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HIGH SPATIAL RESOLUTION IMAGES - A NEW WAY TO BRAZILIAN'S CARTOGRAPHIC MAPPING

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ABSTRACT

This paper aims, from an assessment of the current situation of the Brazil's cartography, demonstrating the viability of using high spatial resolution images as a tool to update products as well as the cartographic mapping of areas without coverage. To do this, obeys the constraints of possible accuracy to be obtained, and evaluates the advantages regarding costs.

KEYWORDS

Cartography, High Spatial Resolution Images, Graphic Error, Accuracy.

INTRODUCTION

Currently Brazil is experiencing a crisis in cartography, due to two factors:

a) lack of government investment in the areas of cartography and mapping;

b) the dynamics increasing of urban growth, which imposes the need for constant updates and, in some cases, a new survey.

Because of high costs and time of execution, such procedures become unmanageable, particularly when made by conventional aerial photogrammetry. The table 1 presents the actual situation of Brazilian cartography.

Table 1 – Synoptic Chart of Brazilian Cartography

Scale	Existing Sheets	Mapped Sheets	[1]Covered Year	Percentage of Coverage of Brazil[1]
1:1,000,000	46	46	1980	**100**
1:500,000	154	68	1965	**36,90**
1:250,000	556	444	1985	**80,72**
1:100,000	3.049	2.289	1982	**75,39**
1:50,000	11.928	1.647	1977	**13,90**
1:25,000	47.712	492	1985	**1,01**

[1]Reference year (approximate) that completed two thirds of the number of sheets mapped

Source: Correia (1997) and Menezes (1999)

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Based on these data, in recent years, much has been discussed about the available options for cartographic updating processes that minimize costs and reduce the execution time of mapping. The speed of collection, treatment and availability of data are factors of major relevance to different users. The advent of high resolution remote sensing has opened an unprecedented opportunity to update the map. Using the scales of 1:100,000 to 1:25,000 already represent an attainable possibility. However, for larger scales, ie from 1:10,000 to 1:2,000, there is a considerable stir both in scientific circles, for aerial survey of firms, lack of consistent data showing that possibility.

Some studies have shown that the orthorectification and geometric correction of images is directly related to what you want the final product and with the topographical features of the area of application. In regions of small vertical variability, the application of an efficient geometric correction, with a good density of points, can fully meet the needs. However, for regions with large topographic gradients and sharp handling, it is necessary that an orthorectification process because it is not the same for all regions, will require improvements and adjustments according to topographical characteristics and the geographical extent of the area.

Another problem relates to the need for a good sampling altimetric without which it becomes impossible to generate the MDE, necessary for orthorectification. They are all understandable concerns. However, we seek solutions, in which images can answer the financial, technical, quality and time to product availability.

Thus, where there is already a base map, the image would be useful for updating and additions of new areas by leveraging the existing equipment, while for areas without a good base level curves, are already found in the market images that enable the generation of stereopairs, just to create them. In these cases, it is necessary to assess the costs of the proceedings.

The other argument is based on the scale can be achieved. Studies developed by Bias (2003), using IKONOS II data, considering the classes of the CAS - Cartographic Accuracy Standard, demonstrated the possibility of working with these images until the scale of 1:10,000, for Class A, and to scale of 1:2500, for Class B.

Finally the last point to observe concerns the values to obtain the two products. Applications and analysis showed that the use of High Resolution images can represent a cost reduction of approximately 30% compared to the conventional product, and allows the release of the final product in much shorter than that spent by conventional methods.

Based on these arguments, this study will seek to present the current images with high spatial resolution (less than 1 meter), high resolution or better, and from the error analysis of graphs, establish parameters for orientation in relation to the possible scale of be achieved by establishing parameters for comparison to a scale of 1:10,000, considering she can attend a series of studies of urban planning.

A brief overview of the current market of high resolution images

Studies by Bias (2003), Ishikawa and Silva (2005) and Tavares Jr. et al. (2006) show that among the sensors ever produced, the most outstanding products for the generation of registration are the sensors of IKONOS II (released in September 1999 by Space Imaging) and QuickBird 2 (released October 2001 by DigitalGlobe).

