

Geospatial Technologies Applied to International Boundaries – the Case Study of Guinea Bissau

Maria NUNES, Adélia SOUSA, João PINTO, Ana MORGADO, Fernando COSTA, Ana CABRAL, Portugal
Augusto BOCK, Viriato CASSAMÁ, Guiné-Bissau

Keywords: Boundary Documentation, GIS, Remote Sensing, Guinea-Bissau.

SUMMARY

Modern geospatial technologies applied to frontiers involve remote sensing data, namely satellite imagery, orthophoto or orthoimages, global navigation technology (GPS/GNSS), as well as Geographical Information System (GIS) tools, which have been used during the last decade for boundary delimitation, demarcation or revision.

This paper intends to present the case study of Guinea Bissau boundary which was the first African Portuguese colonies to settle its boundaries. It was delimited by a Franco–Portuguese convention signed in Paris on May 12, 1886, and ratified later in Lisbon, on August 31, 1887. The demarcation was completed between 1900 and 1905 and recorded in memoranda prepared by the commissioners.

For historical reasons Tropical Research Institute (IICT) concentrates a unique, vast and diverse amount of information concerning the borders of those countries.

The scope of this research is to explore new methodologies and approaches to study frontiers, making use of geospatial technologies. A Boundary Geographical Information System (BGIS) is being developed based on GIS technology which is a powerful tool to integrate various datasets, visualize, analyze and model spatial and territorial specificities. Historical-diplomatic information will be articulated with the geospatial data, in order to be included into the geodatabase and to recover the location of the borderlines.

The original analogue data was converted into digital format, and image processing techniques were applied to remove residual artifacts, improving the appearance of the documents and reducing storage volume. These methodologies prepared the images for the application of optical character recognition (OCR) before integrating them into the geodatabase.

The main objective is to make this information useful and accessible, in a digital platform, to support local authorities, thus promoting cooperation and facilitating public access. The BGIS will be used for present and future management of Guinea Bissau boundaries and as an instrument for policy making.

Geospatial Technologies Applied to International Boundaries – The Case Study of Guinea Bissau (7787)
Maria Nunes, Adélia Sousa, João Pinto (Portugal), Viriato Cassamá and João Bock (Guinea-Bissau)

RESUMO

As tecnologias geoespaciais modernas, aplicadas a questões de fronteiras envolvem informação de deteção remota, como imagens de satélite, ortofotos ou ortoimagens, Sistemas Globais de Posicionamento e de Navegação por Satélite (GPS/GNSS) e Sistemas de Informação Geográfica (SIG), que têm vindo a ser usados desde a última década na delimitação, demarcação ou revisão de fronteiras territoriais.

Este artigo pretende ser um caso de estudo da fronteira da Guiné-Bissau (GB) que foi a primeira colónia portuguesa africana a demarcar os seus limites. Foi delimitada por uma convenção Franco-Portuguesa assinada em Paris em 12 de Maio de 1886. Mais tarde, foi ratificada em Lisboa, em 31 de agosto de 1887. A demarcação foi concluída entre 1900 e 1905 e redigida em relatórios preparados pelos comissários de delimitação da fronteira. Por razões históricas o Instituto de Investigação Científica Tropical (IICT) concentra uma quantidade única, vasta e diversificada de informação sobre as fronteiras daqueles países. O principal objectivo deste estudo, do âmbito do projeto “Geospatial Tools on Demarcation and Management of Guinea Bissau Boundary”, é explorar novas metodologias e abordagens para aplicar à fronteira da Guiné-Bissau, fazendo uso de tecnologias geoespaciais. Está sendo desenvolvido um Sistema de Informação Geográfica de fronteiras (SIG), uma ferramenta poderosa para integrar conjuntos de dados díspares, visualizar, analisar e modelar especificidades espaciais e territoriais.

A informação histórico-diplomática será articulada com a informação geoespacial, a fim de ser incluída no SIG para melhor localizar e descrever a linha de fronteira.

Os documentos originais foram submetidos a uma conversão analógico-digital e sujeitos a técnicas de processamento de imagem, incluindo métodos morfológicos combinados com outras abordagens de realce de imagem e foram aplicadas transformações para remover artefactos residuais, melhorando desta forma a aparência documentos e diminuindo o volume de armazenamento. Estas metodologias permitiram melhorar as imagens, para posterior aplicação de reconhecimento óptico de caracteres (OCR), antes de integrá-las no SIG. O resultado final fará com que esta informação seja útil e esteja acessível numa plataforma digital, para apoiar as autoridades da GB, promover a cooperação e facilitar o acesso ao público. O SIG da fronteira será importante para o gerenciamento presente e futuro das fronteiras da GB e poderá ser usado como um instrumento de desenvolvimento de políticas.

Geospatial Technologies Applied to International Boundaries – the Case Study of Guinea Bissau

Maria NUNES, Adélia SOUSA, João PINTO, Ana MORGADO, Fernando COSTA, Ana CABRAL, Portugal
Augusto BOCK, Viriato CASSAMÁ, Guiné-Bissau

1. INTRODUCTION

The main purpose of International boundaries is the delimitation or recognition of a territory, with own laws and its sovereignty. The majority of African boundaries were delimited between 1884 and 1904 and the definitive delimitation was completed in 1920. The short period of time used to delimitate African boundaries and the type of equipment available then, caused errors and lack of accuracy which have not been corrected to date.

