The “spatio-cadaster” a solution for the Algerian steppe and saharian regions cadastral works

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Abstract. The large surface of Algeria (about 2.38 Million Sq.Km) and the economical growth make difficult to keep up to date cadastral mapping using classic methods for surveying. In this situation we are obliged to look for an alternative to the aerial photographs and conventional survey methods.

The very high resolution satellites have an important impact in the geoinformatic industry. By means of this technology, detailed maps in multiple scales can frequently and easily generated or updated from images with a gain in cost and time of operations.

The Algerian Center of Space Techniques (CTS - Algeria) in collaboration with National Cadastre Agency (ANC- Algeria) develops a new approach to cadastre the large steppe and saharian regions. This approach uses the very high resolution satellite imagery (SPOT 5 Super mode) as main source for the parcel boundaries determination in the steppe which is characterized by very large agricultural and pastoral exploitation. Because of the very high cost of this operation a multiscale approach has been adopted to reduce the cost, the regions that will be covered by the very high resolution imagery is predeterminated as 40km around every town or village where the activity is higher, this gives a total of 500.000 Sq.Km to cover. The rest of the national territory will be covered by ETM+ enhanced images.

This approach is adopted for the willaya (district) of “El Bayadh” in the west of Algeria with an area of over than 7 Million Hectare; this willaya is covered by 18 Scenes of Spot 5 Super mode (2.5m) and 8 ETM+ images (15m) which has been orthorectified. The final product is tested to meet the cadastral requirement. Finally the images are assembled into one mosaic with regularized colors. At the end a pseudo-natural color image is generated to help the user.

Keywords: spatio-cadaster, cadastre, steppe, Sahara, SPOT5, Orthoimage.

1 Introduction

For socioeconomical and climatic reasons, the repartition of the population over the Algerian national territory has been always the source of many problems for the land management, generally, and for landed estate particularly. The National Cadastre Agency (ANC- Algeria) has make a choice for conventional survey methods (classical land survey and aerial photogrammetry), and particular scales (1/500, 1/1 000 for urban regions and 1/2 500, 1/5 000 for rural region) for the hard copy cadastral map edition, for the northern regions of Algeria this choice has been proved and gives a good productivity results, this is because these regions are characterized by the high population density and small parceling (less than 10 Hectares). But in the southern regions which are steppic and saharian and characterized by large pastoral and agricultural landed estate, oil fields and mining zones this choice is limited.
The immensity of the territory to be cadastered and the non homogeneity of area of interest (urban, agricultural, industrial...) distribution, the cost and the limited time to complete the cadastral works, makes indispensable the adoption of a new strategy which take into account the last progress in the acquisition, manipulation and management of the geographic data.
Our approach consist on the use of the high resolution (Landsat ETM+) the very high resolution (Spot5, quickbird, worldview) satellite imagery in a multi scale approach to help the Algerian Cadastre Agency to define the third blanket called “wide area cadastre” to be added to the tow other existing types of cadastre which are “Urban cadastre” and “rural cadastre”.

2 History of spatial imagery

The origin of remote sensing is the aerial imagery that allowed us to collect information about the ground surface without direct contact. The development of the acquisition (satellites and cameras) and the data manipulation technique has accelerated the evolution of the photogrammetry.
Since the First World War, the use of the aerial photography has taken a considerable expansion. Its first civilian use was for archaeology end geology. The Cold War comes to open new perspectives because of the possibility to take images from a very high altitude (with development of the aviation) using new spectral domains other then visible band (development of electronics and new sensors and antenna).
The remote sensing prove to many users the interest of observing earth from space, the first images supply an innovative data source for the meteorology, geology, oceanography and the cartography of the wide area phenomenon. Some characteristics such as a coverage which is wide, homogeneous and synoptic that this new technique offer permits the production of new documents that we can't obtain using the aerial photography[Puis03].
The high resolution satellites appear at the beginning of the 70th such Landsat MSS with 80m resolution. The 2nd generation satellites appear in 1982 with Landsat TM of 30m resolution, SPOT XS of 20m resolution and HRV of 10 m resolution in 1986, this resolution was very sufficient for many new applications such as agriculture, forestry, environment..., but other domain of application such as urbanism and land administration require larger scale which involve higher resolution that remain monopolized for the military purpose.
In September 1999, a new era comes with the lunch of IKONOS, the first civilian satellite able to supply images with 1m resolution, which make the satellite imagery a serious competitor to the aerial photography. After this date many others very high resolution satellites were lunched such EROS-A1 in 2000, QuickBird in 2001 with 0.64m resolution and WorldView-1 at the end of 2007 with 0.5m resolution.

