among sites. Variability in content of soil elements may be a result of construction activities on the property. Due to steep slopes found on the island, construction of large buildings requires cut and fill. If the origin of fill differs from that of the construction site or other fill, large variation may be found in soil nutrient content on the site. After reviewing soil fertility and morphology results we determined that raised beds would provide a solution to producing fruits and vegetables in the shallow, rocky, relatively infertile soils found on site. Weather samples did not reveal any differences among potential sites except for the memorial basketball court, at which wind velocity was lower than that of the remaining sites. This area is protected from prevailing winds by the main building and a large hillside. Further testing of both soil fertility and climatic conditions could prove an informative and educational experience for students at Gifft Hill School and may reveal differences not seen in this study.

The site-selection model that we developed was used to determine the locations for soil sampling and environmental monitoring. We also were able to calculate geometry of potential areas and determine their size. Such information may assist with planning gardens, estimating costs, and ordering materials. Once gardens are constructed, attributes may be added in the GIS to track or plan crop rotations, yields, and pesticide applications. Gifft Hill School students could measure these garden areas using other methods and compare these measurements to ones generated using GIS. This practice is known as “ground truthing” and could be used in classes to explore errors in GPS coordinates. By developing our model further and adding more criteria such as sun exposure, soil moisture, and soil fertility, this model could be beneficial to practitioners installing any type of garden, and GIS technicians could use ArcGIS for garden site selection.

We planned a trail connecting the two campuses using GIS and GPS. GIS informed the placement of this trail by providing and organizing topographical information and the locations of existing buildings. We were able to follow contour lines to minimize change in elevation over the course of the trail. Challenges faced during the clearing of this trail included inaccurate topographical data, steep terrain, and dense vegetation. Topographical maps were obtained from the United States Geological Survey but did not represent current conditions after construction activities. We walked this trail with several stakeholders, including students, teachers, and a board member. They stressed the importance of completing this trail to combine and integrate the two campuses and ensure the safety of students. Gifft Hill School students now walk along a narrow busy road to travel between campuses. Now that the path for the trail has been identified, the board can plan how to continue with construction of a permanent trail. This will be the first time the board has used outputs from this GIS program to construct a key piece of infrastructure. A survey is in development to record both their impressions of the current system and their future expectations.

Maps were created using environmental monitoring and soil test results, information collected from government and nongovernment organizations, GPS, and digitized site plans (Fig 2, 4, 5, 6). These maps demonstrate that GIS can be used effectively to map and organize site information required to make informed decisions. Organizations can save significant amounts of time and money when sufficient information is provided during planning. We will continue to add to this GIS system in the future to increase its ability to assist the executive board and the EARTH program. We also have begun to work with staff at Gifft Hill School to integrate geographic information science into Gifft Hill School technology courses. By handing over management of this GIS to teachers and students, we hope to increase Gifft Hill School ownership of this system and ensure its continued use.

Several other authors had goals similar to ours, to improve site planning and management through the use of information and GIS. Ellis 2000, utilized GIS to select tree species and plan agroforestry systems in Florida. Schumann 2010 made use of GIS and variable rate fertilizer spreaders to eliminate fertilizer applications to areas of citrus orchards not occupied by trees. Zaman, 2010 used GIS to map slope in commercial blueberry fields. These authors worked with large areas and commercial crop production. In contrast, we studied a small six-hectare lot and educational facilities. Even though the projects differ in many aspects, the common theme among them is the benefit gained from an increase in available information through the use of GIS.

One challenge we identified while establishing GIS at Gifft Hill School was the cost of implementation. Our costs of implementing GIS were decreased through the use of site licenses and rental of equipment from the Department of Natural Resource Ecology and Management, Iowa State University, Ames, IA. Typical costs of implementation make small-scale GIS cost prohibitive, but as the cost of technology continues to decrease, the use of GIS should increase. An ongoing challenge likely to impede the expansion of GIS at Gifft Hill School is an absence of technicians trained to create these systems and a lack of skilled users educated in the technology. We hope to assist with overcoming this obstacle by adding GIS coursework to the Gifft Hill School curriculum during subsequent years of the EARTH Program.

