Remote Sensing and Digital Databases to Recovery Terrestrial Boundaries in West Africa – Cape Roxo Region

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SUMMARY

This case study focuses on borderlands located in Guinea Bissau, more specifically on the borderland of Cape Roxo region, with a controversial geographic location which have been raising great interest and several disputes, mainly due to the lack of geographical information. This study intends to contribute to clarify the problem combining geographical information and multitemporal analysis to define the exact position of some boundary beacons.

The geographical information used, includes all available data, from old and actual maps and technical reports to most recent data obtained from new geospatial technologies. Historic and geographic information, describing the Guinea Bissau boundaries, combined with ancient aerial photographs (1950-1960) and recent high spatial resolution satellite images (2013), WorldView-2, are used in a Geographic Information System (GIS) to perform the multitemporal study.

The spatial resolution of WorldView-2 images was improved using several pan-sharpening algorithms to combine multispectral and panchromatic bands in order to obtain a pan-sharpened image with higher spatial resolution. This procedure enhances the spatial information improving the interpretation of terrain features.

Multitemporal analysis detected changes in coastal landforms, in Cape Roxo region, showing significant shoreline erosion/accretion, a high dynamic lagoon-beach system and relative stability of the inshore dune, where a boundary beacon is located.

SUMÁRIO

O presente estudo incide sobre a região do Cabo Roxo, na Guiné-Bissau, cuja localização geográfica suscita bastante interesse, a tal ponto que várias disputas que têm ocorrido principalmente devido à falta de informação geográfica. Neste estudo usa-se os Sistemas de Informação Geográfica e os estudos multitemporais para definir a posição exacta dos marcos de fronteira.

A informação geográfica utilizada inclui todos os dados disponíveis desde os mapas antigos e relatórios técnicos, sobre essa região, aos dados mais recentes obtidos a partir das novas tecnologias geoespaciais. Informação histórica e geográfica, descrevendo os limites da Guiné-Bissau, juntamente com fotografias aéreas (1950-1960) e imagens de alta resolução espacial recentes (2013), WorldView-2. O cruzamento destes dados é feito e analisado no Sistema de Informação Geográfica (SIG), para realizar um estudo multitemporal.

Para melhorar a resolução espacial da imagem WorldView-2, são aplicadas várias técnicas às bandas multiespectrais e pancromática, através da utilização de vários algoritmos de fusão disponíveis, para obter uma imagem fundida com maior resolução espacial. Este procedimento permitirá melhorar a informação espacial e beneficiar a interpretação do terreno.

O resultado da análise multitemporal permitiu detectar algumas mudanças nas formas de relevo litorais na região do Cabo Roxo, mostrando uma significativa erosão / sedimentação costeira, uma dinâmica activa do sistema praia-laguna e uma relativa estabilidade da duna localizada na pré-praia, onde se localiza um marco de fronteira.

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1. INTRODUCTION

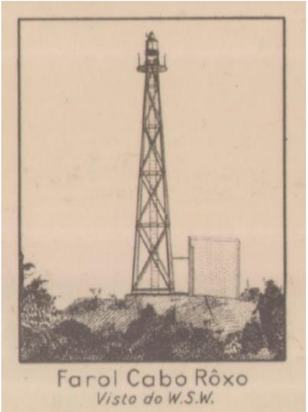
In Africa, most of the states continue without having their boundaries demarcated (AUBP, 2013). Even those with international boundaries well established before the decolonization still show difficulty to identify their borderlines due to the physical loss of the beacons and deficiencies in delimitation or in demarcation which has been a recurrent source of tension and conflict between several African States.

On 12 May 1886, France and Portugal signed a Franco-Portuguese Convention for the delimitation of their respective possessions in West Africa, which was later rectified in Lisbon, on August 31, 1887. Although the two parties recognized the Convention, later both countries differed in their interpretation. Many disputes occurred during the boundary demarcation (1886-1906), mainly due to the lack of knowledge about Africa coast, the lack of details in frontier delimitation and the native resistance, to prevent Europeans from entering their land to demarcate a border (JIU/IICT, 1965; Esteves, 1988). The last paragraph of article I of the 1886 Convention refers that: "Portugal will possess all the islands included between the meridian of Cape Roxo, the coast and the southern limit formed by a line following the thalweg of the Cajet River, and the turning towards the south-west, ..., where it reaches the parallel 10º 40' North latitude, and follow it as far as the meridian of Cape Roxo".

The demarcation of Guinea Bissau frontier, completed between 1900 and 1906, was one of the first works carried out in the Portuguese-speaking countries in Africa. The French and Portuguese commissioners demarcated the boundary with pillars, numbered from 1 to 184, using the more update survey equipment, recorded in memoranda (JIU/IICT, 1965). The final approval with the current Senegal of the southeast and east limits with the current Guinea Conakry, was held in 1904 and the agreement on the northern boundary was implemented in 1906 between Portugal and France, based on limits represented by a 1:250 000 scale map.