3 Methodological approach

3.1 Algeria's steppic and saharian regions description

The Algeria's steppe is located between isohyets 400mm to 100mm in the north and south. She had an area of 20 million hectares, between the southern boundary of the Tellian Atlas and the northern foothills of the Saharan Atlas in the south, divided administratively through eight steppic willayas (District) and 11 agro-pastoral willayas with a total of 354 municipalities. The climate varies from semi-arid in the north to the arid in the south [Nedj2006].
Saharain zones cover over than 80% of the area of Algeria so approximately 2 million square kilometers, consists mainly of ergs, oases and mountains.
The Algerian portion of the Sahara extends south of the Saharan Atlas for 1,500 kilometers to the Niger and Mali frontiers. The desert is an otherworldly place, scarcely considered an integral part of the country. Far from being covered wholly by sweeps of sand, however, it is a region of great diversity. Immense areas of sand dunes called areg (sing., erg) occupy about one-quarter of the territory. The largest such region is the Grand Erg Oriental (Great Eastern Erg), where enormous dunes two to five meters high are spaced about 40 meters apart. Much of the remainder of the desert is covered by rocky platforms called humud (sing., hamada), and almost the entire southeastern quarter is taken up by the high, complex mass of the Ahaggar and Tassili-n-Ajjer highlands, some parts of which reach more than 2,000 meters. Surrounding the Ahaggar are sandstone plateaus, cut into deep gorges by ancient rivers, and to the west a desert of pebbles stretches to the Mali frontier [Wiki2009].

3.2 Multiscale approach

By the fact of steppic and saharian area morphologies, nature of details and human activity which are quasi-inexistent in the saharian region and poorly occupied in the steppic zones, in this kind of area distance between urban centers (cities) are very long and exceed one hundred kilometers in average, multi-scale/resolution approach is an appropriate way to the cadastre by spatiomapping (fig.1).

By this approach, we must consider regions of poor and intermediate parceling level by using homogeneous global high resolution image coverage like ALSAT1, ETM+, ASTER, differently of regions of highest parceling level.

Fig. 1. The multi-scale/resolution approach

In this second case we have to use the very high resolution imagery, first SPOT5 super mode images with a resolution of 2.5m to cover regions where the human activity is present. This kind of images allows us to distinguish and measure parcels surface of at least 5 Hectares.
In the case of existence of smaller parcels which is a limited case like periurban and some other areas of interest, the field survey is the optimal solution if the zone is limited; otherwise the orthoimage of a resolution more than 1m (Ikonos, Quickbird, Worldview…) is recommended.

3.3 Multisource approach

We have to manipulate heterogonous images (resolutions and sensor) and multisource data (digitized plans, photogrammetry plots, field surveys, and GPS). We consider in this approach the conjointly using of these data.

3.4 Validation and control

The choice of a standard for validating and controlling (QA/QC) affect directly the cost and the time consuming for the realization of cadastral operations. It must take into account the specifications of each country in term of nature of areas to be surveyed (size, details level), means and time allowed to the execution.

3.5 Management and organization

The insurance of the reliability of spatio-cadaster in steppic and saharian zones began with foresee an organizational aspect adapted to the specificity of this new technique. This new organization must take into account two important points: the staff and data.
Concerning data, their structuring and management is primordial, through the judicious selection of metadata to be associated in order to be able to manage easily this mass of multisource data. Concerning the staff, a new production workflow must be established, thus a restructuration under the form of specialized team in such a way to guaranty a quality product with high efficiency.