Conducting research at Gifft Hill School presents three main physical challenges. First, the site is difficult to work on due to steep slopes, dense vegetation, heat, and intense sunlight. Second, supplies that we may run to the store for here on the main land may not be readily available on island and if they are they are more expensive. This means careful planning is required before departing for St. John. Third, erosion is a major concern at Gifft Hill School and on the rest of the island. Large rain events from tropical storms and hurricanes cause erosion and landslides on the island that destroy property and cause sedimentation in bays surrounding the island. To ensure that our construction activities at Gifft Hill do not further contribute to these problems we enlisted the help of Dr. David White, Iowa State University Department of Civil Engineering to collect baseline data on the geotechnical engineering properties of the soils at Gifft Hill School and at a property owned by the school in Fish Bay (Fig. 1). Results from these tests indicate that the soils at Gifft Hill School are highly erodible and particle size analysis of samples collected in fish bay revealed gap graded distribution curves resulting from mixing coral sand and eroded materials.

Several cultural challenges were also observed during the first year of this program. First, Gifft Hill School and the island itself have a high turnover rate. One faculty member told us that some islanders are hesitant of becoming friends with new comers until they have lived on island for several years. Second, students were hesitant of entering the forest while we were clearing the trail between the campuses and do not spend as much outside as we would imagine, living on a tropical island. Third many islanders are unfamiliar with how to grow and process fruits and vegetables, just as we are unfamiliar with their growing conditions.

To record base line data on these cultural observations, record pre and post student perceptions of the school garden program, and evaluate the impact of the school garden program on the self efficacy of Gifft Hill School Students a new line of research is scheduled to begin in the Fall of 2011. In addition to this new line of research we will also continue to evaluate GIS as a management tool at the school and begin implementing GIS into the curriculum. A survey has been developed and received IRB approval to record Gifft Hill School board member and faculty perceptions of GIS and their expectations for its implementation at Gifft Hill School. This survey will be conducted during the Fall of 2011.

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Table 1. Data sources and descriptions of layers used at Gifft Hill School, St. John, U.S. VI. Abbreviations are: Coral Bay Community Council, CBCC; United States Geological Survey, USGS (2011); and United States Census Bureau Topologically Integrated Geographic Encoding and Referencing system, TIGER (2011).

Layer	Source	Description
Aerial images	USGS	Spatially referenced satellite images
Drainage ways	CBCC	Locations of drainage ways
Elevation	USGS	Raster digital elevation file
Existing buildings	Digitized	Current buildings as constructed
Gifft Hill soils	Derived	Soils for Gifft Hill School
Land use	Digitized	Land use
Planned buildings	Digitized	Site master plan
Planned trail	Digitized	Trail from previous site master plan
Planned trail 2	Digitized	Trail we planned
Soil fertility	GPS and test results	Nutrient concentrations
Soil structure	GPS and test results	Construction properties of soil
St. John soils	USGS	NRCS soil survey
Topography	CBCC	10 ft contours
Trail as cut	GPS	Trail as we cut it
VI census data	U.S. Census Bureau TIGER	VI demographics
Weather samples	GPS and test results	Weather sampling sites

Table 2. Nutrient content of soils found in four potential garden sites at Gifft Hill School, St. John, U.S. VI. Composite soil samples were collected at depths of 0 to 27.5 cm and analyzed by the Iowa State University Soil and Plant Analysis Laboratory using the Mehlich 3 method. Locations of sample sites are shown in Fig. 4.

