THE UNIFIED ROLE OF GPS, PHOTOGRAMMETRY, GIS AND LAND POLICY IN SECURING LAND TENURE IN DEVELOPING COUNTRIES

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ABSTRACT

Land records management processes and technology developed in the US can be successfully and cost effectively implemented in developing countries. Photogrammetry, GPS surveying and GIS analysis modules can enable citizens in developing countries to quickly achieve secure land tenure.

This paper addresses not only the role today's geospatial technology plays in securing land tenure for citizens in developing countries, but also how policy reform can protect the land rights of the poor and other vulnerable groups such as women.

INTRODUCTION

Developing countries have much in common when it comes to creating an automated land registry. Existing ownership records are often non-existent or in a state of disarray (Fig. 1) and there is often insufficient budget for creating new registry, cadastre and tax databases.

Figure 1

The major challenge encountered by Stewart in the international market was the development of a land records automation program that can be implemented in a short time frame at the lowest cost possible. The ability to utilize the technologies employed in Mobile GIS has greatly simplified the task of acquiring data in the field. A Bluetooth® enabled Mobile GIS enables field based personnel to capture, store, update, manipulate, analyze, and display geographic information. Mobile GIS integrates one or more of the following technologies:

- Mobile devices (Fig. 2) are supported by the ESRI ArcPad software which permit vector map and raster image display)
- Global Positioning Systems (GPS)
- Wireless communications for Internet GIS access

Figure 2

The Mobile GIS technologies play an important role in the creation of street centerline and address databases and ownership data acquired during a "Cadastral Sweep", an ownership determination methodology developed by Stewart. Creation of GIS databases utilizing Mobile GIS is discussed further on in this paper.

What is Bluetooth®?

Bluetooth® is a high-speed, low-power microwave wireless link technology, designed to connect phones, laptops, PDAs, GPS receivers and other portable equipment together with little or no work by the user.

Bluetooth® is the name for a short-range radio frequency (RF) technology that operates at 2.4 GHz and is capable of transmitting voice and data. The effective range of Bluetooth® devices is 32 feet (10 meters). Bluetooth® transfers data at the rate of 1 Mbps, which is from three to eight times the average speed of parallel and serial ports, respectively. It is also known as the IEEE 802.15 standard. It was invented to get rid of wires. Bluetooth® is more suited for connecting two point-to-point devices, whereas Wi-Fi is an IEEE standard intended for networking.

A piconet is a network of devices connected in an ad hoc fashion using Bluetooth® technology. A piconet is formed when at least two devices, such as a laptop computer and a mobile phone, connect. A piconet can support up to eight devices. When a piconet is formed, one device acts as the master while the others act as slaves for the duration of the piconet connection. A piconet is sometimes called a personal area network (PAN).

Why is the technology called Bluetooth®

The heart of the Bluetooth® brand identity is the name, which refers to the Danish King Harald "Bluetooth®" Blaatand who unified Denmark and Norway. In the beginning of the Bluetooth® wireless technology era, Bluetooth® was aimed at unifying the telecom and computing industries.

Bluetooth® can be used to wirelessly synchronize and transfer data among devices. Bluetooth® can be thought of as a cable replacement technology. Typical uses include automatically synchronizing contact and calendar information among desktop, notebook and palmtop computers without connecting cables. Bluetooth® can also be used to access a network or the Internet with a notebook computer by connecting wirelessly to a cellular phone.

Bluetooth® in Mobile GIS

The convenience and flexibility of working with multiple digital devices was the driving factor behind the adoption of Bluetooth® technology by developers and users of Mobile GIS equipment. Taking GIS into the field has always focused on helping work crews complete jobs faster, and few things slow down and irritate Mobile GIS users faster than equipment wires that snag on door handles or cables getting tangled in bushes around utility poles.

Wireless technology's appeal in Mobile GIS has been confirmed by the widespread acceptance of ruggedized handheld GIS devices that incorporate a viewing screen, keyboard and GPS receiver into one integrated unit. The products' popularity will continue to grow now that the latest models have been introduced with Bluetooth® compatibility.

During the last few years, technological advancements in GPS receivers, wireless communications and ruggedized handheld devices have made Mobile GIS a reality. As each of the supporting technologies improved, so has the efficiency and productivity of taking GIS functionality and data out of the office and into the field.