Studies of Bias (2003) with ORTHO KIT IKONOS data, in two localities in the Distrito Federal - the first in the Pilot Plan, the central region of Brasilia, and other in na Administrative Region of Sobradinho, produced results very auspicious.

For the Pilot Plan of Brasília, the total root mean square (RMS) was 0.73 m, as follows RMS in X axis of 0.41 m and the RMS in Y axis of 0.60 m. These values can be justified by the small gradient of the land (approximately 100 meters), the size of the study area (approximately 27 km2) and the satellite elevation angle (86.28°).

As for the region Sobradinho - DF, RMS average of the control points used in the process of orthorectification of the images was 1.64 m in X and 1.04 m in Y. The RMS average of the control points used for verification was 3.47 m in X and 2.10 m in Y, justified by the gradient of the land (approximately 900 meters), the size of the study area (approximately 100 km2) and the angle of high (76.47°).

Technical characteristics of images with high spatial resolution

The following Tables 2, 3, 4 and 5, the main technical characteristics of the IKONOS and Quick Bird images.

Table 2 – Specifications of IKONOS II data

Orbit Altitude	681 km
Orbit	98.1° - Sun-synchronous
Direction of orbit	Descendent 10h30 a.m.
Length of orbit	98 min.
Revisit Time	1.1 day
Width	11.3 km (nadir) 13.8 km (26° off-nadir)
Spatial Resolution	0.82 m (nadir) Pan 3.20 m (nadir) Multispectral 1 m (26° off-nadir) Pan 4 m (26° off-nadir) Multispectral
Spectral Bands	Blue: 0.45 – 0.52 µm Green: 0.51 – 0.60 µm Red: 0.63 – 0.70 µm NIR: 0.76 – 0.85 µm

Source: Space Imaging (2003)

Table 3 – Products of IKONOS II

Products	[1]CE 90% (m)	[2]RMS (m)	Description
GEO	15.00	X	Only georeferencing (Datum and projection)
Reference	25.00	11.8	To receive the image with distortion corrected is necessary to provide control points and a DEM.
PRO	10.2	4.8	Greater accuracy without the aid of control points
Precision	4.1	1.9	Generated with the aid of control points and DEM from stereo pairs
Precision Plus	2.0	0.9	Generated with the aid of control points and DEM from stereo pairs. 1m of spatial resolution
Stereo	25.0	X	Proceeds generated from stereo pairs without control points
Precision Stereo	4.0	X	Proceeds generated from stereo pairs with control points

[1]CE 90% - Circular Error with 90% of confidence; [2]RMS - Root Mean Square Error; * Excluding the relief effects; X - Standard U.S. cartographic accuracy. Source: Space Imaging (2003).

Table 4 - Specifications of Quick Bird data

Orbit Altitude	450 km
Orbit	97.2° - Sun-synchronous
Direction of orbit	Descendent 10h30 a.m.
Length of orbit	93.5 min.
Revisit Time	1.1 day
Width	16.5 km (nadir) 20.8 km (26° off-nadir)
Spatial Resolution	0.61 m (nadir) Pan 2.44 m (nadir) Multispectral 0,72 m (25° off-nadir) Pan 2.88 m (25° off-nadir) Multispectral
Spectral Bands	Blue: 0.45 – 0.52 µm Green: 0.52 – 0.60 µm Red: 0.63 – 0.69 µm NIR: 0.76 – 0.90 µm

Source: DigitalGlobe (2003).

Table 5 – Products of Quick Bird

Products	[1]CE 90% (m)	[2]RMS (m)	Description
Basic	23.0	14.0	With radiometric correction and on the detectors, geometry of the sensor. Has the smallest processing.
Standard	23.0	14.0	Available with a cartographic projection and datum
Orthorectified (RCP)	12.7	7.7	Orthorectified data
Orthorectified (Ephemeris)	10.2	6.2	Orthorectified data
Basic Stereo	23.0	14.0	Image acquired with 30 ° off-nadir, has 90 degrees of coverage

[1]CE 90% - Circular Error with 90% of confidence; [2]RMS - Root Mean Square Error. Source: DigitalGlobe (2003).