	Nutrient content (mg/L)													
Site	P	NH_4^+	NO_3^-	K	Na	Mg	Ca	Mn	Fe	Cu	Zn	Al	OM[z] (%)	pH
1	35	1.4	14.0	106	288	938	3884	124	186	9.3	4.3	360	4.7	6.85
2	3	1.3	36.0	43	1424	796	3716	87	72	17.8	1.6	213	2.2	7.90
3	23	2.8	0.8	61	206	808	2328	168	413	5.3	1.0	327	1.7	7.45
4	16	0.8	5.0	41	560	809	1528	86	126	2.5	0.6	216	0.9	7.30

[z]Organic matter

Table 3. Area of potential garden sites by current land use generated using ArcMap. Forests are steep areas of dense native vegetation. Open areas are flat and cleared of buildings or woody vegetation. Additional areas included sidewalks, entrances, patio space, and similar areas.

Land use	Area (m^2)	Area (ha)	Selected area (%)	Property (%)
Forest	7515	0.75	65.73	12.74
Open	2624	0.26	22.95	12.74
Additional	1295	0.13	11.33	2.19
Total selected area	11434	1.14	100.00	19.00
Total unselected area	48570	4.86	---	81.00
Total property	60000	6	---	100.00

Figure Captions

Fig. 1. Puerto Rico and the U.S. Virgin Islands. Inset shows St. John with the locations of Gifft Hill School and Fish bay.

