Land Use Employing Satellite Image of Low Spatial Resolution: A Case in the Northeastern Argentina Using Landsat TM 5 (*Thematic Mapper*) and Landsat ETM 7 (*Enhanced Thematic Mapper*) Multispectral Optical Sensors

Roberto TORRA, Argentina

Key words: cartography, remote sensing, natural resources, land use, Landsat TM 5-ETM 7 optical sensor images, Northeastern region of Argentina

SUMMARY

In this paper I intend to show how satellite images are useful in order to planning and obtain quick natural resources data recognition from the landscape, topography, relief and geomorphologic main elements and the rock-massif units. These cartographies result of great utility to civil and hydraulic engineering purpose, so as projecting many different types of civil works related with land and management use. Monitoring of cattle-rising activities are greatly benefits at the northeastern region of Argentina.

The study is based on digital image processing (DIP) techniques and visual interpretation methods. Histogram analysis (pixel analysis, digital number reflectivity) band per band, stretching transformations, directional and non-directional filtering, contrast and brightness adjustments, reflexivity enhanced, geometrical corrections, mosaicking, matching images, classification and planimetrical cartography at 1:100.000, with about of 40 - 45 meters of rms were made.

The Landsat TM 5/ETM 7 images employed were 226/79-227/79 *path-row* scenes corresponding to the official *Landsat 5-7 worldwide index map*.

The planimetric cartography at 1:100.000 was made from a 4/5/3 false-colored image, which was previously digitally contrast-enhanced and directionally filtered. The map was linked to the latitude-longitude universal coordinates and to the Gauss-Krüger Argentinian official grid. Datum “Campo Inchauspe 69” was got as reference for mapping correction.

Several automatic (supervised and non-supervised) classifications were done using standard programs of DIP. The best results in classifications (supervised) were obtained by means of the use of the standard neural net system transformation algorithm.

The cadastral net system of the whole area (10,000 km^2) was draw using standard CADs programs. Railroads, high voltages lines, bridges, dams, secondary and tertiary roads as well as services roads for agriculture commodities, among others, were mapped.

The employed tool resulted of help to optimize future projects of territorial management, land use, land management, early desertification alerting (risk geo-indicators), soil degradation mapping, deforestation intensive use, forests inventory, agricultural and its monitoring use, geological and geomorphological studies, hydrological studies, erosion risks, fluvial and pluvial floodable depression areas, soil studies, geo-environment alerting signals and hazardous risks.
The summary indicates the importance of few expensive and rapid use satellite imageries as a principal tool for many geocientists as well as surveyors, topographers, engineers and biologists, among others, at different stages of their specific works.

RESUMEN

En el presente escrito se describe como las imágenes satelitarias resultan de suma utilidad en la planificación del uso del suelo y acerca de los riegos relacionados con su manejo. Asimismo se destaca como este método resulta ser muy rápido para la recopilación de datos humanos y de obras de arte relacionados con el paisaje, la topografía, el relieve y los principales elementos geomorfológicos que afloran en la región noreste de Argentina como así también algunos cuerpos rocosos. Esta cartografía resulta de utilidad para propósitos hidráulicos y civiles en general de manera tal de ayudar en la elaboración de diferentes tipos de obras civiles siempre relacionadas con el uso y manejo del suelo.
El estudio se basó principalmente en técnicas de procesamiento digital de imágenes (DIP) y en la interpretación visual de tales datos. Para tal fin se realizaron estudios y análisis de los correspondientes histogramas de reflectividad, banda por banda, segmentación, filtrado, ajuste de brillo y contraste, mejoramiento del brillo de las imágenes, correcciones geométricas, mosaicazo de imágenes, emparejamiento de contraste de las imágenes, clasificaciones supervisadas y no-supervisadas y cartografía vectorial planimétrica a escala 1:100.000, todo ello con un error estimado medio cuadrático de 40-45 metros (rms).

En este trabajo fueron empleadas las imágenes Landsat TM 5 y Landsat ETM 7 correspondientes a los puntos 79 de las órbitas 226 y 227 de acuerdo con el mapa índice mundial de la serie de satélites Landsat.

La cartografía temática planimétrica a escala 1:100.000 fue realizada a partir de la composición falso color compuesto 4/5/3, la cual fue previamente mejorada en sus brillo y contraste (ecualizada) y filtrada de manera no direccional (*low-pass filters*). El mapa así generado fue enlazado a las coordenadas Gauss-Krüger, que en la Argentina emplean como referencia el dato referente a la localidad de medición inicial o "base" denominada como "Campo Inchauspe 69" (Provincia de Buenos Aires).