Since the African States obtained independence, borders have been a source of conflicts and disputes. The political map of Africa was in general preserved, with the persistence of colonial boundaries as established in 1964, in Cairo, by the Organization of African Unity (OAU), and confirmed in 2002, in Durban, by the African Union. OAU recognized that boundaries are a major prerequisite for peaceful and cooperation among African States. African leaders have adopted a number of decisions to engage in the border subject as a security and peace concern (AUBP, 2013). In 2011, the African Union Border Programme (AUBP) concluded that only approximately one third of African land boundaries were demarcated and part of it using inaccurate methods or using out-of-date boundary techniques (AUBP, 2013).

Frontiers have always been a central issue in Africa concerns. In July of 2011, during the 17th Ordinary Session of the Assembly of the African Union, it was agreed to do everything to successfully complete the delimitation, demarcation, and reaffirmation of African boundaries, extending to 2017 the initial deadline of 2012. The AUBP signed the compromise to assist these states in their efforts to achieve this ambitious deadline. Therefore, nowadays, African borders demarcation is a challenge to attain.

The boundaries are demarcated with permanent marks or pillars based in survey beacons. Their positions are precisely determined based on internationally accepted surveys. Natural features such as rivers, ridge lines of the mountains, hills, ditches, centers of roads and other physical features are also used to determine boundaries. There is a requirement for the authorities to protect these milestones to avoid misunderstandings and consequent conflicts. The public should be informed and aware of the importance of protecting these beacons and do not destroy or move them from their lands. A well-defined boundary whether international or national if respected and maintained defines the possession and becomes a legal reality (Didigwu, 2004).

After the independence the new African states adopted the European model of nation state, integrating multicultural and multiethnic societies within the colonial boundaries; such is the case of Guinea Bissau. The importance of obtaining a geographic accurate map of Guinea Bissau was recognized after the Brussels Conference in 1876, which triggered the colonization of the interior of Africa. In 1883 the Portuguese Commission of Cartography, predecessor of the Tropical Research Institute (Instituto de Investigação Científica Tropical - IICT) was created, to produce cartography of the Portuguese overseas territories, including borderlands delimitation and demarcation. The IICT concentrates a vast and diverse frontiers archive concerning Community of Portuguese Language Countries (CPLC), including official and diplomatic agreements, treaties of delimitation of borders, correspondence, technical reports of fieldwork, and geographic coordinates of the beacons, and maps related with delimitation and demarcation of the borderlines. Some of this information was never studied nor prepared to achieve its great potential, to prevent conflicts and support the sustainable development of those countries.

Official delegations from CPLC, including from Guinea Bissau, have been consulting boundary documentation at IICT. Therefore, it was considered important to carry out the pilot project “Geospatial Tools on Demarcation and Management of Guinea Bissau Boundary”, financed by Fundação para a Ciência e Tecnologia (PTDC/ATP-GEO/4645/2012), to implement a Boundary Geographic Information System (BGIS), to organize, preserve in digital boundary documents and to investigate new methodologies to obtain the accurate location of the boundary beacons and the borderline. This project could be applied to others CPLC countries, since IICT is the holder of their frontier archives. This study constitutes a starting point as a research and operational tool to facilitate further investigation and provide the basis for a continuous dialogue among neighboring countries. It should reinforce international cooperation networks concerning boundaries research, taking into account existing relevant work carried out by specialized international institutions. Guinea Bissau occupies the 177th position in the Human Development Index worldwide. The economy of Guinea Bissau is dominated by agriculture as the primary sector. There is a great need for capacity building on research and systematic observation, as well as financial and technical support for information, awareness, education and training, stability and peace. The country is of coastal and archipelagic characteristics with high vulnerability to adverse effects of climate change.

2. THE INTERNATIONAL BOUNDARY OF GUINEA BISSAU

The Republic of Guinea Bissau is located on the west coast of Africa, covering an area of about 36 125 km². This is a small country with about 700 km of borderline. It is bordered to the north by Senegal and to the east by Guinea Conakri. The latitude ranges from parallel 12° 40' N to 10° 59' N (Ponta Cajet), and the longitude varies from meridians 13° 38' W and 16° 43' W (Cape Roxo). The maximum extent in latitude is 193 km and in longitude 330 km. The Guinea Bissau frontier was delimited by three international agreements between France and Portugal in 1886, 1904 and 1906. The Conventions describe the delimitation of the boundaries based on the intersection of meridians and parallels, azimuthal directions, and middle distance

Geospatial Technologies Applied to International Boundaries – The Case Study of Guinea Bissau (7787)
Maria Nunes, Adélia Sousa, João Pinto (Portugal), Viriato Cassamá and João Bock (Guinea-Bissau)

between Casamansa and Cacheu rivers in Cape Roxo region (JIU/IICT, 1965; Brownlie, 1979; Esteves, 1988; Nunes et al., 2012).