Fig. 2. Current land use and property lines at Gifft Hill School. Additional spaces include sidewalks, entrances, and concrete gathering spaces. Athletic areas are the soccer field and basketball courts. Buildings house classrooms and administrative offices. Forests are steep areas of dense woody vegetation. Open areas have been cleared of vegetation and leveled during construction activities, but are not currently used for other purposes. Areas designated as parking are concrete or gravel and must remain accessible for parking vehicles and egress. Map projection and datum are as follows, U.S. State Plane Coordinate System, Puerto Rico, U.S. Virgin Islands, and North American Datum 1983.

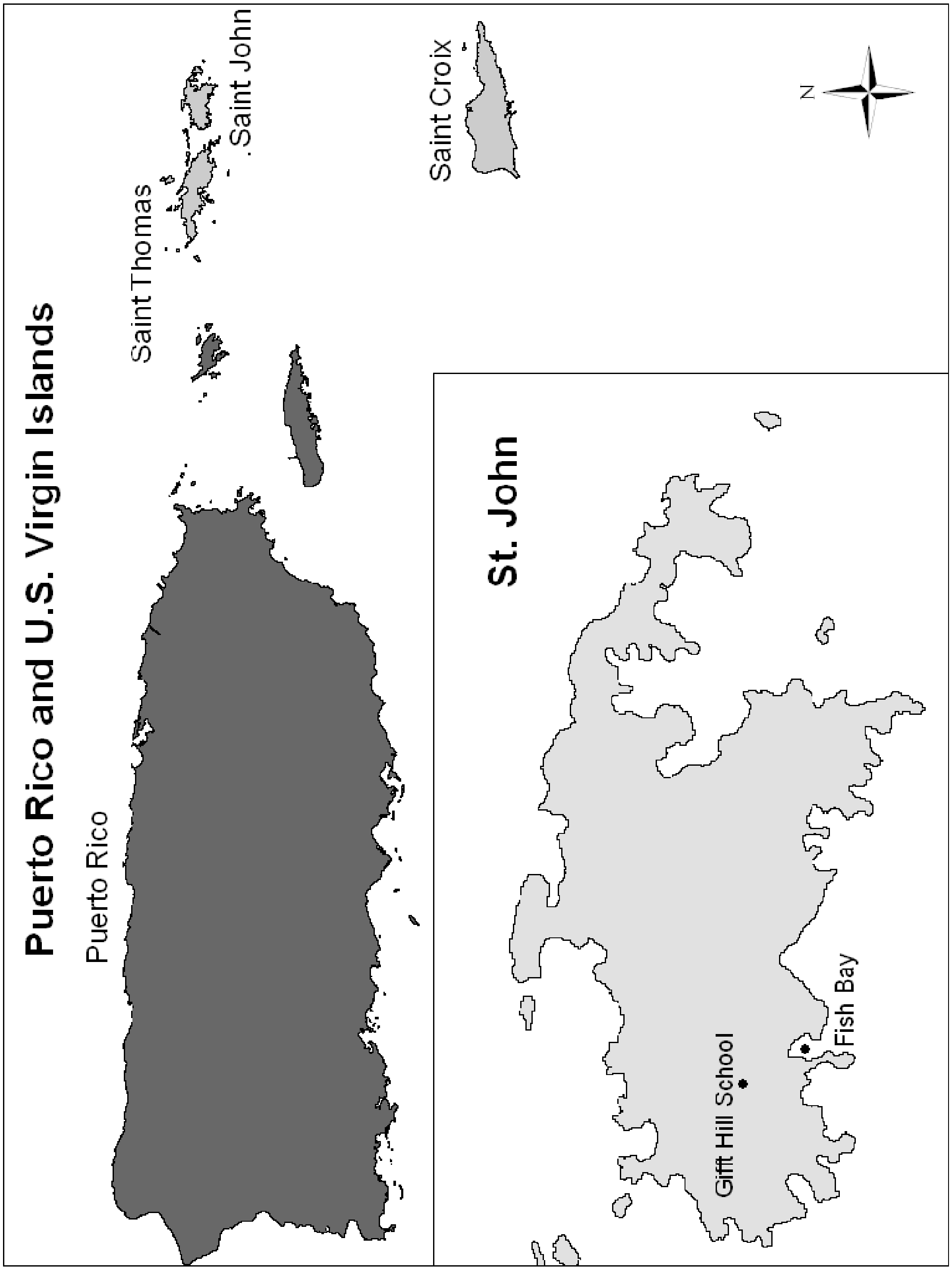
Fig. 3. Flow chart model made for garden site selection using ArcGIS model builder. Circular objects are source layers used from GIS. Squares are geoprocessing tools used to manipulate layers, and squares with rounded corners are intermediate results. The final result is symbolized with a diamond shape.