Se realizaron varias clasificaciones supervisadas y no supervisadas empleando programas estándares de procesamiento digital de imágenes siempre con resultados adecuados incluso en clasificaciones automáticas, especialmente ISO-DATA y K-Means.
El inventario existente de mapas catastrales de la región a escala 1:100.000 y 1:500.000 fueron empleados como apoyo o base para la cartografía temática empleando programas

basados en sistemas CADs. Las rutas, líneas de alto voltaje puentes represas, caminos secundarios y terciarios, usos y manejo del suelo, agricultura y ganadería, deforestación, riesgos de erosión entre otros fueron cartografiados mediante estos programas vectoriales.
Las técnicas empleadas resultaron de gran ayuda para la optimización de futuros programas de uso y manejo del suelo y del territorio, como así también prevenir riesgos de erosión, control de deforestación y como geo-indicador, especialmente de áreas de alto riego de inundación.

Esta breve sinopsis indica claramente la enorme importancia del empleo de imágenes satelitales para estudios de recursos naturales y ambientales tanto para uso de geocientíficos, agrimensores, topógrafos, ingenieros y biólogos en casi todas las etapas de variados proyectos.

Land Use Employing Satellite Image of Low Spatial Resolution: A Case in the Northeastern Argentina Using Landsat TM 5 (*Thematic Mapper*) and Landsat ETM 7 (*Enhanced Thematic Mapper*) Multispectral Optical Sensors

Roberto TORRA, Argentina

1. INTRODUCTION

In the last four decades satellite imagery appears as a primary tool-technique to help many human activities including most types of physical and environment studies. They are strongly related to civil works due to its direct relation with the study of "sites" of medium-to-large civil works emplacements. Land use, hydraulic, railroad, dams were all embraces for the cattle rising and engineering civil works benefits, among others branches.

At the northern area of the Argentina country, the landscape is largelly characterized by an extreme flat and depressed (lowlands) relief (Ameghino 1881). A conspicuous extensive "forest" named as the *Monte Chaco-Salteño* inter-tropical jungle (sometimes called as "*Jungas*" as in Salta ridges) covers mainly the Chaco, Salta and Formosa Provinces. This area constitutes a special case for satellite imagery application in order to take quick knowledge of the whole region which comprises approximately about of 250.000 km^2 (Morello 1968, Morello & Adamoli 1974).

Besides, we must take in consideration that the costs and the fast work in perform all classes of cartographies (i.e. today we are making 3D digital cartography based on satellite imageries and ground position systems points spacially located) are now easily realized with satellite imagery. These results are in this way like largely more effective because of their intrinsic thematic properties, captured for the optical Landsat sensor series which are due to sun electromagnetic radiation reflection over the different earth surfaces objects, either natural or anthropogenic.

In order to overcome a future long time sustainable program of general planning at the northeastern region of Argentina with special emphasis on the San Fernando, Libertad, General Dónovan and 1º de Mayo territories, placed in the eastward of Chaco Province, Argentina, we began several laboratory and field actions. These were in order to carry out a preliminary cartography based on satellite digital data, acquired by means of the Landsat 5 Thematic Mapper and the Landsat 7 Enhanced Thematic Mapper plus sensors series.

The main goals of these preliminary cartographies were focused to serve us for improved the planning, restoration, monitoring the soil use managements, aridification control, desertification and erosional processes (always related to intensive deforestation) and also to greatly contribute to be a master tool for most civil engineers functioning works as well as in

the future planning civil works. This is main valid in the first stage of many engineerical civil projects. At the sustainable development, these documents are necessary in order to planning and monitoring different natural processes and phenomena.

The studied area has many cadastral, geomorphological, edaphological, geological, soil mechanic, geochemistry, forest studies and environmental studies which are cited at the final bibliography.

2. MATERIALS AND METHODS

Satellite imagery analyses were carried out to interpreting and mapping about of 7,000 km^2 area which is located at the right margin of the Paraná river aluvial distal plains (the eastern-ward region of the Chaco Province, northeastern of Argentina).

According to Mauro *et al*. (1998), Sabins (1997) and Torra (2003), we focused in the employed of optical Landsat 5 TM-7 ETM sensors scenes named as the *thematic mapper* optical sensor (a special on-board satellite scanner) and some new ones Enhanced Thematic Mapper plus 7 optical sensors scenes (ETM plus) in order to make some comparisons, either spatial, temporal, seasonal, multispectral and radiometric resolutions.