The north maritime boundary in Cape Roxo was assigned according with the 1960 agreement, and following the last renegotiations with Senegal in 1995. The south maritime boundary was established in 1985, with Guinea Conakry.

The Cape Roxo region, at the Atlantic coast, where the pillar 184, and a lighthouse (Figure 1) are located, is quite remote from Bissau, with non-existent infrastructures or settlements, characterized by sand dune. In this region the frontier is supported by an eccentric geodetic beacon, the pillar 184 located near the lighthouse, on the southernmost dune making up the point of Cape Roxo, at 3,839.67 meters from marker pillar 183. However, according to the Convention description about the pillars location some duties persist.



a)

b)

Figure 1 - Cape Roxo beacon (nº.184) at lighthouse: a) in a map of 1955 (JMGIU/IICT, 1955); b) in 2015 (http://autocaravanaspt.blogspot.pt/2009/03/dia-32-26.HTML).

In the last century, even after the demarcation of the boundaries, the disputes still continued, mainly related with the maritime boundary in Cape Roxo, induced by the presence of suspected natural resources, as offshore oil and fishery. Guinea Bissau government engaged in negotiations with foreign oil companies under the pressure from oil companies.

Therefore, in 1983, Guinea Bissau and Senegal decided to seek to Arbitration Tribunal trial for the delimitation of the maritime boundary (Aquarone, 1995), and the last resolution dates from 1995. Recently Guinea Bissau government and Senegal established a common economic area, defined by the North azimuth 268º and the south by 220º, from the Cape Roxo beacon.

The study is included in the project Geospatial Tools on Demarcation and Management of GB Boundary (PTDC/ATP-GEO/4645/2012) financed by Fundação para a Ciência e a Tecnologia. The main goal of the project is to compile historical, diplomatic, and geographical information related with Guinea Bissau boundaries, existing at Tropical Research Institute (Instituto de Investigação Científica Tropical, IICT, Portugal) and National Institute of Studies and Research (Instituto Nacional de Estudos e Pesquisa, INEP, Guinea Bissau), and to take advantage of geospatial technology, to produce a boundary information system for Guinea Bissau borderlands.

The geospatial technologies, including satellite imagery associated with GIS tools have been used in boundary studies (AUBP, 2013), allowing more accurate production, overlap, manipulation and analysis of geographic information. In this context, a combination of updated high resolution satellite imagery and aerial photography, from 1950-1960, will be used to perform multi-temporal analysis to understand the effect of the earth surface changes on the boundary. These studies will combine existing historical description of boundaries and the topographical features obtained from remote sensing data. The outputs can be directly used by decision makers for security purposes and in studies such as demography, migrations, ethnical, socio-cultural, land management.

2. STUDY AREA AND DATA

2.1 Study area

The northern frontier of Guinea Bissau with Senegal, consists of straight-line segments defined by pillars. It has a length of about 338 km, with an orientation almost west-east. Extends from the Atlantic coast, at Cape Roxo lighthouse (pillar 184), to the east until the tripoint (beacon 58) with Senegal and Republic of Guinea Conakry. This northern borderlands, at the more occidental sector, between Cape Roxo and the pillar 112, was delimited by the middle distance of the Casamance River and Cacheu River (Figure 2b). In the more oriental sector, it is defined by the parallel 12º 40' N. After the demarcation, between 1949 and 1965, a 1:50 000 scale Guinea Bissau map, based on aerial photography was published including the pillars along the frontier (JMGIU/IICT, 1949-1965).

