

GEOMATICS TECHNOLOGIES APPLICATED FOR LANDUSE ON EASTER ISLAND (CHILE)

TECNOLOGÍAS GEOMÁTICAS APLICADAS PARA USO DE SUELO EN ISLA DE PASCUA (CHILE)

Víctor Fernando Herrera González¹

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RESUMEN

El propósito de este proyecto es demostrar la contribución de las tecnologías geomáticas en el catastro de predios fiscales en Isla de Pascua (Chile). Este proyecto recurre al uso integrado y aplicación de imágenes de satélite con alta resolución espacial (QuickBirdII), el uso de equipos de posicionamiento global o GPS y sistemas de información geográfica (SIG) en una zona con una realidad tan particular en administración de uso del suelo como es Rapa Nui o Isla de Pascua. Los resultados obtenidos, producto de mediciones de alta precisión, resuelven la georreferenciación del mapa de uso y ocupación del suelo de la ciudad y, a su vez, permiten definir los puntos de control geométrico para el proceso de corrección de la imagen de satélite. Finalmente, la creación de esta base cartográfica, apoyada en el uso de la imagen de satélite combinada con el mosaico cartográfico a actualizar, permite conocer la realidad de los predios fiscales necesaria para el Ministerio de Bienes Nacionales y su futura transferencia a los antiguos dueños de la isla, la etnia Rapa Nui. De esta manera, existe una gran importancia y especial relevancia en la innovación y aplicación de tecnologías geomáticas en la isla para mejorar la planificación del crecimiento urbano y, por ende, las condiciones de vida de sus habitantes.

Palabras clave: Imágenes de satélite, aplicaciones catastrales, planificación urbana, teledetección.

ABSTRACT

This project resorts to use integrated and satellite images application with high spatial resolution (QuickBirdII). The purpose of this project is to demonstrate the contribution of geomatics technologies for cadastral applications in Easter Island (Chile). This project resorts to use integrating satellite images with high spatial resolution (QuickBirdII), GPS equipment and geographic information system (GIS) in a very particular zone in land use administration like Rapa Nui or Easter Island. The result obtained with high accuracy measurements, resolved the geo reference for the land use map of the city and also defined the geometric control point for the satellite image correction process. Finally, with the creation of this cartographic data base we can mix the information with the cartographic mosaic necessary for the Ministry of National Assets. The data gathered with this technique is very important for the government actions regarding future transference of land to the descendants of ancient inhabitants of the island. Also, there is special relevance in the application of geomatics technologies in the island, when it comes to improve the urban growth planning and people's life conditions.

Keywords: Satellite images, cadastral application, urban planning, remote sensing.

INTRODUCTION

The observation of the Earth from space is an advantage for those who wish to obtain information about its defining elements, as well as about the changes that happen on it [1,2]. Putting sensors in orbit to study the

earth's surface is a way of obtaining this information. In this area, the technological advance of satellites in the last few decades has contributed significantly towards the study and planning of urban space. In this context, the digital processing of high spatial resolution satellite images has proved to be a very useful tool when used to

¹ Área de Geomática. Departamento de Ingeniería Geográfica. Universidad de Santiago de Chile. Ministerio de Bienes Nacionales. Casilla 10233. Correo Central Santiago, Chile. E-mail: vherrera@lauca.usach.cl

detect and evaluate the situation of government property on Easter Island or *Rapa Nui* located in the middle of the Pacific Ocean, lat 27° 07' long 109° 22' in front to the Chilean coast. Due to this, the Regional Secretariat of the Ministry of National Assets (*Secretaría Regional Ministerial de Bienes Nacionales*) of Chile's 5th Region decided to call for the development of the project titled: "Cadastral of Government Properties on Easter Island", in order to update the information on state properties, and their current administrative status. This work was undertaken mainly during 2006 and considered the integrated use of GPS equipment, digital processing of the QuickBirdII image that was used as base for the cartography of the land and the use of SIG ArcView to generate the cadastral data bases and their respective maps, duly georeferenced.