PROJECTIONS AND DATUMS

A recent land registry automation project was undertaken by Stewart International for the Government of Antigua and Barbuda, an island nation located in the eastern Caribbean. Research on the Antigua and Barbuda grid and datum turned up the following information compiled by Cliff Mugnier, a teacher of Surveying, Geodesy and Photogrammetry at Louisiana State University.

"Antigua Island Astro 1943 Datum was observed at the U.S. Navy "astro" point named Bowditch 1943 (station A14) where, thanks to John W. Hager, Φ = 17° 10' 35.633" N, Λ = 61° 47' 45.268" W, and the orientation is based on the azimuth from James (station A13) to Pointed Hill (station A12) as ά = 268° 33' 09.8" from north. That "astro" point is located at the northern most point of land on Antigua Island. The ellipsoid of reference is the Clarke 1880 where a = 6,378, 249.145 m and 1/f = 293.465. Hager went on to mention that, "Also found are (seconds only) latitude = 36.371"N and longitude = 45.268"W and values marked U.S.C.&G.S. 1943 of latitude = 35.506"N and longitude = 45.380"W. I make the difference on the first at 1.2 meters and on the second at 4.9 meters."

Mugnier continues, "Possibly the astro was observed a short distance from the trig station. The British West Indies (BWI) Grid for Antigua and Barbuda is based on the Transverse Mercator where the central meridian, λo = 62° W, the latitude of origin is the equator, the scale factor at the latitude of origin m_o = 0.9995, False Easting = 400 km, and False Northing = nil. The formulae are the Gauss-Krüger, but for such a small span of latitude and longitude that includes all three islands; the distinction in this case is irrelevant. The National Imagery and Mapping Agency (NIMA) lists the three-parameter datum shift values (dated 1991) from Antigua Island Astro 1943 Datum (Clarke 1880) to WGS 84 Datum as:

$\Delta a = -112.145$m, $\Delta f \times 10^4 = -0.54750714$,

$\Delta X = -270$m ±25m, $\Delta Y = +13$m ±25m, and

$\Delta Z = +62$m ±25m, and the solution is based on one station."

It was quickly determined that the published coordinates of the Antigua control monuments were on the BWI grid and the Barbuda coordinates were published as UTM Zone 20 North..

Barbuda, which is due north of Antigua, was mapped some time after Antigua, and the grid coordinate shift (200,000 meters in eastings) was not noticed until the aerial triangulation of Barbuda was underway. After a great deal of research and GPS field observations the two islands were finally geospatially tied together in the BWI grid, for the first time in their history.

Barbuda Published Control

BA16	1940164.143	630915.878	6.400m
BA12	1953399.289	628241.369	38.100m

Antigua Published Control

ANT 69	1890542.127	434373.877	9.160M
ANT 43	1896761.377	422403.663	15.310M

Table 1

THE GEODETIC CONTROL NETWORK

Airborne GPS was utilized for the aerial photography of both islands. In addition to tying in the NGS control monuments (Fig. 3) on both islands, additional photo identifiable points (Fig. 4) were provided for inclusion in the digital aerial triangulation block adjustment. The resulting block adjustments achieved a sigma nought of better than 5 microns for each island.

Figure 3 - NGS Control Monument in Barbuda

Figure 4 - Photo Identifiable Control Point

STREET CENTERLINE AND ADDRESS DATABASE

GPS derived street centerlines are the basis of locating building centroids when no mapping exists and there is an urgent requirement to create a new and low cost land registry, cadastre and tax database. Laser technology is used to determine the angle and distance from the GPS derived street centerline to features such as property ingress and egress locations or the main entrance to a structure and Bluetooth® technology transmits the information to a ruggedized data collector.

Each street centerline is broken only at street intersections and each segment is snapped to another street segment unless it is the end of the segment. The centerlines are the mid-point between the edge of pavement on a paved street and unpaved street centerlines are the center of the drivable path. The streets database includes any street or path that could potentially have a structure located in the vicinity. (Fig.5)