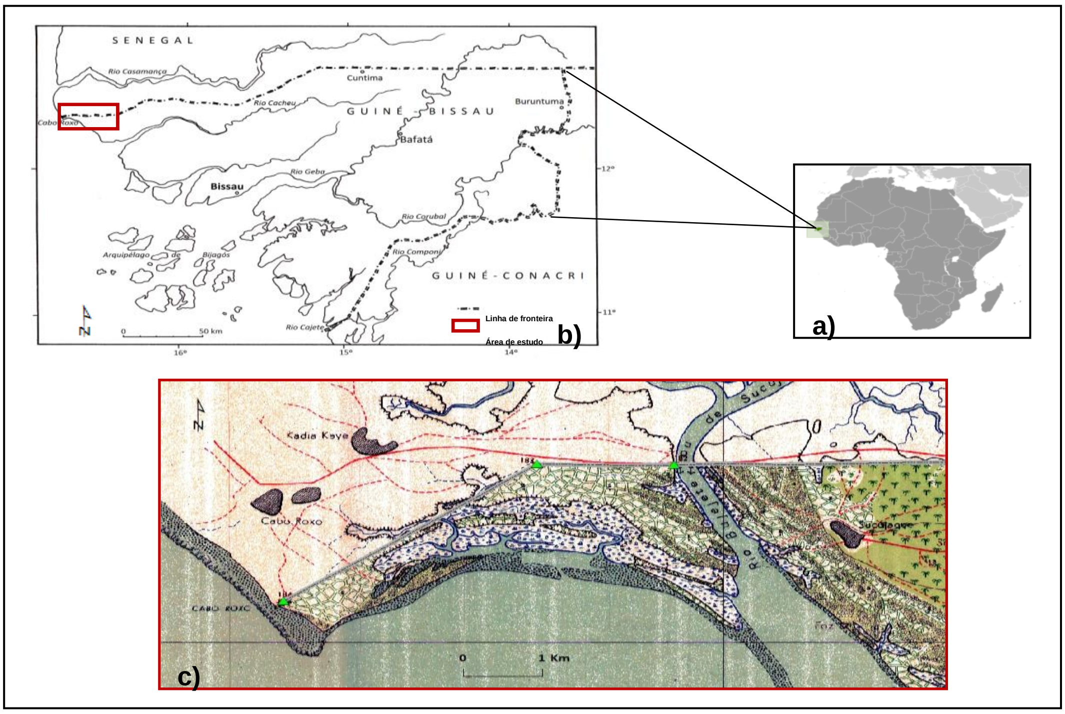


Figure 2 - Framework of Cape Roxo study area: a) Guinea Bissau in the African continent; b) study area in Guinea Bissau; c) Cape Roxo region (JMGIU/IICT, 1954).

The Guinea Bissau is characterized as a flat region, in terms of topography, with a maximum altitude of about 292 m. In the Cape Roxo region, the altitude ranges from approximately 2 to 4 meters, which reduces the need of images orthorectification, a process that consists in the correction of the image to minimize the distortions caused by the relief. In this region, in the southwest coast and at its inner limit a 2 m high beach with a rocky offshore and a dune stabilised by vegetation, can be found. At the southeast coast beach-lagoon system (Figure 2c) is located, induced by an active continental fluvial and marine dynamics.

2.2 Data

The 1:50 000 scale map of Varela, (Figure 2c) of 1954, based on two aerial photographs taken in 1953 at a scale of 1:30 000 and two satellite images from the sensor WorldView-II (WV-2) collected in 2013, were used in this study. The WorldView-II images, have a panchromatic band, with a spatial resolution of 0.50 m and eight multispectral (MS) bands (b1 - Coastal, b2 - Blue, b3 - Green, b4 - Yellow, b5 - Red, b6 - Red Edge, b7 - NIR1 and b8 – NIR2), with 2.0 m of spatial resolution (Figure 3), and a radiometric resolution of 11 bits.

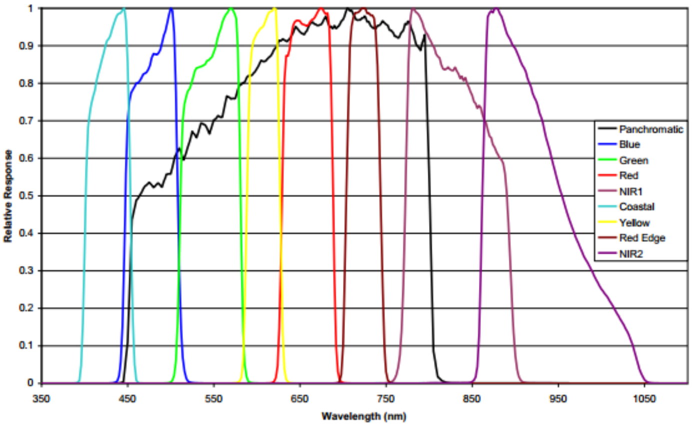
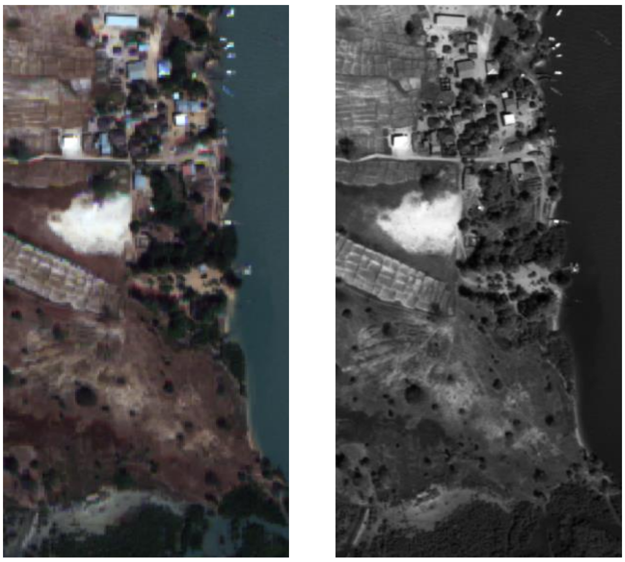


Figure 3 - Spectral response bands of Worldview II sensor (DIGITALGLOBE, 2010a).