PROCEDURE

The project dealt mainly with the execution of the following stages:

1. The compilation of documents and cartography of the area to be studied.
2. Field expedition for geodesic measurements with GPS.
3. Revision and inventory of the cadastral archives on Easter Island.
4. Updating of the cartographic mosaic of transferred government property
5. Result verification

The first was to examine the degree of reliability of the compiled cartographic information, to digitalize any information that was lacking, outdated, or non-existent in the data base of the Ministry of National Assets (Ministerio de Bienes Nacionales) on Easter Island. Having ascertained the cartographic state of the island, the field expedition was undertaken, consisting mainly in making denser the existing GPS network in Hanga Roa (new network denominated HR with 16 vertexes and old geodesic network called IP with 14 vertexes) and the rest of the island (refer to Figure 1). This allowed the positioning of control points required for the process of geometrical correction of the satellite image, and the generation of a reliable cartographic base for the cadastral process of State property which were maintained by the State or in a transferal situation. Also, the new data base created took as its support base the cartographic mosaic which had to match the satellite image, due to which the information obtained from the GPS network was vital for the later processes of cartographic matching described further on.

The same fieldwork allowed the identification of each property vertex, as shown in figure 2, leaving the vertexes established in the field. These will also serve as support for future projects to be carried out on the island (expanding the sewer system, construction of boreholes, electric lines and more).

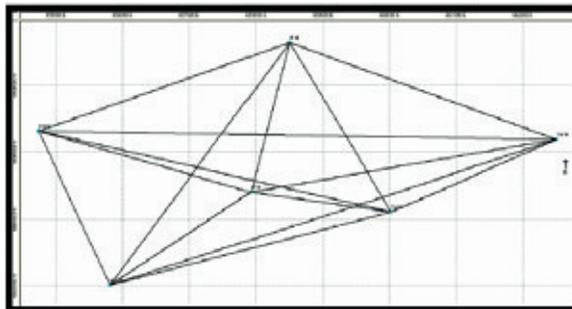


Figure 1. Geodesic network with GPS vertex in Easter Island using UTM coordinates.

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CATASTRO DE LOS BIENES RAÍCES FISCALES EN ISLA DE PASCUA

3.2. Monografías de los vértices de la red GPS HR.

Monografía Vértice Red Hanga Roa		Código V - 2006	N° Monografía HR - 1
Nombre : HANGA ROA 01	ID : HR01	Proyecto :	Catastro de los Bienes Raíces Fiscales en la Isla de Pascua
Región : 5	Provincia : Isla de Pascua	Comuna :	Lugar : HANGA ROA
Fotografía Panorámica		Fotografía del Punto	
Croquis Detallado		Descripción	
		Señal de bronce, de 2.5 cm. de diámetro y 8 mm. de espesor, empujado en la solera, esta ubicado en la Caleta Hanga Roa Otai, plaza Hota Matus, entre la intersección de las calles Policarpe Toro y Tepilo Tehenua.	
Coordenadas			
DATUM	SISTEMA	PROYEC.	SAD 69
Latitud			
Longitud			
Altura	0.807		
Coord. UTM	6995024.242		
Escala	200000000		
UTM	12		
Otras Antecedentes			
Intersección	H012 - H013		
Tipo Marca	Alfiza Elasmolite		
Fecha Inst.	Enero - febrero 2006		
Fecha Exp.	12 - 01 - 2006		
N° Documento			

Figure 2. Example of file structure used for all the vertex that defined the GPS geodesic network densification.

These vertexes were established in stable rocky places of easy access, that wouldn't create problems to do with their use and equipment installation for future measurements, and that wouldn't interfere with activities peculiar to Easter

Island (tourism, archaeological locations, etc). During this stage the GPS Stop and Go technique was used [3], which allowed the georeferentiation of the vertexes of the properties, due to which, the HR network defined in a previous stage was used.