After digital image composition was generated and histogram matching and directional and non-directional filtering was concluded, then we made a mosaick with a 4/5/3 enhanced composition. The software employed was IDRISI® for win, version 1.0 which was licensed to Facultad de Ingeniería, National University of Northeastern (UNNE), Argentina.

This software has several modules which are applicable both digital image processing analyses (PDI) and geographical information system (GIS).

Herein, we worked with the 226/79 and 227/79 Landsat TM 5 images obtained from an investigation co-operation free-agree with the Comisión Nacional de Actividades Espaciales (CONAE) of Argentina and the UNNE.

The mosaick was geo-referenced by means of control points take from the older 1:50.000 - 1:100.000 Instituto Geografico Militar cartography's and others points were get by means of gps stations and navigators at the railroad crossings, bridges and central city parks.

Previously, we made the histogram matching and the feathered processes. We used the seven bands that carry the Landsat satellite sensor series in order to make a master "bill archive".
With this bill archive we create the false-colored images, the unsupervised and supervised classifications and so, we also used it for other transformations as the Principal Components Analysis (PCA). These actions were useful for later geomorphological interpretations.

However, field recognition was made out in several selected field-points to check out interpretations, with special attention to the railroad crossing places. These points were of considerable utility to generate geo-referential points.

We use a common navigator (a basic ground positioning system instrument) which has an rms (square medium error) of 100 meters. It is necessary to remember that the maximum exactitude obtained with a Landsat TM 5 images is about or 40-45 rms meters and that is in exacted relation with the size of the spatial Landsat "pixels" resolution, which are of about 30 meters for spectral bands 1 to 7, excepting for the new band "P" (panchromatic) also present in the Landsat ETM 7 plus. That is of about 15 meters of spatial resolution.

On the other hand, and related to the pixel size of Landsat TM 5 images, scales that ranges on the 1.00.000 to 1:250.000 values are the normal ones. At our case, the maps were plotted at 1:100.000 scale in brilliant paper using an standard A0 full color plotter (90 width cm).
The technique of digital image processing was employed to examine extensiveness distal aluvial and non-aluvial plain areas and in this way we are able to analyze the tectonical and geomorphological elements present in the actual landscape, which is a relief according to Sabins (1997).

We finally used this temathic-planimetric preliminary cartography for structural analysis and interpretation as well as to outline lowland areas (recurrent floodable sectors) and many geomorphic elements. Herein, it is include the drainage network system which is basic for any planning of medium-to-large projects as well as a fundamental quantification of the forest and vegetated scarce wrapper area.

3. RESULTS

We obtained the following results after image processing:

A base-map 1:100.000 false-colored composition (4/5/3) was obtained. Over this cartography appears the Gauss-Krüger grid system (a series of rectangles of real 10 x 10 km black lines). This was plotted as standard one.
A layer with geomorphologic units
A layer with all the cattle-rising activities with discrimination of common commodities
A layer with drainage system work
A layer with cadastral system
A layer colored zones with potential floods zones
A layer colored zones with soil risks aridification and desertification processes
A layer colored zones with the forest remains (islands and patches that resemble the sabana inter-tropical morpho-climatic region system model with many isolated patches of autoctonous palms).

A vector layer with human works corresponding to railroads, villages, cities, dams, bridges, high voltage lines and ports was outlined.

An archive with a Principal Components Analysis
An archive with a non-supervised classification
An archive with a supervised classification, using Neural Net Analysis
An archive with a NDVI transformation (universal vegetation index)
An archive with a tasseled cup transformation (a special vegetation index mainly employed in USA).

Some of the layers and archives wasn't plotted yet because they are easily observable in a desk PC and because we are continuing in make several enhancements and actualizations.
The cartographic thematic map was plotted in a full colored A0 plotter.

4. CONCLUSIONS

Teledetection constitute a first order tool to make basical cartography. Low cost and rapid synthetic and resolution is one of the more outstanding characteristics. All this, always depends on the kind of satellite and sensor that we are using.

At this specific region located at the northeastern zone of Argentine regions we can determine areas of covered wrapper vegetation by robust forests, scrubs and associated with lowlands and wetlands (typical mangroove riverside jungles), as it is our case, the use of satellite imagery results a tool of very high significant importance.
The mapping of the landscape result of great utility in order to ensure a correct management of the use of the soil having in mind the planning of sustainable cattle-rising increasingly activities.

On the other hand, risk and hazardous problems were outlined and planimetrical mapped.
In order to make a realistic control over evolution and development into the whole environment evolution, we are now designing a strategy to embedded these data and process into a geographic information system (GIS).