A colour composition of the MS image (RGB-5/3/2) and the PAN image is show the Figure 4.



a) b)

Figure 4 - Right bank of river Bujejete: a) MS image with a spatial resolution of 2.0 m

(RGB-5/3/2); b) PAN image with a spatial resolution of 0.5 m.

The WorldView-2 satellite images were initially georeferenced using the WGS84 coordinate system, and the Bissau datum, in order to use a common coordinate system.

3. METHODS

The increase of the spatial resolution of multispectral bands can be a valid tool in multitemporal studies. Pan-sharpening is a type of data fusion that increases the spatial resolution of the data through the combination of low-spatial resolution images with high resolution panchromatic image in order to produce a high resolution multispectral image (Laben et al. 2000; Padwick, 2010).

To improve the spatial resolution of the multispectral images several fusion algorithms merging PAN band with the MS bands were applied. The Pan-sharpening methods used were the most cited in literature, Gram-Schmidt (GS), Principal Component (PC), Intensity-Hue-Saturation (IHS) and Colour Normalized (Brovey).

The GS fusion method simulates a PAN band from the lower spatial resolution spectral bands (Laben et al, 2000). This method removes the redundant information in the dataset by an orthogonal transformation applied to the simulated PAN band and the spectral bands. The statistics of the PAN band are adjusted to the statistics of the first transformation bands obtained from GS transformation. Then the high spatial resolution PAN band replaces the first Gram Schmidt band and at the last step an inverse GS transform is applied to produce the pan-sharpened multispectral bands (Laben et al, 2000).

The IHS method is a standard image fusion procedure, to separate spatial (intensity) and spectral (hue and saturation) information from an image (Chavez et al., 1991; Carper et al., 1990). The major limitation of this method is that only uses three bands (Chavez and Bowell, 1988; Tu et al., 2001). It first converts a RGB image into its intensity (I), hue (H) and saturation (S) components, afterwards intensity is substituted by the high spatial resolution panchromatic image and at the last step an inverse transformation was applied, converting IHS components into RGB colours.

The PC spectral method transforms a multivariate dataset of correlated variables into a dataset of uncorrelated linear combinations of the original variables (Chavez et al., 1991). In this method the PAN image histogram is matched with the first principal component, and then it replaces the PAN band. The last step consists of an inverse PC transform. This method is similar to the IHS method with the advantage that can use more than three bands.

The Brovey method is a fusion technique which uses a mathematical combination of colour images and high resolution data. Each spectral band is first divided by the sum of the three chosen bands and then multiplied by the panchromatic image (Hallada and Cox, 1983). The function automatically resamples the three colour bands to a high-resolution pixel size using nearest neighbour techniques, bilinear or cubic convolution. The output RGB images will have the pixel size of the input high-resolution data (Vrabel, 1996; Bovolo et al., 2010).

The accuracy of the results is based on: i) visual comparison and ii) correlation analysis, calculated using the original PAN band and the output bands resulting from the sharpening methods applied.

Figure 5 shows the flow diagram of the methodological procedures and the data used in the multitemporal study, based on remote sensing data and existing cartography at IICT.