Next, an inventory of the information existing in the cadastral archives of Easter Island was undertaken. This work was carried out partly in collaboration with the Provincial Office of the Ministry of National Assets (*Oficina Provincial del Ministerio de Bienes Nacionales*), and consisted in a detailed revision and the creation of the inventory of all the documents contained in each of the Cadastral Archives in the offices of Easter Island.

This activity was carried out following the guidelines established in the Ministry of National Assets' Technical and Cadastral Procedure Manual (*Manual Técnico y de Procedimiento Catastral del Ministerio de Bienes Nacionales*), according to which each folder must contain the following information:

- Filing card of relation of the documentation.
- Cadastre filing card.
- Assignment or cancellation of the contract (Decree, Resolution, Act, Contract, Law, etc.) of the property.
- Map of the property (if existent).
- Valuation Certificate of the Internal Revenue Service (*Servicio de Impuestos Internos*) (if existent).
- Certificate from the Municipal Works Director (*Dirección de Obras Municipales*), when appropriate, on the situation of the property with respect to the Regulating Plan.

Following these guidelines, the process of inventory of cadastral documentation was carried out for each of the folders available in the Provincial Office of the Ministry of National Assets (*Oficina Provincial del Ministerio de Bienes Nacionales*). This process included the information on the land managed by the state and the information on government land transferred to the ethnic Rapa Nui community.

Subsequently, the transferred government land was updated on the cartographic mosaic. To achieve this, the mosaic was regenerated starting from the input and cartographic documents obtained for the project. This included a new georeferentiation process of the image considering control points obtained during the initial fieldwork stage, corresponding to the following table 1.

Once the image had been georeferenced, the georeferenced property information from the original mosaic, obtained from the Provincial Office of the Ministry of National Assets, was transferred onto the new image, as shown in figure 3. The same procedure was followed for the case of the following maps provided by the Ministry of National Assets in digital AutoCad format, extracting from them only the properties. Next, the georeferentiation of the already digitalized maps was carried out.

Table 1. Coordinates and elevation of control points.

Id	East	North	Elevation
ANAK	666677.769	7003742.037	9.156
CAKI	659418.912	6995706.720	108.879
FARO	661880.528	6994175.323	7.848
PITO	668238.578	7002722.554	21.412
POIK	670833.683	6999861.565	44.056
PUI	666230.626	7002014.441	107.569
RAKU	670168.995	6997388.998	10.216
TM16	662503.518	6995186.484	60.313

Also, recent studies on the topic of digital manipulation of satellite images, resorting for this purpose to different types of mathematical algorithms and different sensors [4,5]; coincide in applying remote sensing as part of the process that favors a more efficient urban growth and order on Easter Island. In this way, the QuickBird II image used in its multispectral and panchromatic formats.

Finally, the results obtained in collaboration with the Ministry of National Assets (*Ministerio de Bienes Nacionales*) were verified and inspected technically. This was checked in the field itself, resulting in an approval of the procedures used and the results obtained on the satellite image.

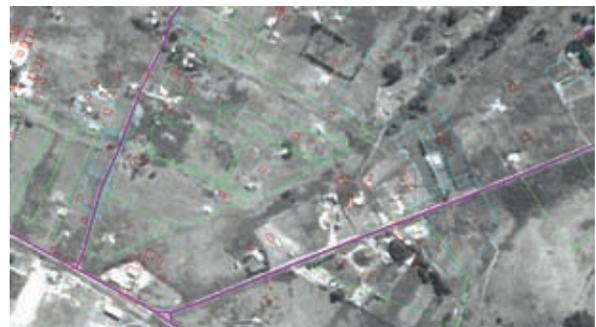


Figure 3. QuickBird II image with cartographic information.

At last, and as observed in the field, the property element acquires another method of information handling, since

for the Rapa Nui ethnic group land is a right that is not for sale, but can only be transferred from generation to generation, and therefore is not subject to laws of any kind, as each clan or family knows what is theirs. This enters in conflict with the administrative cadastral concept of the government property on the island, and due to this special care was taken in duly informing the Rapa Nui community about the work that the Universidad de Santiago de Chile (USACH) was to undertake on the topic.