Data obtained from Engesat (2010) explain that the company GeoEye, Inc., headquartered in Dulles, Virginia, USA, announced on September 6, 2008 the successful launch of GeoEye-1 satellite with the highest spatial resolution in the commercial sector of spatial imagery of the Earth. GeoEye-1 is capable of imaging up to 700,000 km2 of panchromatic images, and 350,000 km2 of multispectral images plus panchromatic (PSM), per day, allowing visitors to revisit any area of interest on Earth, every three days or less. Products are available in four different levels of image processing - BASIC, GEO, and ORTHO STEREO - as well as products and services derived from images, including Digital Elevation Models, DEM / DEM mosaic of large and thematic maps. Table 6 presents the main characteristics of the image and Table 7, the values of each product.

Table 6 – Specifications of GeoEye data

Orbit Altitude	684 km
Orbit	97.2° - Sun-synchronous
Direction of orbit	Descendent 10h30 a.m.
Length of orbit	93.5 min.
Revisit Time	1.1 day
Width	15.2 km (nadir)
Spatial Resolution	0.41 m (nadir) Pan
	1.64 m (nadir) Multispectral
Spectral Bands	Blue: 0.45 – 0.52 µm
	Green: 0.52 – 0.60 µm
	Red: 0.625 – 0.695 µm
	NIR: 0.76 – 0.90 µm

Source: Engesat (2010)

Table 7 – Prices of GeoEye Products

Type	Minimum Area (km²)	Value (R$/km²)
Geo Ortho Kit (catalog)	49	50.00
Geo Ortho Kit (Programming)	100	95.00
Reference Stereo (catalog or programming)	49 and 100	210,00

Source: Engesat (2010)

According to Embrapa (2010), WorldView mission had its first satellite was launched in 2007 with WorldView-1 and the second in 2009. Both have a high resolution panchromatic sensor, besides the multispectral bands inserted in WorldView-2. Such satellites are the first commercial use to use Control Moment Gyroscope technology (CMGs), which provides a level 10X acceleration over other sensors, and so much better maneuverability such as targeting. With the CMGs, to achieve a coverage of a range of 300 km, the time is reduced from 60 seconds to just 9 seconds, which means that the satellite WorldView2 can move from one target to another with accuracy and speed, allowing the observation multiple targets in a single orbital pass. Tables 8 and 9 show the technical characteristics and price image WorldView2.

Table 8 – Specifications of WorldView2 data

Orbit Altitude	770 km
Orbit	97.2° - Sun-synchronous
Direction of orbit	Descendent 10h30 a.m.
Length of orbit	93.5 min.
Revisit Time	1.1 day
Width	16.4 km (nadir)
Spatial Resolution	0.50 m (nadir) Pan
	2.00 m (nadir) Multispectral
	0.46 – 0.52 m (20° off-nadir) Pan
	1.84 – 2.08 m (20° off-nadir) Multispectral
Spectral Bands	Costal: 0,40 – 0.45 µm
	Blue: 0.45 – 0.51 µm
	Green: 0.51 – 0.58 µm
	Yellow: 0.585 – 0.625 µm
	Red: 0.63 – 0.69 µm
	Red Edge: 0.705 – 0.745 µm
	NIR 1: 0.77 – 0.895 µm
	NIR 2: 0.86 – 1.04 µm

Table 9 – Prices of WorldView2 Products

Type	Minimum Area (km²)	Value (R$/km²)
Pan and Multispectral (catalog)	25	63.00
Pan and Multispectral (programming)	90	90.00
Stereo – Pan (catalog)		126.00
Stereo – MS 8 bands (catalog)	210	153.00
Stereo – Pan (programming)		180.00
Stereo – MS 8 bands (programming)		207.00

Source: Engesat (2010)

Another aspect that differentiates the sensors mentioned those of low spatial resolution is high radiometric resolution, in this case 11 bits or 2048 gray levels, which increase considerably the power of differentiation and discretization of several targets imaged.