4 Spatio-Cadastral mapping of EL BAYADH

In the aim of achieving the cadastral works in the steppic and saharian regions, the district of EL BAYADH has been taken as test area to develop this new methodology that will be generalized for the entire national territory.

4.1 Study area

EL BAYADH is willaya (district) situated in the north west of Algeria (fig.2). The northern regions of this willaya are typically steppic and the southern regions are perisaharian and saharian in the extreme south. Its area is about 71500 Sq.Km including 22 communes. It is situated between λ=0°25' west to λ=2°22' and φ=30°41' to φ = 34°27'.

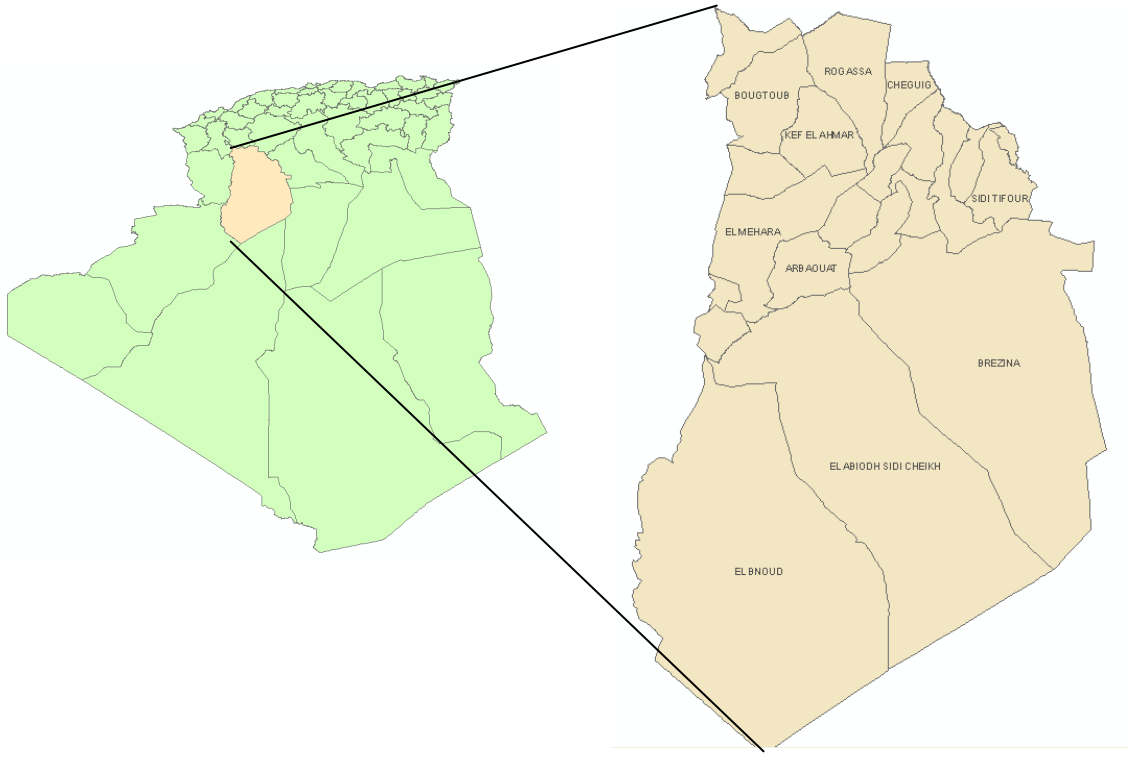

Fig. 2. EL BAYADH district situation

4.2 Spatiomaps generation

After several meetings with the essential organizations which play an important role in the geographic data Algerian market, Space Techniques Center / Algerian Space Agency (Scientific), National Cadastre Agency (User/Production), National Institute of Cartography and Remote Sensing (Production/Policy), it has been decided that an equivalent to 1 / 200 000 map scale as basic spatiomap will be produced. For this ETM+ at 14.25m resolution is used. The orthoimage at the resolution of 14.25m will be used for the pre-cadastral works in the north (steppic regions) and as a cadastral map in the south (saharian regions).
For the populated area (zones of interest) mapping, it has been decided that all the area within a radius of 40 Kilometers around communal county town will be covered by a SPOT5 super mode color images at a resolution of 2.5m and equivalent to 1 / 10 000 map scale.