So, this tool should be useful for several communities of South America that shared many similar environment characteristics as some many sectors of Paraguay, Bolivia, Peru, Brazil, and the northeastern region of Argentina.

ACKNOWLEDGEMENTS

I sincerely express my gratitude to the anonymous colleagues which made a strong effort to enhanced earlier manuscripts.
Also, I would like to express my sincere acknowledge to expert Juan Carlos Gómez who greatly help me in satellite imagery digital image processing tasks.
Engineers Federico Daniel Miño and Guillermo Mario Torra Nistal collaborated in several gabinet and field works, directly engaged with collection of data and gps control points.

REFERENCES

References cited

Ameghino, F. 1881, La Formación Pampeana o estudio de los terrenos de transporte de la cuenca del Plata. Buenos Aires-Paris. 371 p.

Mauro, M., Pellegrino, A, Ramondini, M. & Urciuli, G. 1998, A contribution to the geotechnical characterization of large areas for landing planning. pp. 195-201. In: Geotechnical site characterization, Robertson & Moyano (eds.). Balkema. Rotterdam.

Morello, J. 1968, La Vegetación de la República Argentina. Las Grandes Unidades de Vegetación y Ambiente del Chaco Argentino. Primera Parte: Objetivos y Metodología. Centro Nacional de Investigaciones Agropecuarias. Instituto de Botánica Agrícola. Serie Fitogeográfica Nº 8. Buenos Aires. 124 p.

Morello, J. & Adamoli, J. 1974, La Vegetación de la República Argentina. Las Grandes Unidades de Vegetación y Ambiente del Chaco Argentino. Segunda Parte: Vegetación y Ambiente de la Provincia del Chaco. Centro Nacional de Investigaciones Agropecuarias. Instituto de Botánica Agrícola. Serie Fitogeográfica Nº 13. Buenos Aires. 124 p.

Sabins, F.F. 1997, Remote Sensing. Principles and Interpretation. 3rd edition. W. H. Freeman and Company. New York. 494 p.

Torra, R. 1998a, Detección de Antiguos Cauces del Río Paraná mediante el empleo de Imágenes Satelitales. III Reunión de Comunicaciones Científicas y Tecnológicas. Universidad Nacional del Nordeste. Actas. 4: 181-184. Resistencia.

Torra, R. 1998b, El Estudio de los Sedimentos del Cuaternario de la Provincia del Chaco y Regiones Aledañas. III Reunión de Comunicaciones Científicas y Tecnológicas. Universidad Nacional del Nordeste. Actas. 4: 197-200. Resistencia.

Torra, R. 1999, Geología del subsuelo del Gran Resistencia y Regiones aledañas. Comunicaciones Científicas y Tecnológicas 1999. Tomo VII Ciencias Tecnológicas. pp. 169-172. Corrientes.

Torra, R. 2003, Satellite Images (Landsat TM 5) applied to geologic, landscape and management risk map of the Maipú Department, Chaco Province, northeastern region of Argentina. 2003 Annual Conference of the American Society of Photogrammetry and Remote Sensing (ASPRS). CD Rom Proceedings. Anchorage.

Torra, R. & Miño, F. D. 1999, Propiedades Mecánicas de las Pelitas de la Formación Ituzaingó (Mioceno medio), en la localidad de Empedrado, Provincia de Corrientes, Argentina. Comunicaciones Científicas y Tecnológicas 1999. Tomo VII Ciencias Tecnológicas. pp. 173-176. Corrientes.

Technical and specialized PDI-GIS bibliography

ACSM, ASPRS, ASCE 1994, Glossary of the Mapping Sciences. Co-published by the ASPRS-ACSM-ASCE. Arlington. 594 p.

Allum, J. A. 1978, Fotogeología y Cartografía por zonas. Editorial Paraninfo. Madrid. 139 p.

ASOCIACIÓN ARGENTINA DE GEOLOGÍA APLICADA A LA INGENIERÍA. 1995, Simbología para Mapas Geológicos - Ingenieriles. Publicación Especial de ASAGAI Nº 2. Córdoba. 105 p.

Atkinson, P. M. y Tate, N. J. 2000, Advances in Remote Sensing and GIS Analysis. John Wiley & Sons, Inc. New York. 273 p.

Bosque Sendra, J. 1992, Sistemas de Información Geográfica. Ediciones RIALP. Madrid. 451 p.

Cambell, J. B. 1996, Introduction to Remote Sensing. Taylor & Francis Editions. Londres. 583 p.