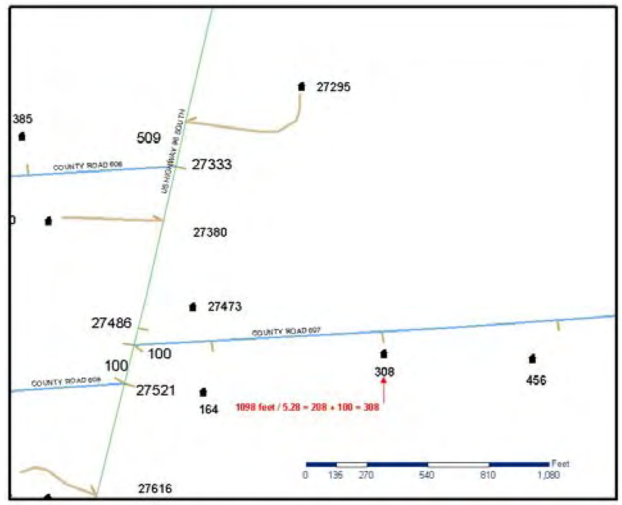

Figure 5 – GPS Derived Street Centerlines

Street names are assigned to each centerline segment within the street database using the Government provided street names database as the source for the data entry exercise. (Fig. 6) shows how GPS derived centerline data were used to confirm the accuracy of a parcel database in the island nation of Nevis.

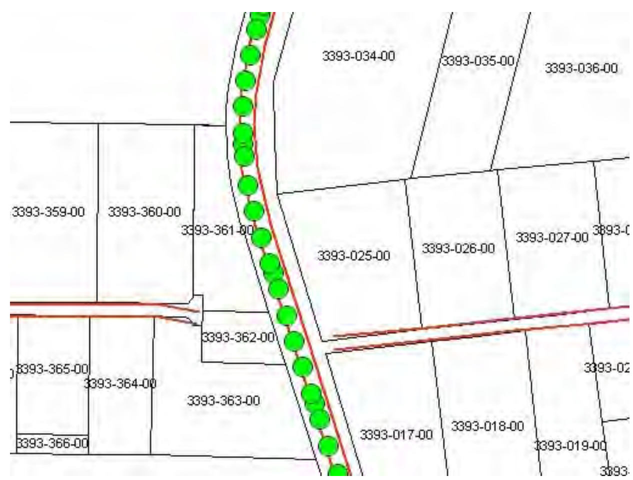

Figure 6 – GPS Centerline Data Overlaid on Parcel Data

If digital orthophotos are included as a project deliverable, they can be incorporated into the GIS as a backdrop to the GPS street centerline data. The final address is comprised of the street name and house number with a GIS linkage created between each house and the appropriate street centerline. A major advantage of street centerline and address database creation utilizing GPS is the ability to provide such data as much as 120 days before digital orthophotos or aerial mapping can be delivered. This enables a new land registry to be created and tax calculation and billing to commence as quickly as possible.

THE CADASTRAL SWEEP

A Cadastral Sweep is a methodology of determining property ownership by teams of surveyors and paralegals who conduct interviews with the owners/occupiers of property within jurisdictional boundaries of countries or municipalities. There are many factors that can affect the interview process. For example, the owner/occupier may not wish to talk about the intended use of the property, if it was inherited, the purchase and sale of the land or other similar events.

Issues may also arise regarding the paperwork regarding land ownership or real property ownership. It may be that the paperwork required to obtain a Deed of Title was never completed because of the onerous process and cost. A likely question might be "What will you do with my papers?" Also, those owners/occupiers who do not have the required paperwork may find themselves in an embarrassing public situation. Under such circumstances, the interviewee may indicate that the documents are located elsewhere, hopefully bypassing an uncomfortable situation.

It is very important for the interviewers to observe local customs, local events, appropriate religious holidays, dress in an appropriate manner and be respectful and courteous. For the most part, individuals are naturally distrustful of Government officials and institutions. For this reason, it is important to present the objectives of the project clearly with due professionalism and neutrality. For the same reason, a well planned and designed public information campaign is extremely critical and valuable for ensuring the success of this process.

The interview is conducted by a topographer and a paralegal equipped with GPS survey equipment, a GPS capable digital camera, a ruggedized hand held data collector, questionnaire forms (digital and hardcopy) and pamphlets or promotional material describing the property ownership program.

The paralegal is responsible for obtaining the information and filling out the hardcopy questionnaire. The topographer is responsible for filling out the electronic questionnaire or form, relating the captured information with any existing alphanumeric databases, verifying the information obtained and relating all the information to the GPS linked photographs which have been taken of the property. The ruggedized data collector captures the GPS readings of the structure or land parcel and determines the need of a complete field total station or GPS survey. If field surveys are required, additional equipment would be brought on a second visit by a field survey team as part of the ownership adjudication process. In a final review of the process, the digitized information facilitates the review of each case supported by GIS software especially designed for this task.