The whole block consists of 18 SPOT5 images of 2.5m resolutions with overlaps between them, for the 1 / 10 000 mapping (fig.3a).

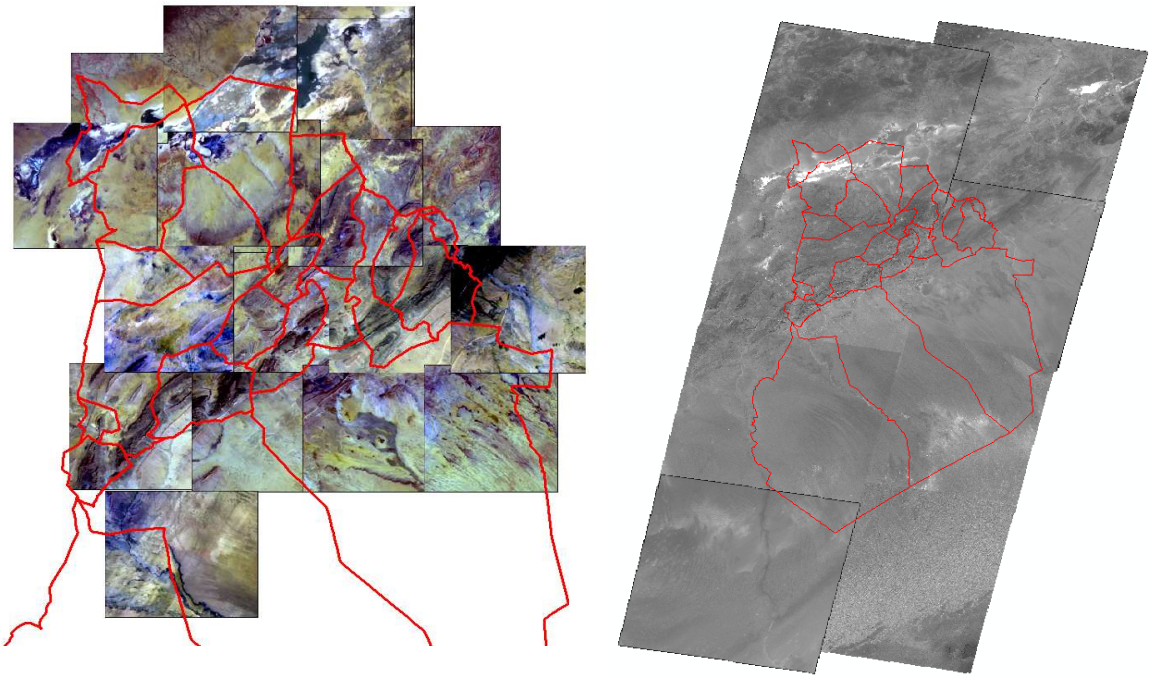

Fig. 3. a. SPOT5 images block b. ETM+ images block

The orthorectification process of this block is accomplished using GEOVIEW the IGN-FI solution for spatial block adjustment via a physical geometric model [Fra03] [Tou02] and “Réference Alpha” which is a subset of a continental size orthoimage that has a high geometrical (positioning) quality.
Under Geoview manual tie and control point’s collection is realized for the reason that a great part of this block presents relatively homogeneous texture. Also this software offers a very good color balancing possibilities to create a higher visual quality mosaics generated in pseudo-natural colors.
Concerning the ETM+ coverage 8 images were used of L1G, after mosaic and color balancing 4 GPS points were used to improve the geometric quality of the mosaic (fig.3b).

4.3 Control and validation of the product

The obtained product was controlled, visual aspect in the first time (colors, details continuities between overlapping images) and in the second time the positioning accuracy.
In this way and without any standards imposed for this kind of works in Algeria, we used NMAS standards used and tested in further works.