Chuvieco, E. 1990, Fundamentos de Teledetección Espacial. Ediciones RIALP, S. A. Madrid. 453 p.

Chuvieco, E. 2002, Fundamentos de Teledetección Espacial. 3ra. Edición revisada. Editorial RIALP. Madrid. 567 p.

Delleur, J. W. 1998, Handbook of Groundwater Engineering. Springer-Verlag. Berlín. 967 p.

Eastman, R. J. 1997, IDRISI® for Windows. User's Guide. Clark Labs for Cartographic Technology and Geographic Analysis. Idrisi Production. Clark University. 18 capítulos.

Eastman, R. J. 1997, IDRISI® for Windows. Tutorial Exercises. Version 2.0. Clark Labs for Cartographic Technology and Geographic Analysis. Idrisi Production. Clark University. 18 capítulos.

EDICIONES TERRA. Revista Geoinformación®. 1998-2001, Revista bimensual sobre tecnologías y sistemas de información espacial integrado. 14 números.

Foody, G.M. 1999, The Continioum Processes of Classification Fuzziness in Thematic Mapping. Photogrammetric Engineering & Remote Sensing. 65 (4): 443-451.

Giraut, M., Soldano, A. & Ludueña, S. 2000, Cuantificación de la evolución de coberturas hídricas durante las recientes inundaciones en el nordeste de la República de Argentina: Una propuesta metodológica. Dirección Nacional de Política Hídrica. Subsecretaría de Recursos Hídricos. Secretaría de Recursos Naturales y Desarrollo Sustentable. Buenos Aires. Informe inédito. 15 p.

Jensen, J. 2000, Remote Sensing of the Environment: An Earth Resource Perspective. Prentice Hall Editions. New York. 544 p.

Gómez, J. C. 1998, Interpretación Visual de Imágenes Aplicada a Catastro Rural. Dirección Provincial de Catastro. Geomática de Argentina S.A. Provincia del Chaco. 85 p.

Lilleland, T. M. & Kiefer, R. W. 2000, Remote Sensing and Image Interpretation. 4th Edition. John Wiley & Sons, Inc. New York. 724 p.

Merritts, D. & Dewetts, A. 1998, Environmental Geology. Mc Graw Hill. Nueva York. 550 p.

Miller, R. 2000, Ecología y Medio Ambiente. Grupo Editorial Iberoamérica. Madrid. 652 p.

Ñ-Ediciones. 2001-2002, Curso Completo de AUTOCAD® Avanzado. Versión 2000-2002. 72 fascículos, 6 CD-Roms

Pinilla Ruíz, E. 1995, Elementos de Teledetección. Editorial RAMA Ediciones. Madrid. 315 p.

Ryerson, R.A. 1999, The Manual of Remote Sensing: Remote sensing for the Earth Sciences. 3rd Edition. John Wiley & Sons, Ind. New York. 701 p.

SISTEMA DE INFORMACION TERRITORIAL. 1991, Colección Territorio. Generalitat Valenciana. Conselleria de Obres Publiques, Urbanisme i Transports. Valencia. 49 p.

Torra, R., Sisti, J.M., Murisengo, W.G., Gómez, J.C. & Colamntoni, L. 2000, Procesamiento de Imágenes y Cartografía Digital. XI Congreso Nacional de Fotogrametría y Ciencias Afines. Actas. Santiago del Estero

Western van, C. J., Soeters, R. & Sigmons, K. 2000, Digital Geomorphological landslide hazard mapping of the Alpago area, Italy. International Journal of Applied Earth Obserbation and Geoinformation. Special Issue: EU RUNOUT Project. ITC Journal. Enschede. pp. 51-60. 1 Mapa Color

BIOGRAPHICAL NOTES

I'm working as a teacher and researcher at the Geociences Department, Engineery Faculty, Northeastern National University (UNNE).

I'm currently working as an assistantship in the Remote Sensing area Civil Engineery *curricula* and I acts as a Co-Chairman of the Geosciencies Department from 1991.
I reached the geologist degree at the National University of Córdoba (1979) and the PhD at the National University of Tucumán (2001).

I dedicated the main time of my works to handled mapping through aerial photography and later this to interpret satellitary images all along Argentina and South América.

CONTACTS

Departamento de Geociencias. Facultad de Ingeniería. Universidad Nacional del Nordeste (UNNE).
Güemes st. No. 749
H3500CBO. Resistencia
Chaco
ARGENTINA
Tel + 54 3722 423401
Fax + 54 3722 439895
Email: roberto_torra@arnet.com.ar
Web site: www.ing.unne.edu.ar/roberto