Graphic Error and Scale

The graphic error is related to planimetric accuracy of the cartographic product, being closely related to its scale. It is the shortest length chart that can be achieved in a cartographic representation and corresponds to 0.2 mm, and is also the maximum permissible error when making a measurement on a graphical representation. Because the scale is a proportional relation between an imaging surface and represented the accuracy of this representation is the ratio between the error and scale of chart cartographic document:

Eg = 0.0002 x Fe Eq. 1

E = 1/Fe Eq. 2

Where:

Eg= tolerable error in meters

E= scale

Fe= scale factor

The calculations derived from equations 1 and 2 should be performed before the start of surveying, so you can make a selection of features that will be registered.

Based on Equation 1, Table 10 presents the accuracy of the graphical features on the basis of the adopted scales.

Tabela 10 – Accuracy depending on the adopted scale

Scale	Accuracy	Minor Object (m^2)
1:500	0.1 m	0.01
1:1,000	0.2 m	0.04
1:2,500	0.5 m	0.25
1:5,000	1.0 m	1.00
1:10,000	2.0 m	4.00
1:25,000	5.0 m	25.00
1:50,000	10.0 m	100.00

Analysis of the Relationship Between Spatial Resolution and Error Graph and Its Applications

Kasser (2002) says it is not possible to distinguish in a digital image details smaller than the pixel size, because even the shape of this target can't be discerned the shape of the pixel. Therefore, the spatial resolution is the minimum separation between two objects represented distinct and separate, it is not the size of the smallest thing possible to see (SABINSA, 1987).

The maximum frequency of a scene that can be represented by an image is given by the Nyquist frequency (Wolf, 2000), which is equivalent to half the sampling frequency. The sampling frequency is given by the pixel size as the PSF (Point Spread Function) is less than the spacing between rows and columns. Thus, only targets with a size of at least two pixels can be represented by the image in question.

Table 11 shows the sampling frequencies of the images IKONOS, QUICK BIRD, GeoEye and WORLDVIEW2.

Table 11 – Sampling frequencies

Sensor	Sampling frequencies (m^{-1})	Nyquist frequencies (m^{-1})	Equivalence in pixels (m)
IKONOS II	1	0.5	2
Quick Bird	1.64	0.82	1.22
GeoEye	2.43	1.22	0.82
WorldView2	2	1	0.5

Cost of generating a map base

After this analysis, it becomes necessary to assess the cost of a map base, by conventional aerial photogrammetry, and one generated by images of high spatial resolution.

Data provided by one of the organs of direct administration of the Distrito Federal government, for the hiring of aerophotogrammetric coverage and generation of a base map scale of 1:10,000, are detailed in Table 12.

Table 12 - Values for the generation of mapping aerophotogrammetric

Stage	Cost / km²	Estimated Area (km²)	Total (R$)
Aerophotogrammetric coverage	80.00		464,160.00
Field support basic and supplementary	60.00		348,120.00
Aerotriangulation	20.00		116,040.00
Digital Restituition	280.00	5.802	1,624,560.00
Digital Orthophoto	80.00		464,160.00
Reambulation	40.00		232,080.00
Edition	80.00		464,160.00
Final Technical Report	50.00		290,100.00
Total			**4,003,380.00**
Mean for km²			**690,00**

Source: TERRACAP (2010)

To generate a map base, using high-resolution images, we must consider two situations: the existence of contours that allow the generation of the DEM or the acquisition of stereoscopic images that allow the generation of this product. Tables 13 and 14 present both these situations.