Disputes and conflicts between Guinea Bissau and Senegal were mainly concerned with the Cape Roxo maritime boundary. Since the nineteenth century the question arises between France and Portugal. The maritime limits were defined by a 1960 agreement. Guinea Bissau argued that the line defined in Article I of the Franco-Portuguese Convention of 1886 constituted a boundary and Guinea-Bissau argued that such line was merely a line of allocation of sovereignty over islands. The Tribunal concluded that the line had not been established as a maritime boundary, which seems to mean that the limit was viewed as a line of allocation (Antunes, 2002). In 1983, Guinea Bissau and Senegal decided to seek for a Tribunal Arbitration concerning the delimitation of the maritime boundary (Aqarone, 1995). The determination of maritime boundary was given by the International Court of Justice, on 23 august 1989. On 12 November 1991, as a result of a Guinea-Bissau request, the same Court validated these decisions (Gaudin, 1993).

On 18 February 1983, Guinea Conakri and Guinea Bissau concluded a Special Agreement with the purpose to establish an Arbitral Tribunal, to decide, in accordance with the relevant rules of international law, whether the Convention of 12 May 1886 between France and Portugal and the protocols annexed to that Convention established the maritime boundary between the respective states (Dundua, 2006-2007). A detailed publication of the historical facts related with the Guinea Bissau frontier describes the Casamansa question and some aspects of diplomatic agreements, pointing out many incidents which occurred during frontier delimitation and its demarcation process (Esteves, 1988).

Concerning the terrestrial boundary, the lack of a detailed demarcation led to frequent misunderstandings and required field surveys, between 1888 and 1905, to rehabilitate or to build additional beacons position. A survey, took place, between 1925 and 1931, using more accurate surveying instruments and applying geodetic techniques, to review some positions of the frontier beacons (JIU/IICT, 1965). The terrestrial frontier was demarcated by 184 major pillars or beacons, and later, six additional beacons were included between beacons 1 and 2 (1a, 1b, 1c, 1d, 1e, and 1f). The boundary archive includes a list of geographic coordinates calculated for each boundary beacon and a complete description of the boundary line, segment by segment, between beacons.

Between 1949 and 1963, a map composed by 72 sheets, at scale 1:50 000, in UTM projection, based on aerial photography from 1949 to 1956 (Figure 1) was published, by JIU/IICT (JIU/IICT, 1963). These maps include the position of all the boundary beacons. Later, in 1961, a map of Guinea Bissau, at scale 1:500 000 was re-published including all boundary beacons (JIU/IICT, 1961).

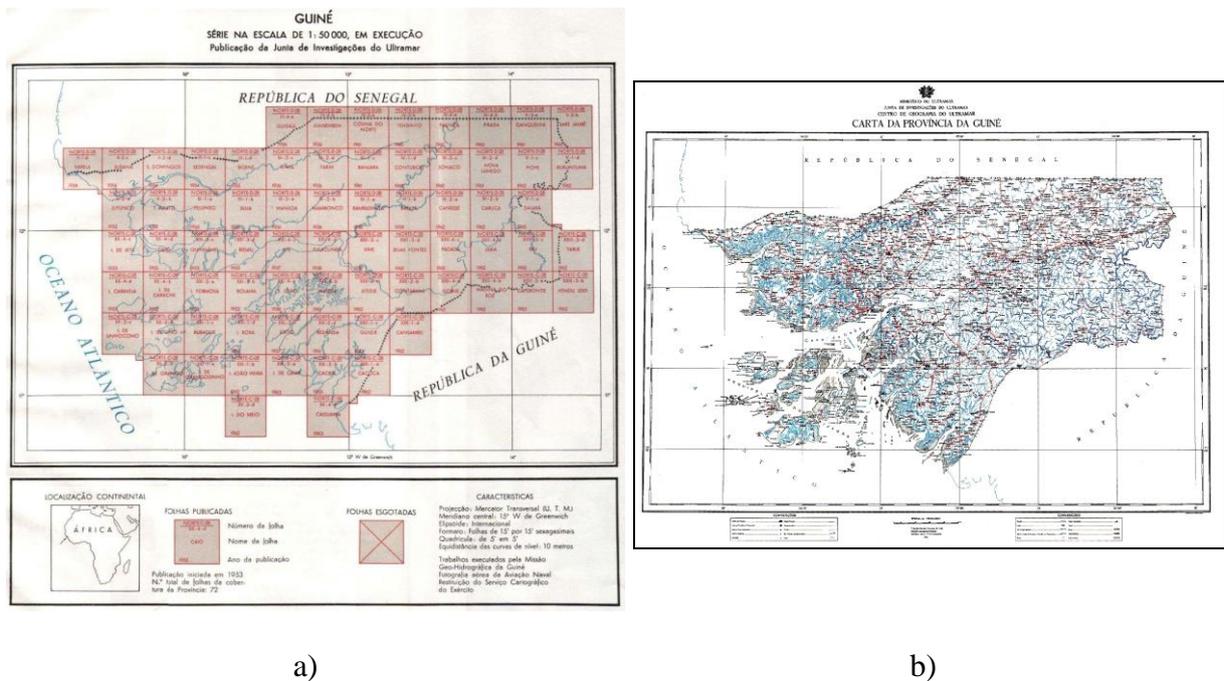


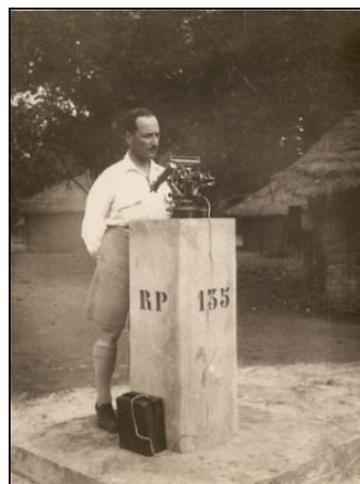
Figure 1 – a) Sheet layout of maps including boundary beacons at scale of 1:50 000 (JIU/IICT, 1963); b) Guinea Bissau map at 1: 500 000 scale (JIU/IICT, 1961).