Fig. 4. Possible locations for school gardens and fruit and vegetable production gardens at Gifft Hill School, St. John, U.S. Virgin Islands. Requirements for selection include current land use, proximity to drainage ways (Coral Bay Community Council, 2006), and proximity to classrooms. Gardens are classified by

current land use. Open areas are flat and cleared of woody vegetation; forest refers to areas that have a steep incline and dense vegetation. Additional areas include sidewalks, patios, entrances, and paved meeting spaces. Map projection and datum are as follows, U.S. State Plane Coordinate System, Puerto Rico, U.S. Virgin Islands, and North American Datum 1983.

Fig. 5. Data collection points for weather monitoring including which instruments were used at each point. Locations are as follows: 1, lower field; 2, memorial basket ball court; 3, along the soccer field; and 4, middle school social area. Conditions at point one were collected using both a Davis weather station and PASCO SPARK. Conditions at points two, three, and four were collected using the PASCO SPARK. Areas where composite soil fertility samples were collected. Map projection and datum are as follows, U.S. State Plane Coordinate System, Puerto Rico, U.S. Virgin Islands, and North American Datum 1983.

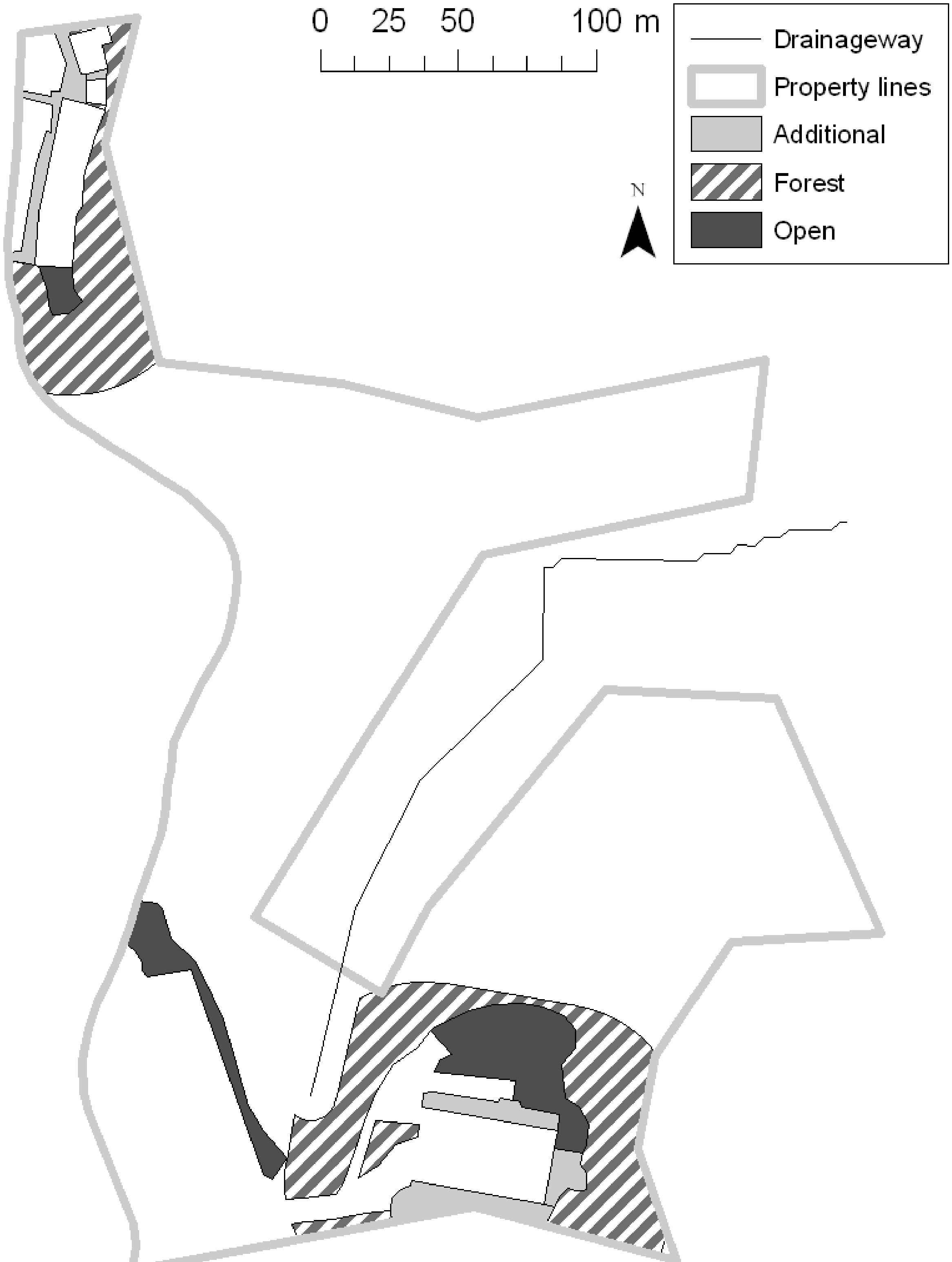
Fig 6. Master campus plan supplied by Gifft Hill School executive board February 2010 and scanned into GIS. This map includes existing buildings, planned buildings, and the post-GIS analysis trail connecting the upper and lower schools. Map projection and datum are as follows, U.S. State Plane Coordinate System, Puerto Rico, U.S. Virgin Islands, and North American Datum 1983.