4.3.1 Cartographic standards

The choice of the standards was based on the results obtained on the work carried out on the commune of EL BAYADH, taking in consideration the specificities of the region (large area with poor details, means and the allowed time). In this context, we based our focus on the standards defined in “United States National Map Accuracy Standards” (NMAS); applied in USA.
For the 1/10 000 scale suggested by the National Cadastre Agency in this study, this standard require a tolerance of CE90=8.47m [Cly62] [NMAS] [NSSDA].

4.3.2 Orthoimage geometric quality assessment

For this control we use the points determined by GPS field works. The field works were carried out conjointly by the Space Techniques Center and Cadastre Services of the willaya of EL BAYADH between the 27th April and 08 May 2009 and 67 points were observed.
This test is based on a comparison between the coordinates of the observed points and the coordinates of the same points derives from the spatiomap **Table 1** and **Table 2.**.
For the spatiomap at scale 1/200 000 and 1/10 000; the statistical results are:

Table 1. Accuracy obtained for ETM+ mosaic (17 GPS points).

	Dx(m)	Dy(m)	Dr(m)
Mean	32,636	-9,538	35,976
RMS	11,768	14,499	14,210

sigmamin/sigmamax	0,812
CE90	30,494
Max Scale	60028,247

Table 2. Accuracy obtained for SPOT5 mosaic (62 GPS points).

	Dx(m)	Dy(m)	Dr(m)
Mean	0,812	2,585	4,270
RMS	2,935	2,871	2,400

sigmamin/sigmamax	0,978
CE90	5,150
Max Scale	6082,466

Where Dx and Dy are respectively X and Y direction error, Dr is the radial error

4.3.3 Discussion

For the ETM+ orthoimage the mean error is 35.976m with 14.21m RMS, the σmin/σmax is 0.812 which indicate that the error is close to circular (no bias in X nor Y dierection), CE90 indicator is 30.494m which allow us to edit maps at max scale of 1 / 60 028.
concerning the SPOT5 orthoimage the mean error is 4.27m with 2.4m RMS, the σmin/σmax is 0.978 which indicate that the error is close to circular (no bias in X nor Y dierection), CE90 indicator is .15m which allow us to edit maps at max scale of 1 / 6083.

4.4 Pseudo-natural color transformation

The pseudo-natural color transformation is used to reconstitute an approximation of natural color visualization (green vegetation, brown soil …) using the original bands.
As it is known SPOT 5 hasn't the blue band, so the generated Ortho-image is in false colors, this product is not suitable for non professional user. This oblige as to try to find a methodology that allow us to present the final product in pseudo natural colors, this has been done by calculating a transformation between tow spaces, as input the false colors and output the natural color (fig.4).
The final edition was based on the communal limits given by the National Institute of Cartography and Remote Sensing with 2 km buffer.