It is important to preserve the boundary's appearance in the field and the intervisibility between beacons, by maintaining the frontier line not obstructed by forest. This is essential in cases where the boundary line passes through woodland or when it is defined by a river channel. The consequences of destroying survey beacons is described by Didigwu (2006) with the case study of Nigeria, where boundary beacons are deliberately or unknowingly tampered, displaced or removed entirely, affecting government, individuals and surveyors. It is important to explain to the public the importance of survey beacons for determining boundaries and securing property and the consequences of destroying them. The maintenance with continually monitoring of the boundary line will prevent unintended invasions and violations of sovereignty avoiding possible military conflicts.

The disappearance of boundary pillars is frequent due to natural (sand dunes or muddy soil) or man-made reasons. This is the case of Guinea Bissau frontier, between Guinea Conakry, wherein some marks were made of loose stones that meanwhile vanished. The boundary line in Ponta Cajet was defined along the Cajet river thalweg, in an almost flat and very muddy region, therefore it is a borderline that needs to be monitored and studied. Also part of the Guinea Bissau boundary goes through forest areas, for this reason, it was demarcated by opening four meters wide trails (Figure 2), which are vanished nowadays.



a)



b)

Figure 2 - a) Borderline defined by a trail; b) beacon n°.135 with a transit theodolite (JIU/IICT, 1965, Nunes et al., 2012).

Geospatial Technologies are currently robust tools, in constant development, with a dominant role in multidisciplinary studies, continually contributing for higher quality and precision. Since last decades, geospatial technologies, including Remote Sensing data and Geographic Information Systems have been used for international boundary making, delimitation, demarcation and borderlands studies. Also Global Navigation Satellite Systems (GNSS) receivers have been contributing to demarcation and revision of terrestrial and maritime boundaries which are also recommended by borderlands commissions and borders experts (Adler, 2001; Chen, et al., 2013; AUBP, 2013, Pinther, et al., 2013).

Satellite image has now reached high spatial resolution which makes it as useful in these studies as aerial photography. The acquisition of commercially available high-resolution imagery can be prohibitively expensive for wide areas. Geospatial applications have been used during the past decade, in some international boundary projects involving the United Nations Cartographic Section. Recently, the developments and the proliferation of Unmanned Air Vehicle (UAV), with ultra-high spatial resolution imagery, at a low-cost, are used to get updated images allowing access to remote locations. This is a promissory technology to be used in borderlands studies.

3. GEOSPATIAL TECHNOLOGIES IN GUINEA BISSAU BORDERLANDS

The cartographic representation of international boundaries is critical especially in areas disputed by two countries. Authoritative information, such as, treaty text, treaty coordinates, and treaty maps integrated into a GIS database, with updated satellite imagery can be a very useful and efficient instrument to provide more reliable information to support borderlands disputes, cross-boundary planning, development and management and to evaluate historical changes in territory and borderlands.

The project “Geospatial Tools on Demarcation and Management of Guinea Bissau Boundary” aims to produce a Boundary Information System (BGIS) of the Guinea Bissau borderlands through a comprehensive analysis of the existing geographical and historical information, exploring new methodologies and approaches, and taking advantage of geospatial technologies. The BGIS will support present and future management of these boundaries and can be used as an instrument for policy making and management.

First task of the project includes organization, digitalization and processing of the Guinea-Bissau geographical and historical boundary archive, containing the diplomatic treaties of the boundary delimitation, agreements, sketches, beacon frontier coordinates, demarcation, field reports of scientific missions, maps and aerial photography (Figure 3).



Figure 3 - Historical maps, aerial photography and borderlands documents.

The original data were submitted to an analogue-digital conversion followed by processing these images based on image analysis and filtering techniques, including morphological filters combined with image enhancement approaches, to remove residual artifacts, and improve in this way the documents appearance, and also reducing storage volume. During the analogue-digital conversion special care was taken in order to minimize the damage caused by the scanning process, in order to preserve the historical and geographical documents, some of the nineteenth century. The policy usually followed is to perform the scan operation only once and therefore with the best quality. These electronic documents should not be directly

available. The digital documents should be prepared: (1) to obtain a new collection to be accessed by the web, with the lowest storage volume but without degrading the quality of the visual appearance of the documents; (2) whenever possible to obtain a version of the same collection in which the characters have been recognized applying optical characters recognition (OCR) technique; (3) to extract a set of descriptive metadata of the content of the document that can help in the data mining process. The extraction of descriptive metadata from handwritten and typed documents was done regarding the presence of artifacts, such as, stamps, underlines and annotations that were considered relevant, for indicating the presence of noteworthy information. Stamps, underlines and annotations are features affecting OCR accuracy. Due to the handling of documents throughout the time, these may suffer multiple transformations and may become almost imperceptible. These methodologies and approaches were applied to prepare the images for further application of OCR before integrating them into the geodatabase (Mata, et al., 2014, Mata, 2014).