Puerto Rico and U.S. Virgin Islands
Puerto Rico
Saint Thomas
Saint John
Saint Croix
N
St. John
Gift Hill School
Fish Bay

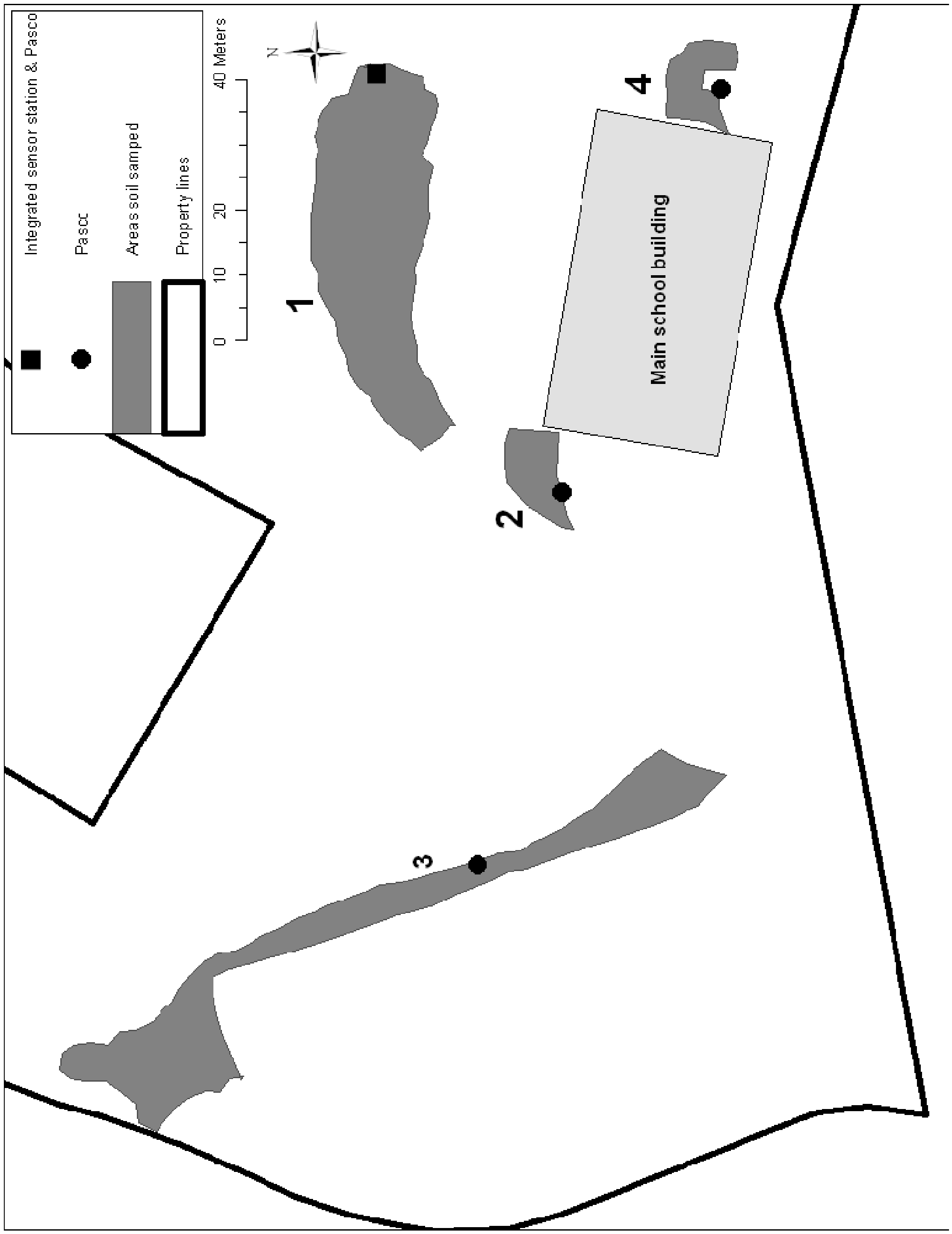
(Fig. 1)

(Fig. 2)