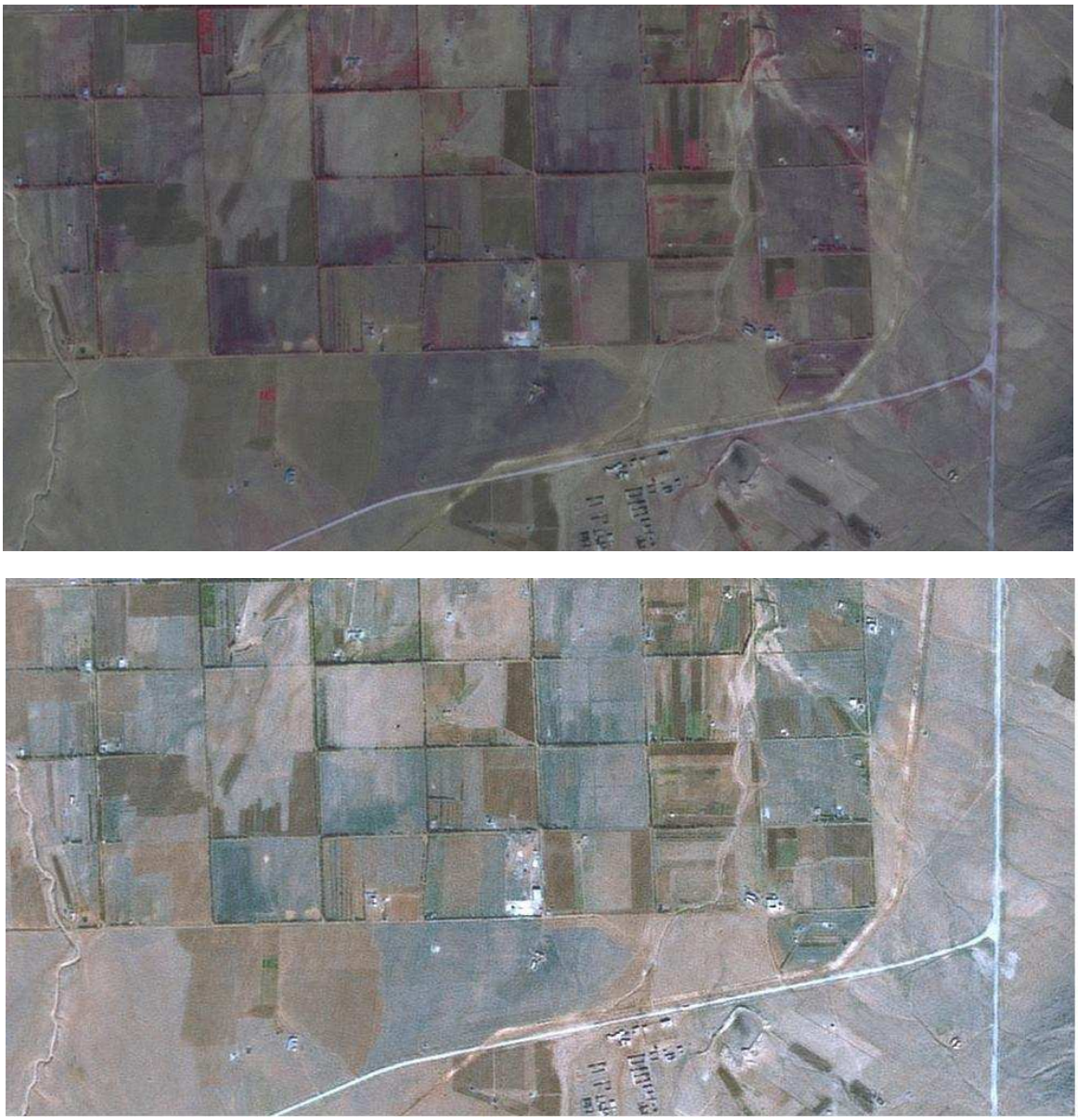

Fig. 4. The original and pseudo-natural color image of SPOT5

5 Conclusion

The experience of EL BAYADH district was the proof that the spatial imagery can be used to accelerate the cadastral works, regarding to the time limitation and the large surface to be cadastered. Our methodology was very helpful for the Algerian National Cadastre Agency to define a new kind of cadastre called "**wide area cadastre**" to be added to the tow other existing types of cadastre which are "**urban cadastre**" and "**rural cadastre**".

ETM+ and SPOT5 images were used to generate two types of digital color orthoimages at equivalent scales of 1 / 200 000 as base map and the delimitation of areas in the saharian regions, the second type of orthoimages is at equivalent scale of 1 / 10 000 to be used in a perimeter of 40Km around every communal county town in the steppe and the Sahara.

In EL BAYADH district case of study 8 ETM+ (14.25m) enhanced images were used to generate a base spatiomap and 18 scenes of SPOT5 super mode images (2.5m) has been orthorectified and used to generate a color regularized mosaic and transformed to pseudo-natural color that allow the non accustomed (professional) users the possibility of direct interpretation which facilitate the use of this orthoimage.

This product is now used by the Cadastre Services of the willaya of EL BAYADH that give them global satisfaction. Also this methodology will be adopted by the Algerian National Cadastre Agency and generalized for the rest of 21 willayas of Algerian steppe and Sahara, this is equivalent to 2 million Sq.Km to be covered with ETM+ imagery and 500 000 Sq.Km with 2.5m.
The standard used to control the geometric quality of the product was the United States National Map Accuracy Standards because of the lack of such standard in Algeria, for the future works a study for a national mapping standard definition must be done.

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