The Functionality Developed for Field Personnel

- Retrieving selected sections of the new building database for individual field data collectors
- Field data collection to include viewing and selecting the parcel or structure on the map, entering data and associating images with the parcel
- Synchronizing the data with the central database upon the return of the field data collector to the office
- Exporting the data in a format that is acceptable for import into the current, or new, tax valuation system

Field Data Collector Takes Picture(s) of Property

The user enters Property Attributes into the application and gets to the point of adding GPS embedded pictures of the property. The user positions the camera using the image viewer or camera viewfinder. To see the current viewfinder image in the application image viewer, the user clicks the "Viewfinder" button. The user then clicks the "Add Picture" button in the application. If the user is satisfied with the image, he may add additional pictures in the same way or the user may remove the current picture by clicking the "Remove Picture" button. The user can navigate between pictures by clicking the "Next" and "Previous" buttons. The GPS coordinate is calculated when the camera data are transmitted to the GPS receiver.

The Interface

The field data collector screen consists of the parcel or structure map, GPS embedded photo of the property and data entry fields. (Fig. 7)

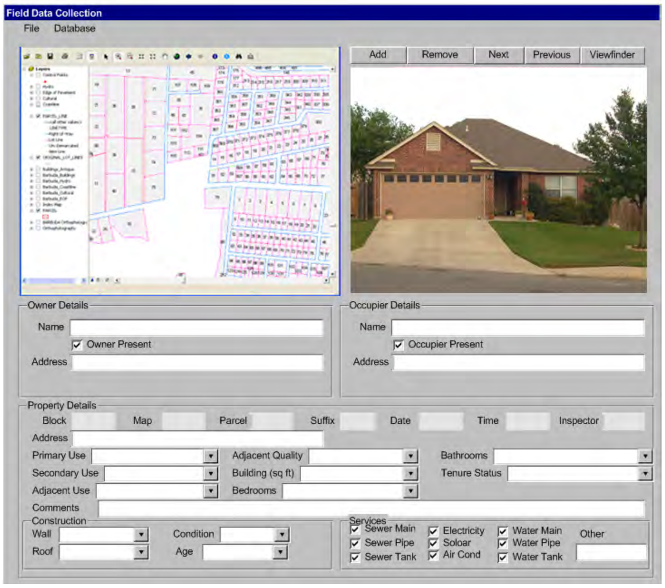

Figure 7 – Attributes Tied to GPS Embedded Property Photo

Application Updates Property Attributes to Government Tax System

This application begins when the user decides to synchronize the central database with the updated records in the local database. The user must be connected to the local area network and have access to the central database. The user selects the "File" -> "Synchronize" commands from the main menu. For each updated property on the client, the application will update the central database and remove the flag on the local database indicating that the local record has been changed.

WEB BASED GIS

The Antigua and Barbuda databases are hosted on a Web Portal containing all data generated during the conduct of the Land Registry automation project including aerial mapping, digital orthophotos, scanned registry documents and digital parcel maps. The Web Portal provides authenticated subscribers with the means to download a variety of GIS data layers (Fig. 8) including planimetric mapping, digital orthophotos, parcel maps and title records. Data downloads are accomplished within secure networks and the Web Portal offers secure access and the ability to purchase information and products via credit card while generating a revenue stream for the Government and providing greater public service to the citizens.