In a second phase a BGIS was developed integrating the selected geographical and historical, boundary documentation previously compiled. Multitemporal studies are being carried out based on satellite high resolution imagery of WorldView-2 satellite and aerial photography, to understand land surface changes on the borderlands, focusing in regions where the borderline is defined by landscape features, such as, a thalweg of a river or a ridge line (Sousa et al., 2015). Also a Digital Elevation Model (DEM), from Shuttle Radar Topography Mission - SRTM (NASA), is being used to study borderlands (Figure 4).

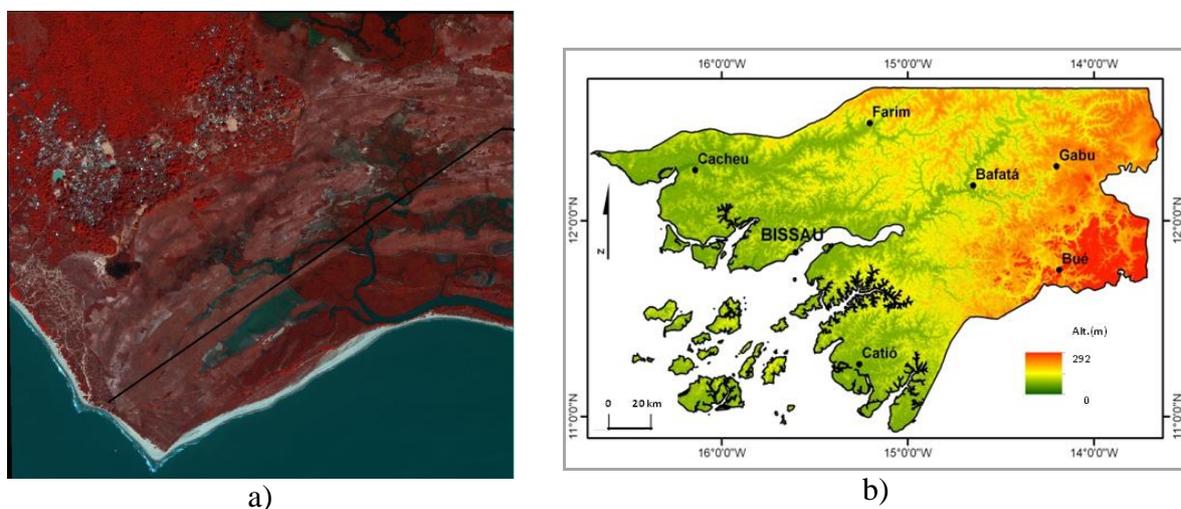


Figure 4 – a) Cape Roxo satellite image of the sensor WorldView-II (2013) and DEM from SRTM (NASA).

A study aiming to assess the regional development of the territory of Guinea Bissau in comparison with the two neighboring countries (Guinea Conacry and Senegal) was done and to evaluate the complexity of the spatial relationships in their borderlands (Costa, et al., 2014; Melo, et al., 2014). Road network's connectivity and accessibility and the village centrality were performed, as well as, an analysis of the spatial heterogeneity of land cover in the borderlands of the tree countries using basic concepts of graph theory and network analysis

Geospatial Technologies Applied to International Boundaries – The Case Study of Guinea Bissau (7787)
 Maria Nunes, Adélia Sousa, João Pinto (Portugal), Viriato Cassamá and João Bock (Guinea-Bissau)

techniques in a GIS (Morgado and Costa, 2011). Satellite images were also used to obtain land cover maps to find changes in spatial pattern between borderlands. The study was applied to three areas located on the borderlands of Guinea Bissau with Senegal (in the northern sector) and with Guinea Conakry (in the eastern and southeastern sectors).

The results showed that the villages located in the side of Guinea Bissau have more direct road links with Senegal and a road network more structured than with Guinea Conakry. The density and the structure of the road network and the degree of connectivity at local level are similar between the neighboring countries. The road network has continuity between countries and reveals a certain similarity in terms of cross-border accessibility. Land cover maps were produced to analyze the pattern of each cover type in both sides of the frontier. Savanna woodlands cover type is in majority of the region, and the rice agricultural areas and the main villages occupy the irrigated valleys. The land cover pattern shows continuity between countries, and a certain similarity in the neighbor countries in each of the regions. According the study performed can be concluded that the regional development of the territory and the complexity of spatial relationships in the borderlands of Guinea Bissau are similar with their neighboring countries (Costa, et al., 2014; Melo, et al., 2014).

A third task of the project intends to validate the BGIS database by obtaining consistent geo-information taking advantages of Global Navigation Satellite Systems. In cases of disputed boundaries, the establishment of a global boundary datum has the advantage that it is not the datum of either party, showing advantages as a coordinate reference system for future boundary surveying and mapping activity and border identification, administration and management.