RESULTS OBTAINED

Starting with the measurements taken with GPS equipment on the field, it should be stated that not only the measurements for the properties (land) but also for the control points (GCP) were done with this technology. The distribution and location of the GCP aimed at securing a coverage across the width and length of the satellite image and the island, in order to avoid the concentration of the GCP in only one part of the island, which would result in a pivot effect of the image and would leave without control the areas in which there were no GCP [6,7]. All this was done with the aim of being able to subsequently superimpose vector type information on the image (cartographic mosaic). The distances of these measurements did not exceed 20 Km, using fixed solution, simple frequency (L1) and RMS lower than 3 cm. The number of control points or GCP was 8, which gave an RMS of 0.9 in pixel value, which is the equivalent of 0.56 meters. This fell within the value of the smallest spatial unit of the image which is the pixel, and in the case of the QuickBird II image is 0.62 m.

For the geometrical correction of the image, first order transformation functions of the following form were applied:

$$u = a_0 + a_1x + a_2y \tag{1}$$

$$v = b_0 + b_1x + b_2y \tag{2}$$

In this equation the actual coordinates (x,y) of the GCP are transformed into corrected coordinates (u,v) of the reference map, defined by eq. (1) and (2), in a set cartographic projection [8]. The cubic convolution method, which uses the average of the 16 closest pixels to the pixel in question, was used for the transfer of the original levels to their new position.

In this method, the digital levels of the sixteen closest cells of the transformed image are linearly interpolated in groups of four lines of four pixels each to form four

interpolants. Subsequently, another linear interpolation for the four values obtained is done, to assign the resultant to the corrected cell. The expression that gives us the one-dimensional interpolation as a function of the four closest values of a line is:

$$f(m) = \Delta x \{ \Delta x (\Delta x [f(x+2) - f(x+1) + f(x) - f(x-1)] - [f(x+2) - f(x+1) + 2f(x) - 2f(x-1)]) + [f(x+1) - f(x-1)] \} + f(x) \tag{3}$$

Where f (m), eq. (3), is the interpolant assigned to the central cell (m) of each of the four lines of the corrected image, and f (x) is the value corresponding to the pixel of the transformed image, located in a position delimited by a real number.

Upon finishing the tasks of this stage it should be mentioned that all the information generated in this project was duly validated, therefore special care had to be taken when trying to complement it with cartographic information coming from other sources, as the complementation with other information could present differences, particularly with regards to the matching with other cartographies. These differences could be scale, Datum and differences in the method used to obtain the coordinates, whether topographical, photogrammetrical, etc.

With regards to the task of inventory of the cadastral folders on Easter Island, made available by the Ministry of National Assets, the study concluded that of the properties that are subject to different acts of administration, public and also private, there currently exist on Rapa Nui (Easter Island) a total of 95 folders, of which only 72 are currently administered by the government, with the rest of them being in different stages of processing. In the same way, the preliminary inventory of the information referring to the government property transferred by domain titles to the community of the ethnic group Rapa Nui was carried out, on all the folders available in the Provincial Office of National Assets on Easter Island, that is, a total of 954 folders.

With regards to the updating of the existing mosaic, it was verified previously that georeferentiation errors existed in the cartography of the Ministry of National Assets, meaning that the graphical information corresponding to the properties updated by this Ministry does not prove a perfect match. This analysis makes apparent the lack of clear norms for the mapping of georeferenced properties, with noticeable errors of superimposition of properties and rotation of some of these, a result of the different technologies used to obtain the information (Total Station, GPS Navigator, simple frequency GPS, etc).