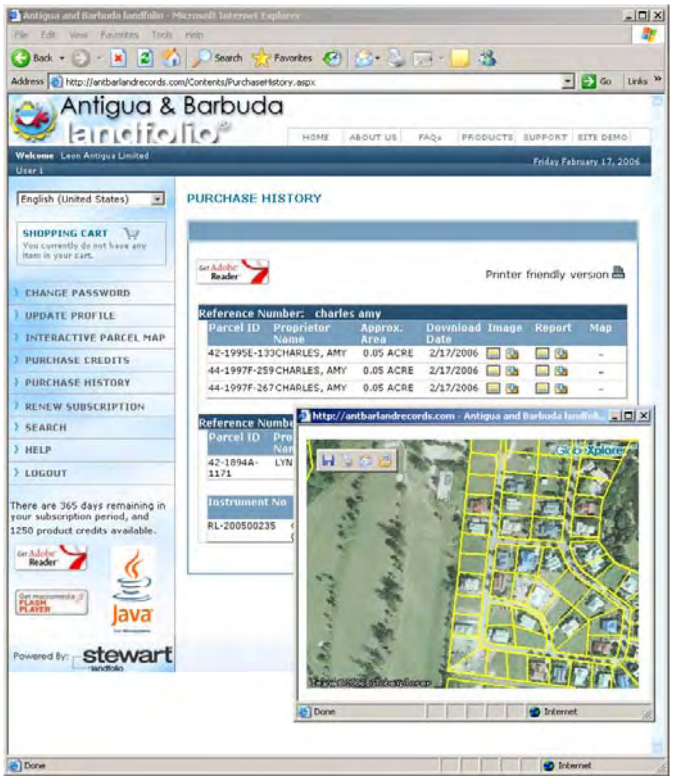

Figure 8 - Parcel and Digital Orthophoto Download

LAND TENURE INFORMATION AND POLICY MAKING

For the purposes of this discussion, a land tenure solution is defined as not only land tenure data and IT systems, but also corroborating land tenure policy and enforcement. Therefore, when presented with the opportunity to develop a land tenure solution, it is important to look beyond the traditional database-only contexts of mapping, surveying, photogrammetry, cadastre sweeps, GIS, etc. and other data collection, development and maintenance techniques. It is key to consider that land tenure is not 1-dimensional (i.e. the representation of ownership and property locations), but is indeed a multi-dimensional diagram of numerous sociological, economical and geographically related components. That is, the data needed for operational functions for securing rights, managing public assets, etc. is different than the data needed for policy development.

Overview

There is a growing awareness of the role played by property rights (and natural resource access and use) in economic growth, governance, conflict abatement and resource management. This awareness has matured from the development of national laws that define formalized land transfer and titling processes, procedures and technologies, to include not only the recognition of the existence of customary land transactions, but to also acknowledge the need to embrace these customary rights, rights of women and the poor and the associated transactions.

"Land tenure defines the relationship between people and land and other natural resources….A land tenure system means that a number of interests can exist simultaneously in the same parcel of land….The ability of a land tenure system to allow for the creation of a number of different and intersecting rights over land makes it likely that there will be a number of people who have interests in the same parcel of land. Land tenure is concerned with regulation of these different interests and overcoming potential conflicts among them." (Grover, Törhönen, Palmer 2006) The volume of information that exists in a customary land tenure environment is significant. The capture of this data into a form that is retrievable, searchable, reliable and durable is an important first step in creating a secure tenure environment. "Securing and protecting tenure rights…require the creation of land tenure databases rather than just proprietorship registers...the full range of land tenure rights should be secured and protected by being recorded in order to ensure that justice and human rights prevail, as well as by the development of effective policies for environmental protection, food security and economic development." (Grover, Törhönen, Palmer 2006)

Land Tenure Information

The nature of land tenure, the functioning of access and control of land and land policy all combine to influence information production and use. "As with all information, land tenure information can also be manipulated, controlled or monopolized by various persons depending on their interests, goals and positions. Disruption in the chain of land data production and circulation can reflect technical and institutional dysfunction as well as individual or collective strategies of control over information flows." (Le Meur 2006)

It is important for the policy-makers to be able to develop sustainable and enforceable land tenure policies so as not to (intentionally or unintentionally) marginalize any sectors of the population. Poorly conceived land tenure policies can be just as effective as no policy at keeping segments of the population "out" of the land tenure system.

Land tenure information can be divided into 2 categories: 1) primary and 2) secondary. "Primary data are directly generated through procedures implemented or controlled by the land administration system: legislative texts, policy frameworks…land titles, deeds…sales agreements, cadastral maps, taxation registers…and various informal acts aiming at validating, at least locally a land transaction…and written complaints and claims related to land conflict." (Le Meur 2006)

Secondary land tenure data is diverse, and is "…based on the processing of primary information: statistical databases; cadastral maps; GPS data; GIS; …rural land plans and urban land register…." (Le Meur 2006)

Additionally, the archiving and availability of all the land tenure data is a critical indicator of the seriousness of policy-makers in providing access to all sectors of the population.

Concluding Remarks

The link between information and decision-making is a matter of negotiation, alliance and compromise. The development of public policy based on land information is a matter of accessibility, knowledge and understanding. There are many aspects to a successful land tenure policy, some of which have only been lightly introduced in this paper: robust data collection (to include geographic, anthropologic and sociological components), development of land tenure policy that recognizes customary rights as well as the land rights of women and the poor, and effective law enforcement that is capable of penetrating both urban and rural areas and the potential conflicts between statutory and customary law.

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