Field campaigns will be done, also to collect GPS/GNSS data, to determine parameters for coordinates transformation between global geodetic systems (ITRS or WGS84) and the Bissau geodetic datum. There exist some different transformation parameters however none of the sets seems to give satisfactory results.

The process will be done based on the re-observation of some well distributed geodetic benchmarks of the classical terrestrial network (Figure 5), throughout the entire country. Spatial data will be transformed from the existing referential coordinates systems (Bissau datum) to global reference systems used nowadays.

The classical terrestrial triangulation network (Figure 5) was established between 1944 and 1962 by the geo-hydrographical mission of Guinea Bissau consisting of 32 first order network benchmarks and calculated on the Bissau geodetic datum which was established by astrogeodetic methods (Serra, 1945).

The field observations, reports, and all the elements regarding this network are kept at IICT. After several decades this large amount of geodetic data and their mathematical treatment carried out so far are still important for the economic, technologic and scientific development of Guinea Bissau, since it has been used as the basis for the cartography produced until now.

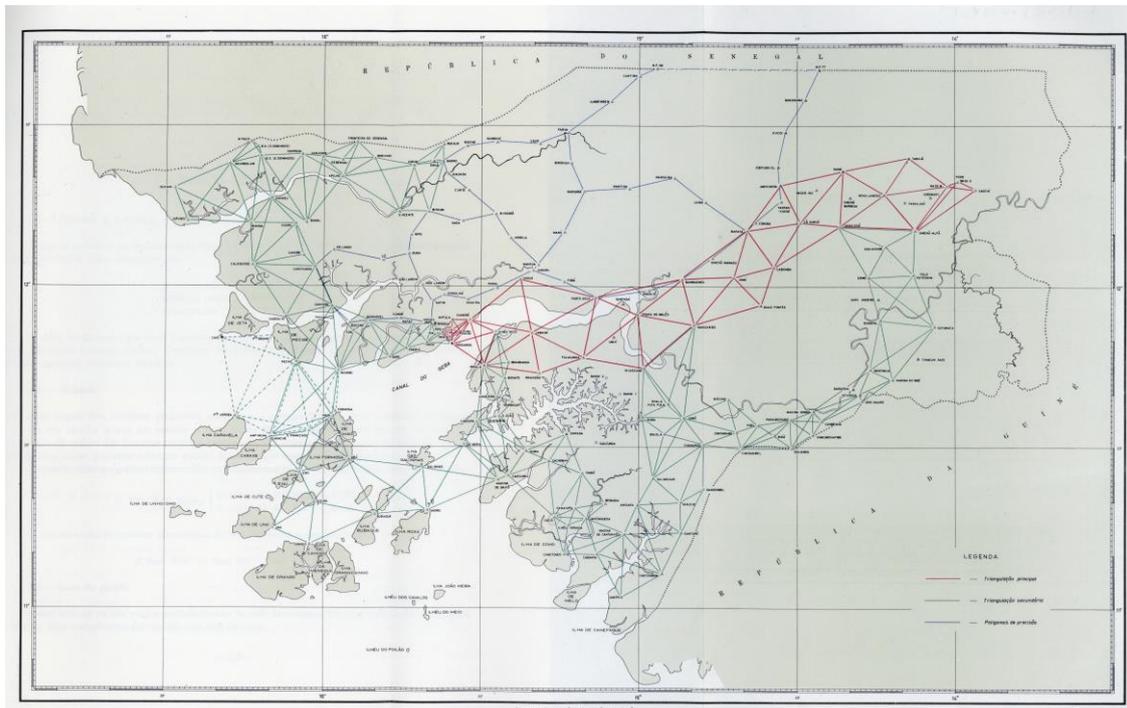


Figure 5 - Classical terrestrial triangulation network (IH, 1968).

4. CONCLUSIONS AND RECOMMENDATIONS

The proposed BGIS system intends to provide reliable information and facilitate the management of the boundary. The final output will make this information useful and accessible, in a digital platform, thus promoting cooperation and facilitating public access. The BGIS will be used for present and future management of boundaries and as an instrument for policy making. This is a starting point as a research and operational tool to facilitate further investigation and provide the basis for a continuous dialogue among neighboring countries. It should contribute to reinforce international cooperation networks concerning boundaries research, taking into account existing relevant work carried out by specialized international institutions.

To summarize, borderlands studies are an interdisciplinary issue that can have a great benefit from recent developments in geospatial technology, concerning remote sensing, GIS and GNSS. Borderlands are regions that need continuous monitoring and particular attention for political reasons and cross-border activities.

ACKNOWLEDGEMENTS

This work was funded by the Project "Geospatial Tools on Demarcation and Management of Guinea Bissau Boundary" - PTDC/ATP-GEO/4645/2012, financed by Foundation for Science and Technology (Fundação para a Ciência e a Tecnologia, Portugal).