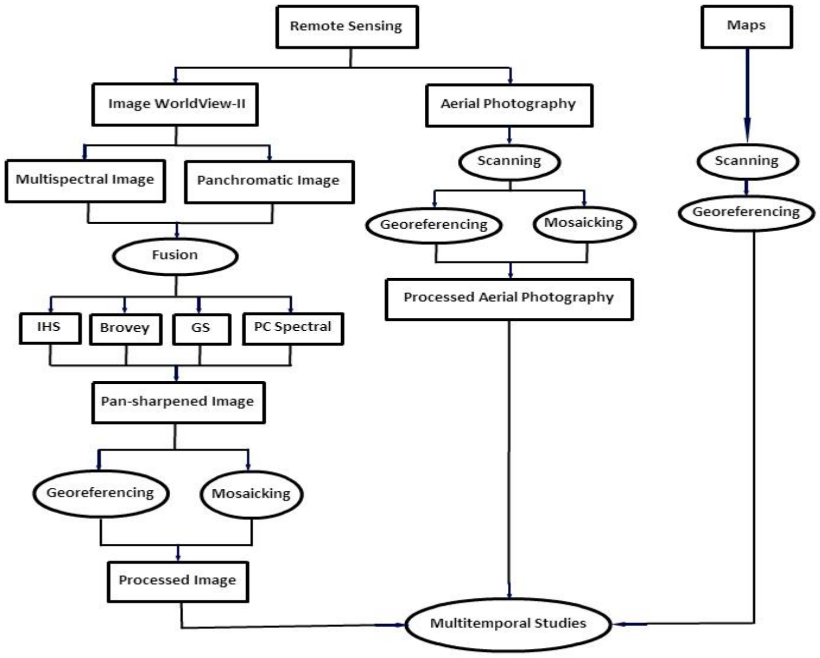


Figure 5 - Flow diagram of the methodological procedures.

The resampling method used in the fusion procedure was based on the nearest neighbor. This type of resampling assigns the value of the nearest pixel to the pixel in the output visualization, not changing the original values (Ruikar and Doye, 2012). The spatial resolution of the final image was the same of panchromatic band (0.5 m).

4. RESULTS

The evaluation of the accuracy of the methods tested is based on the verification of the improvement of spatial resolution and the preservation of spectral characteristics. Firstly, the analysis of the spatial quality of the fused images was performed by visual inspection (Li, 2000; Ehlers et al., 2010). This analysis is done by comparing the original image with the multispectral images generated by fusion tests (Figure 6).

Comparing the output images with the multispectral original image (Figure 4a), the IHS and the PC methods, in comparison with GS and Brovey methods show objects with less contrast and reduced sharpness, especially in vegetation and urban areas. These two latter methods showed higher contrast and better sharpness, improving the image interpretation, and showing more similarity with the original multispectral image.

Figure 6 - Right bank of river Bujejete pan-sharpened images resulting of fusion methods: a) IHS ; b) PC; c) GS; d) Brovey.

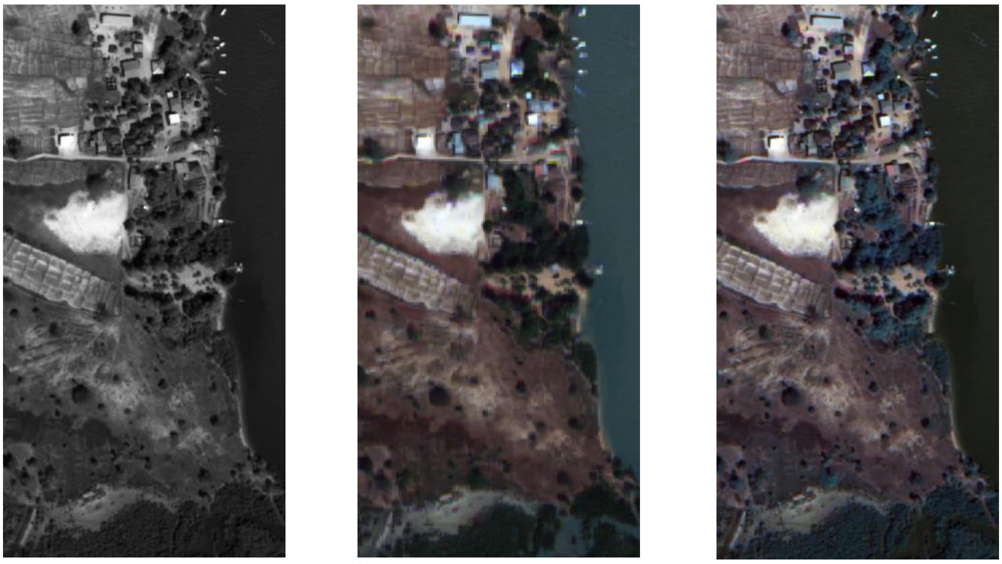
To validate the results, the correlation coefficient was computed between the original MS bands and the equivalent fused bands (Table 1). This method is objective and reproducible.

Table 1 shows that the higher correlation with the original panchromatic image is obtained applying IHS and Brovey methods, with correlation coefficients above 0.9300. This means that these methods allow a higher spatial detail in the pan-sharpened image. The GS and PC methods also show a good correlation, respectively, for bands 3, 4, 5 and 6 and bands 6, 7 and 8. However, for the remaining bands, they show lower values. In summary the Brovey method showed the best results, with a mean correlation value of 0.9648.

Table 1: Correlation coefficients between the pan-sharpened images and the original PAN.