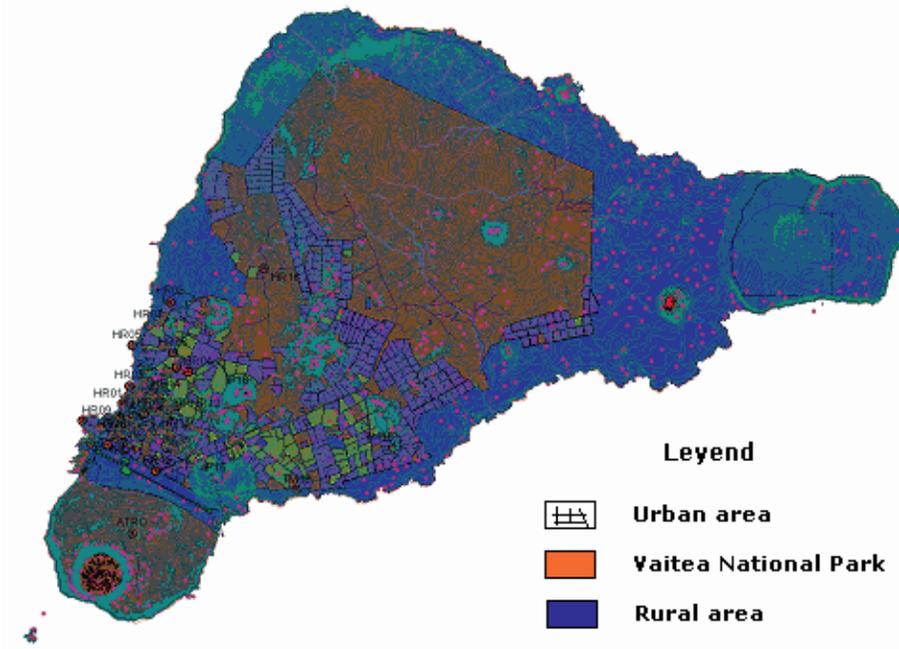


Figure 4. Easter Island or Rapa Nui map where show the general and final situation in the island.

Because of this problem, georeferentiation through graphic matching couldn't be done; on top of this the plans of the plots of land in the mosaic are displaced on the Y axis (North) between 15 and 20 meters. The resulting image duly georeferenced, showing vectorial property information, is displayed in figure 4. This figure shows the property Vaitea in the centre of the island, owned by CONAF (National Forest Corporation), also showing the urban sector of Hanga Roa with its respective geodetic vertexes (HR network), in the lower left, and the properties that encircle the urban area with tendencies of expansion towards the centre of the island.

It is worth considering the possibility of the periodic and simultaneous updating of both the cartographic mosaic in AutoCad, and of the coverage and database of the geographical information system, to ensure their validity and effectiveness in their function of supporting the management of state property on Easter Island done by the Provincial Office of the Ministry of National Assets.

CONCLUSIONS

Given the integrated character of the information handled in this project, in order to be able to generate a reliable cartographic product it is advisable to update periodically and simultaneously, for both the cartographic mosaic and AutoCad, the databases with information on the government properties of Easter Island. The

administrative work in their management could be strengthened by the use of the geographical information system in operative order, by the Ministry of National Assets. Another point that must be mentioned is that it is by no means advisable to mix drawings, drafts, maps and letters from different sources and cartographic bases (surveys with measuring tape, compass, theodolite, total stations, GPS and others), when updating the cartographic information on the mosaic and/or satellite image. The currently prevailing technical specifications, defined by the Ministry of National Assets, must be followed, and will serve as cartographic base for future development projects on Easter Island.

With regards to the task of densifying the geodetic GPS network in Hanga Roa, incremented in a 110% in Hanga Roa, the measurement of new vertexes and the re-measurement of pre-existing points allowed a greater consistency in the created cartographic base, thus, the precaution was taken of covering the covered area in a homogeneous fashion, favouring the periphery of urban regions which present the possibility of urban growth around Hanga Roa.

Finally, an optimal planning and orderly development of the land favours the development of activities including social, tourist, and economic activity in general, with all the indirect productive consequences this generates. Thus, the geomatic discipline comes into play as a tool that contributes in a determining way to the processes of regional development.

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