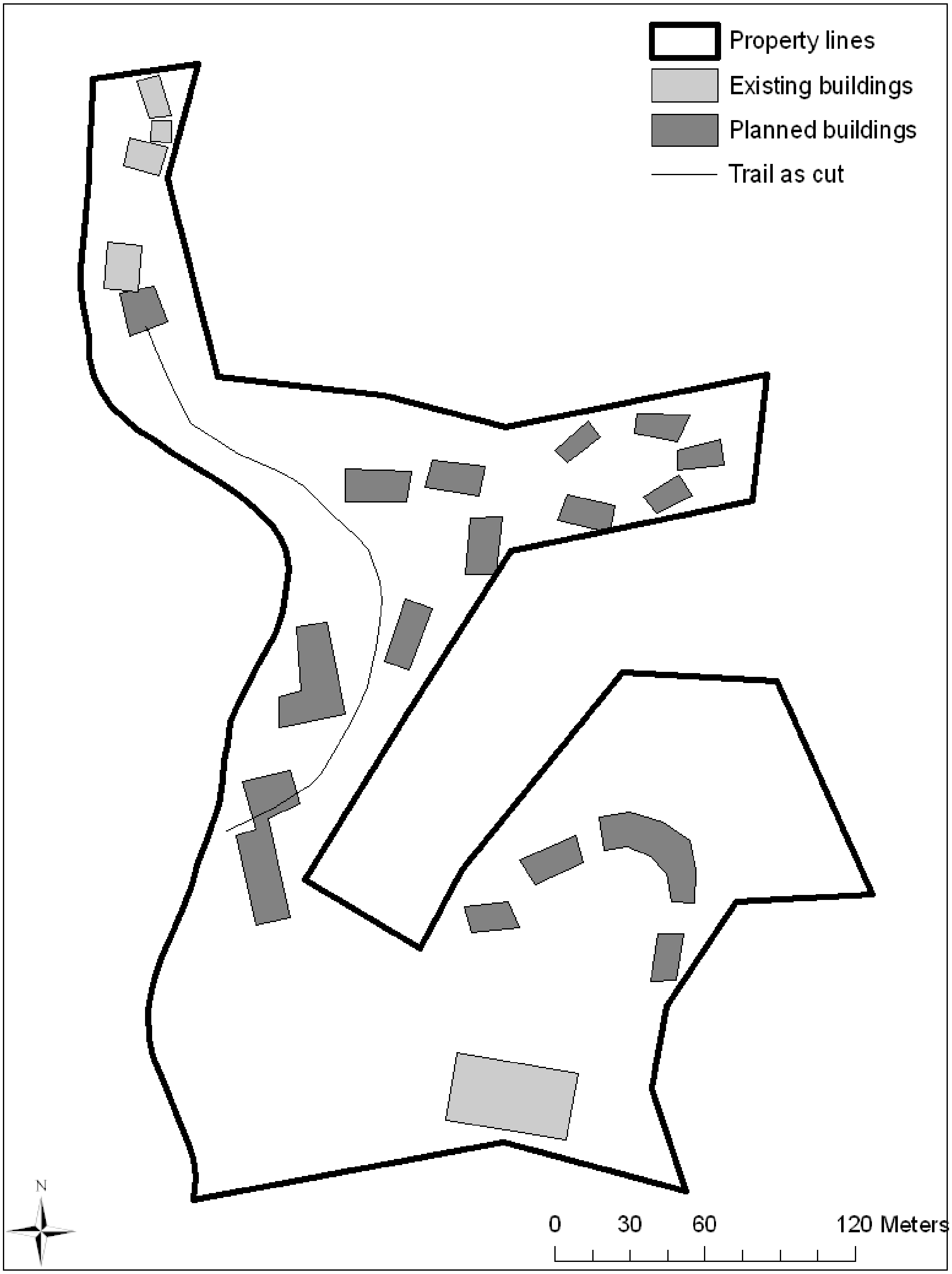
(Fig. 3)


0 25 50 100 m
Drainageway
Property lines
Additional
Forest
Open
N

(Fig. 4)


Integrated sensor station & Pasco
Pasco
Areas soil samped
Property lines
0
10
20
40 Meters
N
1
2
3
4
Main school building

(Fig. 5)



Property lines
Existing buildings
Planned buildings
Trail as cut
N
0
30
60
120 Meters

(Fig. 6)

CHAPTER 4. GENERAL CONCLUSIONS

We are beginning to witness significant changes on the island thanks to the EARTH Program. The school now has an artificial turf soccer field designed by Iowa State University before the inception of the EARTH Program, a half court basketball court, raised vegetable gardens and shade structure on an existing patio, and a new outdoor classroom that is also utilized as a yoga studio and social area for middle school students. We have frequently seen these facilities being used by not only Gifft Hill School students but also many community members. These facilities are a major asset to not only Gifft Hill School but the whole the island.