	Band 1	**Band 2**	**Band 3**	**Band 4**	**Band 5**	**Band 6**	**Band 7**	**Band 8**
IHS	–	0.6760	0.7486	–	0.8941	–	–	–
Brovey	–	0.9652	0.9836	–	0.9456	–	–	–
PC	0.9360	0.4332	0.5583	0.5097	0.3304	0.1475	0.9391	0.9799
GS	0.6786	0.7238	0.8064	0.9195	0.9454	0.8018	0.6221	0.6165

The Figure 7 shows the original PAN and MS images and the result of the best pan-sharpened method.



a) b) c)

Figure 7 - Right bank of river Bujejete: a) original PAN image; b) original Worldview-2 MS image (RGB-5/3/2); c) Brovey pan-sharpened image (RGB-5/3/2).

The best pan-sharpened image obtained was georeferenced with aerial photographs according to the 1:50 000 Varela map (Figure 2c) and a multi-temporal study using the aerial photographs (1953) and satellite images (2013) was performed. This study, tried to understand if there are changes, between the referred dates, at the beach from the southwest to the southeast coast (Figure 8). Comparing Figure 8a) with 8b) it can be concluded that between 1953 and 2013, at the southwest coast, the width of the beach was maintained with very small variations. Regarding the southeast coast, there was an enlargement of the beach, in the southern sector, due to the increased of the sedimentation in the shoreline and in the beach, which has reduced at the lagoon area. In the north sector of this southeast coast, the lagoon increased and the sedimentation in shoreline was reduced, contributing to a decrease of the beach width.

On the southwest coast, the inner limit of the beach does not vary during the period of time considered and retreated only in its southern sector, due to the lagoon retraction and an increase of marine sedimentation conditions in the beach. The inner limit of beach on the southeast coast had major changes caused by an increase of the lagoon area.

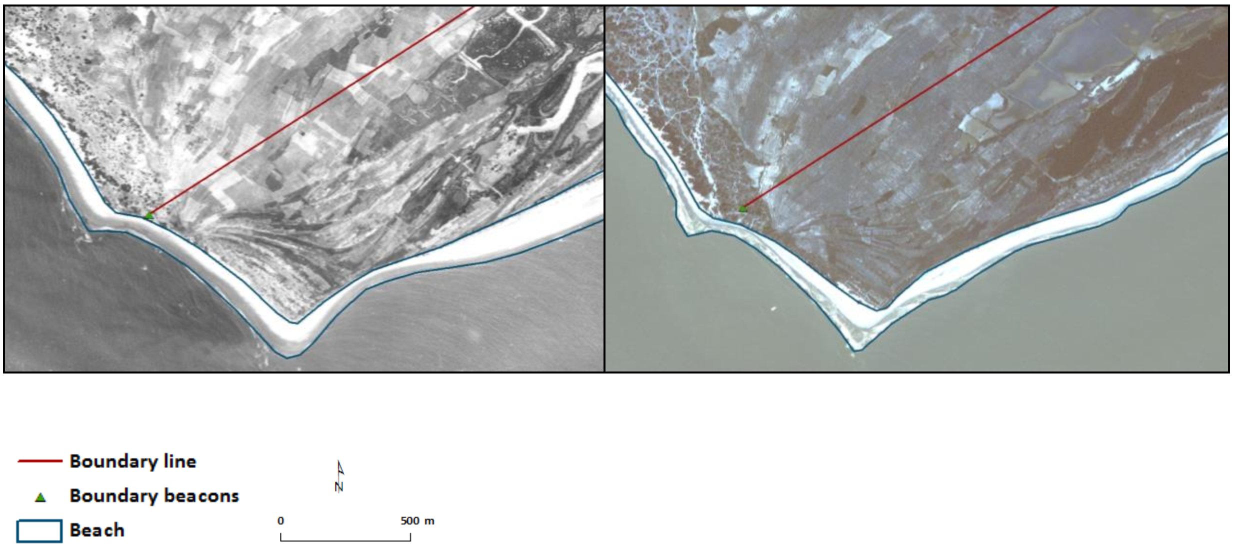


Figure 8 - Cape Roxo region: a) aerial photography (AN, 1953); b) satellite image WorldView-2 RGB-5/3/2 (DIGITALGLOBE, 2013).

In summary, on the southwest coast the beach dimensions were similar between 1953 and 2013 and its inner limit was stable, due to the stabilization of the inshore dune by vegetation (where is located the pillar 184) and the regular conditions of sedimentation in this offshore rocky beach. At the southeast coast the changes during the above mentioned period are evident, due to continental fluvial dynamics, responsible for the lagoon area changes, and ocean currents, inducing a certain temporal variability of sedimentation conditions along the shoreline.

5. CONCLUSIONS AND FINAL CONSIDERATIONS

The qualitative and quantitative analysis of the results obtained with the application of fusion techniques to the WorldView-2 images, Cape Roxo region, showed that the best performance was obtained with the Brovey technique. However, this is not feasible for the location of the boundary beacons. Therefore, it was conclude that concerning the boundary study, the spatial resolution of the PAN and MS images must be higher to obtain a greater contrast and better sharpness, in order to improve the interpretation of the pan-sharpened image. However, the potential of the satellite image can be enhanced with the use of control points collected during the fieldwork.