REFERENCES

- Adler, R., 2001, Geographical Information in Delimitation Demarcation and Management of International Land Boundaries, in *Boundary and Territory Briefing* vol. 3, no. 4, International Boundaries Research Unit, University of Durham (U.K.).
- Antunes, N., 2002, *Towards the Conceptualization of Maritime Delimitation: Legal and Technical Aspects of a Political Process*, Durham theses, Durham University. Available at Durham E-Theses. <http://etheses.dur.ac.uk/4186/> (accessed on 27/02/2015).
- Aquarone, Marie-Christine, 1995, 'The 1985 Guinea/Guinea-Bissau Maritime Boundary Case and Its Implications,' 26 *Ocean Development & International Law*, vol. 4, 413-431, Taylor and Francis.
- AUBP (African Union Border Programme), 2013, *Delimitation and Demarcation of Boundaries in Africa, General Issues and Case Studies*. Commission of the African Union, Department of Peace and Security, Addis Ababa, September 2013, pp.292, ISBN 978-99944-890-8-4.
- AUBP (African Union Border Programme), 2014, *Delimitation and demarcation of boundaries in Africa, The User's Guide*. Commission of the African Union, Department of Peace and Security, pp.84, May 2013, Addis Ababa, ISBN 978-99944-890-2-2.
- Brownlie, I., 1979, *African Boundaries: a legal and diplomatic encyclopaedia*. London: Hurs.
- Chen, J.; Ge, Y-J; Cheng, Y.; Li, R.; Cao Y., 2013, *Borderlands Modelling and Understanding with GISS: Challenges and Research Agenda*. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-4/W3, 2013, ISPRS/IGU/ICA Joint Workshop on Borderlands Modelling and Understanding for Global Sustainability, 5 – 6 December 2013, Beijing, China.
- Costa, F.L.; Cabral, A.I.; Nunes, M.C.; Melo, A.R., 2014, *Acessibilidade e Povoamento nas Regiões de Fronteira da Guiné-Bissau*. Guimarães, Actas do XIV Colóquio Ibérico de Geografia, 'A Jangada de Pedra'. Geografias Ibero-Afro-Americanas: 2495-2500 (ISBN 978-972-99436-8-3 / 978-989-97394-6-8).
- Didigwu, A. U. S., 2004, *Principles and Methods of Basic Surveying*. Academic Book Publishers 33 Edingbur Road Enugu.
- Didigwu, Augustus, 2006, *The Consequences of Destroying Survey Beacons by the African Public – A Case Study of Nigeria*. FIG 2006. Promoting Land Administration and Good Governance, 5th FIG Regional Conference, March 8-11, 2006, Accra, Ghana.
- Dundua, N. 2006- 2007, *Delimitation of Maritime Boundaries Between Adjacent States*, United Nations – The Nippon Foundation Fellow.
- Esteves, M.L., 1988 - *A Questão do Casamança e a Delimitação das Fronteiras da Guiné*. Lisboa, Instituto de Investigação Científica Tropical, Instituto Nacional de Estudos e Pesquisa, 310 p.
- Gaudin, A., 1993, *De la Contribution de la Guinée-Bissau à L'élaboration du Droit International Maritime la Fixation par Arbitrage des Limites de la Guinée-Bissau, Géopolitiques des Mondes Lusophones*, 1993, pp. 143-153.
- IH, 1968, *Trabalhos Geodésicos Executados pela MGHG na Província da Guiné*, 125p., Instituto Hidrográfico, Lisboa.
- JIU/IICT, 1961. *Carta da Província da Guiné*. Escala 1/500 000. Lisboa, Junta de Investigações do Ultramar / IICT.

Geospatial Technologies Applied to International Boundaries – The Case Study of Guinea Bissau (7787)
Maria Nunes, Adélia Sousa, João Pinto (Portugal), Viriato Cassamá and João Bock (Guinea-Bissau)

- JIU/IICT, 1963, *Cartas Geográficas das Províncias Portuguesas Ultramarinas*, Lisboa, Publicadas pela Junta de Investigação do Ultramar.
- JIU/IICT, 1965, *Fronteira da Guiné*, Lisboa, Junta de Investigações do Ultramar, Centro de Geografia do Ultramar, (not published).
- Mata, Henrique; Pinto, Caldas, J.R. and Nunes, Maria, C., 2014, *Metadata Extraction from Ancient Documents*, pp.32-33, Covilhã, Universidade da Beira Interior, RecPad2014 - 20th Portuguese Conference on Pattern Recognition.
- Mata, Henrique., 2014, *Image Restoration and Metadata Extraction of Ancient Documents*, MSc. Thesis, Instituto Superior Técnico, Universidade de Lisboa, 81p.
- Melo, A.R.; Costa, F.L.; Cabral, A.I.; Nunes, M.C., 2014, *Acessibilidade e ocupação do solo em regiões de fronteira da Guiné-Bissau*. Porto, GOT. *Revista de Geografia e Ordenamento do Território*, 6: 223-239 (ISSN-2182-127).
- Morgado P. and Costa N., 2011, *Graph-based Model to Transport Networks Analysis Through GIS*. Proceedings of European Colloquium on Quantitative and Theoretical Geography, 2-5 September, Athens, Greece.
- Nunes, M.C.; Morgado, Ana and Costa F.L., 2012, *Digital Delimitation of Guinea Bissau Terrestrial Boundaries*, pp.223-237, *Borders and Borderlands: Today's Challenges and Tomorrow's Prospects*. Proceedings of the Association for Borderlands Studies, Lisbon Conference, Iva Miranda Pires (Ed.), ISBN: 978-972-636-230-2.
- Pinther, M.; Robertson, W., Shoshany, M. and Shrestha, Buddhi and Srebro, Haim, 2013, *International Boundary Making*, Nº 59, 188p, FIG Commission 1, Helsinki, Finland, Haim Srebro (Ed.).
- Serra, Victor, 1945, *Relatório da Missão Geo-Hidrográfica da Guiné*, Campanhas de 1944 e 1945, JIU/IICT, Lisboa (not published).
- Sousa, A.; Melo, R.; Nunes M.C.; Cabral A.I.; Costa, F.L.; Morgado, A., 2015, *Remote Sensing and Digital Databases to Recovery Terrestrial Boundaries in West Africa – Cape Roxo region*, 15p., FIG Working Week, 17-21 May, Sofia, Bulgaria.