In one year, we have seen dramatic changes in the attitudes and behaviors of the students. They are excited to work outside and are very proud of the vegetables they have grown. We receive weekly updates from the program coordinator at Gifft Hill School showing us students enjoying the gardens and eating fresh produce. This fall, the EARTH program will begin a line of research to record student's initial views of horticulture, environmental science, and eating fruits and vegetables in relation to self efficacy in the classroom. Research presented in this thesis was a small part of the overall program conducted in support of these other objectives

In 2010, we began organizing data to be used for site planning at Gifft Hill School. We collected locations of facilities, topography, climatic data, soil fertility and engineering properties, and other information about Gifft Hill School's property from sources such as the United States Geological Survey, Natural Resource Conservation Service, local non-governmental organizations, and on site. We then organized this information using GIS to help Gifft Hill School with site planning. We were able to record current land use and create a model to select possible locations for initial school gardens to be constructed. We also planned and cleared a trail through the property to connect the two campuses. We then used GIS to make measurements of the trail's length and its change in elevation and used these measurements to solicit estimates from a local contractor.

A survey has been developed and will be given to faculty, staff, and board members at Gifft Hill School during the fall of 2011. This survey will record their perspectives and expectations for the use of GIS at Gifft Hill School. After recording initial perspectives, we will present to the school board the GIS and the information we have discovered through its use. The next challenge will be shifting management of the GIS to students and faculty at Gifft Hill School. To accomplish this we plan to add GIS as a component of computer science courses at Gifft Hill School. This will ensure its continued use and ensure that Gifft Hill School receives the maximum benefit from GIS. GIS classes will modify the system created for planning future facilities so that it can also be used to record historical information and manage facilities.

We hope to develop a second survey after further implementing GIS at Gifft Hill School to record board members' post perceptions of the system and evaluate the use of GIS for planning, recording, and coordinating site management activities. We also hope to modify research tools used in evaluating the impact of the school gardening program on student self-efficacy to measure the effects on students when we integrate management of the Gifft Hill School GIS into science and technology courses. The idea of integrating GIS into classrooms settings to increase students' self-efficacy is not new. Baker and White (2003) found that students who used GIS had an increased positive attitude toward technology, increased self-efficacy toward science, and greater ability to analyze geographic data. Integrating our GIS into classes at Gifft Hill school will not only benefit the students, but also will benefit the school by providing valuable information to the school board and faculty.

We collected numerous soil samples and conducted tests to evaluate both soil fertility and soil geotechnical engineering properties. Information gathered from soil fertility tests will be used to properly amend the soil before planting fruits and vegetables and to assist with identifying causes of poor plant growth and low productivity. We conducted particle size analysis, which revealed samples collected near Fish Bay have unique gap graded distributions. We believe these are a result of mixing eroded sediment and coral sand. Further geotechnical engineering research that should be conducted includes conducting more extensive soil samples in Fish Bay and along the drainage way to the school. This will give us a clearer picture of how much sedimentation is being caused by activities at Gifft Hill School. We will also be installing and evaluating different technologies to mitigate soil erosion and stabilize slopes at Gifft Hill School.

Our research has lead to increased knowledge of the property of Gifft Hill School, which can be used for site planning and management and shows that GIS can be used for small-scale projects. We have collected baseline data on soil erosion and fertility and have installed weather monitoring equipment that lays the foundation for future work on the property and in the classroom.

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