The results will be validated through fieldwork by collecting ground control points, mainly over the boundary beacons in the Cape Roxo region, using the Global Navigation Satellite System (GNSS) technology. Another alternative is to make flights with Unmanned Aerial Vehicle (UAV), swinglet CAM (SenseFly), which due to its high spatial resolution (0.06 m) it may be can make possible to identify the boundary beacons location on the ground contributing to a better definition of the boundary. This approach can be extremely helpful for the interpretation of the border treaties and conventions, conducing to promising results and taking advantage of geospatial technology applied to boundary issues.

To improve the analysis and the definition of the boundary, a WorldView-3 satellite image, with high spatial resolution, will be acquired in order to study the Ponta Cajete region, located in southern Guinea Bissau sector. This satellite images have very high spatial resolution, the panchromatic band has 0.30 m and multispectral bands have 1.24 m. The boundary line in Ponta Cajete was defined by the Cajete river thalweg, located in an almost flat and very muddy region which must be monitorized. Cape Roxo and Ponta Cajete, should be studied to analyse the evolution of the border line and the boundary beacons to precisely locate the terrestrial frontier. It is foreseen to provide to the local partners an instrument for borderland monitoring and policy making, supporting support Guinea Bissau boundaries' management, contributing for its documented characterization.

ACKNOWLEDGMENTS

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REFERENCES

Aquarone, M.-C. (1995) - The 1985 Guinea/Guinea-Bissau maritime boundary case and its implications. Ocean Development & International Law 26 (4), pp. 413-431, Taylor and Francis.

AN (1953) – Fotografia aérea. 585, Março 1953. Escala 1:30 000. Lisboa, Aviação Naval.

AUBP (2013) - Delimitation and demarcation of boundaries in Africa. General issues and case studies. African Union Border Programme. Commission of the African Union, Department of Peace and Security, Addis Ababa, 292 p. (ISBN 978-99944-890-8-4).

Bovolo F., Bruzzone L., Capobianco L., Garzelli A., Marchesi S. (2010) - Analysis of effect of pan-sharpening in change detection on VHR Images. IEEE Transaction on Geoscience and Remote Sensing Letters, 7 (1), pp. 53-57.

Carper, W.J., T.M. Lillesand, and R.W. Kiefer (1990) - The Use of Intensity-Hue-Saturation Transformation for Merging SPOT Panchromatic and Multispectral Image Data, Photogrammetric Engineering b Remote Sensing, 56(4), pp. 459-467.

Chavez, P.S., S.C. Sides, and J.A. Anderson (1991) - Comparison of Three Different Methods to Merge Multi-Resolution and Multispectral Data: Landsat TM and SPOT Panchromatic, Photogrammetric Engineering b Remote Sensing, 5 7(3), pp. 295-303.

Chavez, P.S., and J.A. Bowell (1988) - Comparison of the Spectral Information Content of Landsat Thematic Mapper and SPOT for Three Different Sites in the Phoenix, Arizona, Region, Photogrammetric Engineering & Remote Sensing, 54(12), pp.1699-1708.

DIGITALGLOBE (2010) – WhitePaper. The benefits of the 8 spectral bands of WorldView-II. March 2010a. (http://Worldview2.digitalglobe.com/docs/Worldview-2_8-and_ Applications_Whitepaper.pdf).

DIGITALGLOBE (2013) - WorldView-2, February and December remote sensing image.

Ehlers, M.; Klonus, S.; Åstrand, J.P.; Rosso, P. (2010) - Multisensor image fusion for pansharpening in remote sensing, International Journal of Image and Data Fusion, 1 (1), pp. 25-45.

Esteves, M.L. (1988) - A questão do Casamansa e a delimitação das fronteiras da Guiné. Lisboa, Instituto de Investigação Científica Tropical, Instituto Nacional de Estudos e Pesquisa, 310 p.

Hallada, W.A. and Cox, S. (1983) - Image sharpening for mixed spatial and spectral resolution satellite systems. Proceedings 17th international symposium on remote sensing of environment, Environmental Research Institute Michigan Ann Arbor, MI, pp. 1023-1032.

http://autocaravanaspt.blogspot.pt/2009/03/dia-32-26.HTML (acessed February-23, 2015)

JMGIU/IICT (1949-1965) - Carta da Província da Guiné. Escala 1:50 000. Lisboa, Centro de Geografia do Ultramar, Junta de Investigações do Ultramar / Instituto de Investigação Científica Tropical.