BIOGRAPHICAL NOTES

Maria do Carmo Nunes is a senior researcher at Tropical Research Institute, in Lisbon. She is a Geomatic Engineering, holds a PhD degree equivalence and a Master degree in Georesources. Her multidisciplinary background on remote sensing, GIS 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.

Adélia Sousa is an Auxiliar Professor at the Dep. of Rural Engineering, School of Science and Technology of the Évora University, Portugal. The graduation is Geographic Engineering and Master in Geographic Information Systems from Lisbon University. The PhD (2007) was obtained in Évora University, with the thesis “Burned area mapping and spatial patterns analysis of the fires in Brazil”. The main research and teaching interests are in precision agriculture and application of GIS and remote sensing data to management natural resources.

Geospatial Technologies Applied to International Boundaries – The Case Study of Guinea Bissau (7787)
 Maria Nunes, Adélia Sousa, João Pinto (Portugal), Viriato Cassamá and João Bock (Guinea-Bissau)

João R. Caldas Pinto was born in Leiria, Portugal in 1951 and graduated from Instituto Superior Técnico, Lisbon in 1974. He received his PhD in control systems in Manchester in 1983. He is Associate Professor at the Instituto Superior Técnico. His research interests include image processing and pattern recognition, principally with respect to old documents and vision based control chiefly as it applies to robotics.”

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).

Fernando Lagos Costa is a senior researcher of the Tropical Research Institute (ICT), 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 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, and with over 15 years experience. She holds a degree in Geographic Engineer, a master degree in Geographic Information Systems and a PhD. Degree equivalence in Earth Observation. Since 2005, she is a senior researcher in Tropical Research Institute in Lisbon, Portugal.

Augusto João Bock is a researcher of the National Institute of Studies and Research (INEP) of Guinea Bissau, coordinating the Center for Environmental Studies Appropriate Technology, holds a PhD thesis in Agricultural Engineering, about potential resources and food safety policy in Guinea Bissau, having a large scientific experience agro-food production in tropical environments, quality control and integrated pest management techniques, environmental impact assessment and promotion of sustainable and durable development.

Viriato Cassamá is a researcher of Directorate-General for Environment, PhD student in environmental remote sensing and climate change in Guinea Bissau, holds a MSc thesis in georesources and geosystems, having a particular scientific experience in land cover changes, natural resources uses and management, multitemporal mapping of forest vegetation and calculation of deforestation rates, economic valuation of goods and services provided by ecosystems, agricultural and forestry uses and impacts on forest degradation assessment.

Geospatial Technologies Applied to International Boundaries – The Case Study of Guinea Bissau (7787)
Maria Nunes, Adélia Sousa, João Pinto (Portugal), Viriato Cassamá and João Bock (Guinea-Bissau)

CONTACTS

Maria do Carmo Nunes; Fernando Lagos Costa; Ana Morgado and Ana I. R. Cabral.
Instituto de Investigação Científica Tropical (IICT)
Travessa Conde da Ribeira, 9, B, 1º, 1300-142, Lisboa, Portugal
E-mail: mcarmonunes15@gmail.com; flcosta1955@gmail.com; anammorgado@gmail.com;
anaicabral70@gmail.com
Web site: <http://www2.iict.pt/>

Adélia Maria Oliveira de Sousa
Departamento de Engenharia Rural, Escola de Ciências e Tecnologia,
Instituto de Ciências Agrárias e Ambientais Mediterrânicas (ICAAM),
Centro de Inovação em Tecnologias de Informação (CITI)
Universidade de Évora Apartado 94, 7002 – 554, Évora, Portugal
E-mail: asousa@uevora.pt
Web site: <http://www.uevora.pt/>

João Caldas Pinto
Instituto de Engenharia Mecânica (IDMEC - Pólo do Instituto Superior Técnico)
Avenida Rovisco Pais
1049-001 Lisboa, Portugal
E-mail: jcpinto@dem.ist.utl.pt
Web site: <http://web.ist.utl.pt/ist11390/>

Augusto João Bock
Instituto Nacional de Estudos e Pesquisas (INEP)
Bissau – Complexo 14 de Novembro – CP - 112, Guiné-Bissau – Bissau.
E-mail: augustobock68@gmail.com
<http://www.inep-bissau.org>

Viriato Luís Soares Cassamá
Secretaria de Estado do Ambiente, Direcção Geral do Ambiente (SEA/DGA)
Avenida dos Combatentes da Liberdade da Pátria, Palácio do Governo, Bissau, Guinea Bissau
E-mail: cassamavilus@gmail.com