Table 13 - Values for the costs with high image resolution and other services (GeoEye and WorldView2[1])

Stage	Number of professionals	Cost/Hour		Cost (R$/km²)
		Professionals	Equipment	
Color Composition	01	10.00	4.40	14.40
GCPs Selection	01	15.00	4.40	19.40
GCPs Lifting	03	36.80	8.00	44.80
Differential Correction	02	24.50	4.40	24.90
DEM Generation	01	15.00	4.40	19.40
DEM's Collection Points	01	15.00	4.40	19.40
Orthorectification	01	15.00	4.40	19.40
Restituition (Heads-up digitalization)	01	10.00	4.40	14.40
Editions and corrections	02	36.80	4.40	41.20
Reambulation	02	30.00	4.40	34.40
Evaluation of precision / accuracy	03	36.80	8.00	44.80
Final Edition	01	10.00	4.40	14.40
Transport	01	0.00	65.00	65.00
Technical Coordenation	01	30.00	-	30.00
Total[2]				**405.90**

[1]Imagem with ephemeris

[2]Values without considering the cost of images

Source: Bias (2003)

Table 14 – Products Cost by km2 (GeoEye and WorldView2)

Feature Image	Cost (R$/km²)	Total Services Table 13	**615.90**
Geoeyes Reference Stereo	210.00		**615.90**
Geoeyes Ortho Kit	95.00	**405.90**	**500.90**
WorldView2 Stereo	207.00		**612.90**
WorldView2 Basic	63.00		**468.90**

RESULTS AND DISCUSSION

Based on the evidence reviewed, one can evaluate the ability of high resolution images GeoEye and WorldView2 satisfy a generation of cartographic maps at 1:10,000 scale.

According to the evaluation of the graphic error was shown in Table 9, which, to a scale of 1:10,000, it (the graphic error) must be equal to or less than 4 m². Thus, the images in question are within the range: 1.68 m², the images GeoEye, equivalent to 42% of the pixel boundary, and 2.50 m² in WorldView2 images, representing 62.5% of the pixel limit.

The Nyquist frequency that only targets with a size of at least two pixels can be represented by the image and based on the graphic error. There is, through it, which analyzed the images show the possibility of representation of the targets, since they are within the limits of the graphic error.

Relating the graphical error with the number of pixels defined by the Nyquist frequency, it is possible to obtain the maximum range of representation of cartographic products, generated based on this data source. The graphic error (Eg) is equivalent to twice the spatial resolution (Re), obtaining the scales shown in Table 13.

Eg = 2x Re Eq. 3

Equating Eq. 1 and 3 we have

Fe = 10,000 x Re Eq.4

where:

Fe = Scale factor;

Re = Spatial Resolution.

;

Applying equation 4, we obtain the maximum range of representation for cartographic products, according to Table 15

Table 15 - Values of scale in relation to the spatial resolution

Sensor	Spectral Band	Spatial Resolution (m)	Fe = 10,000 x Re	Maximum Scale
IKONOS II	Panchromatic	1	10,000	1:10,000
Quick Bird		0.61	6,100	1:6,100
GeoEye		0.41	4,100	1:4,100
World View2		0.50	5,000	1:5,000

Finally, relating the data in Table 1 - which offers coverage of only 1% of the country at 1:25,000 scale - at the cost shown in Table 11 (R$ 690.00 km²), one arrives at the conclusion of that would require an investment of about R$ 6 billion to cover the entire national territory (8,514,876 km²).

As regards the construction of the base map scale of 1:10,000, some studies also point to a percentage of coverage of about 1% depending on various investments made by municipalities. Thus, based on the costs of that Table 12, one can evaluate the results in Table 16 and verify that the cost of the images is reduced quite considerably.

Table 16 - Evaluation of the percentage between the mapping and aerial photographs with the use of high resolution images

Baseline for comparison – R$ 690,00[1]		Difference (%)
IKONOS Stereo	615.90	- 10.75
IKONOS Ortho Kit	500.90	- 27.74
WorldView 2 Stereo	612.90	- 11.20
WorldView 2 Basic	468.90	- 32.04

[1]Aerophotogrammetric Mapping

CONCLUSION

The evidence presented and evaluated in this study showed that the use of high resolution images represents a real possibility, with substantial savings of resources to meet the current need for cartographic mapping.

As this assessment took into account the minimum image acquisition, it is easy to admit that one buys them in large quantities will certainly result in cost reductions and more significant.

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