JMGIU/IICT (1954) - Guiné Portuguesa. Folha de Varela. Escala 1:50 000. Lisboa, Junta de Missões Geográficas e Investigações do Ultramar

JMGIU/IICT (1955) - Carta hidrográfica da barra e foz do Rio Cacheu. Escala 1:80 000. Lisboa, Junta Missões Geográficas Investigações Ultramar / Instituto de Investigação Científica Tropical.

JIU/IICT (1965) - Fronteira da Guiné. Centro de Geografia do Ultramar, Junta de Investigações do Ultramar/Instituto de Investigação Científica Tropical, Lisboa (not published).

Laben, C.A.; Bernard, V.; Brower, W. (2000) - Process for enhancing the spatial resolution of multispectral imagery using pan-sharpening. United States Patent Application, No. 6,011,875.

Li, J. (2000) - Spatial quality evaluation of fusion of different resolution images, ISPRS International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 33 (B2-2), pp. 339-346.

Padwick, C.; Deskevich, M.; Pacifici, F. Smallwood, S. (2010) - Worldview-2 Pan Sharpening. Proceedings ASPRS 2010 Annual Conference, San Diego, California, pp. 26-30.

Ruikar, S. D. and Doye, D. D. (2012). Image Denoising Using Tri Nonlinear and Nearest Neighbor Interpolation with Wavelet Transform. I.J. Information Technology and Computer Science, 9, pp. 36-44.

Tu, T.M., Su, S.C., Shyn, H.C. and Huang, P.S. (2001) - A new look at IHS-like image fusion methods. Information Fusion, 2, pp. 177–186.

Vrabel J. (1996) - Multispectral Imagery Band Sharpening Study. Photogrammetric Engineering & Remote Sensing, 62, pp. 1075-1083.

BIOGRAPHICAL NOTES

Adélia M. Oliveira de Sousa is an Auxiliar Professor at the Dep. of Rural Engineering, School of Science and Technology of the Évora University, Portugal. She has a graduation in Geographic Engineering, and a Master degree in GIS, Lisbon University. The PhD degree was based on application of remote sensing data to map and analysis of spatial patterns of occurrence of fires in Brazil, Évora University. The main research and teaching interests are in precision agriculture and application of GIS and remote sensing data to maintenance / management of natural resources. She participate in multidisciplinary national and international projects and published papers in national and international journals.

Ana Raquel Melo is research fellowship at the Tropical Research Institute (IICT), Lisbon, at project “Geospatial technologies on demarcation of Guinea Bissau boundary” (PTDC/ATP-GEO/4645/2012) funded by the Foundation for Science and Technology. She holds a degree in Geographic Engineering and has a Graduate in Science and Geographic Information Systems.

Maria do Carmo Nunes is a senior researcher at Tropical Research Institute, in Lisbon. She is a geomatic engineering, holds a PhD and a master degree in georesources. Her multidisciplinary background on remote sensing, GIS, GPS/GNSS, multivariate statistics, and geostatistics, allowed participation in about 10 multidisciplinary financed research projects. Now she is the principal investigator of the “Geospatial Tools on Demarcation and Management of Guinea Bissau Boundary” project. She has published papers in national and international conferences, book chapters and journals.

Ana I. R. Cabral is a Geographic Information System and Remote Sensing expert, working in tropical regions, mainly in African countries, in the areas of deforestation, mapping and modeling of land cover/land use change scenarios and quantification of carbon emissions, with over 15 years experience. She holds a degree in Geographic Engineering, a MSc in Geographic Information Systems and a PhD equivalence in Earth Observation. Since 2005, she is a senior researcher in Tropical Research Institute in Lisbon, Portugal.

Fernando Lagos Costa is a senior researcher of the Tropical Research Institute (IICT), Lisbon, holds a PhD thesis in Physical Geography about the quaternary valley landforms and slope geomorphological processes at Cape Verde Islands, having more than 20 years of field experience in physical geography and planning in tropical regions, natural hazards assessment and man impacts on slope morphodynamic, soil erosion and sedimentary processes in tropical semiarid and volcanic conditions, particularly in Cape Verde, Guinea Bissau and Angola.

Ana Morgado is a senior researcher at Tropical Research Institute, in Lisbon. She holds a PhD in Geomatic Engineering from University College London. Since 1996 coordinated and/or participated in research and cooperation projects in the context of Earth Observation (EO) applications mainly applied to African Portuguese Speaking Countries, namely Cape Verde, Guinea Bissau, Angola and Mozambique. Coordinator of “Bridging Actions for GMES & Africa" BRAGMA FP7 Project, responsible for organising 4 pan-African Workshops in conjunction with both EC and AUC on EO applications for Africa. EU co-chair of the Space component of the 8th partnership of the Joint EU-Africa Strategy (JAES).

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