MAPPING WITH SPOT SATELLITE IMAGERY: THE NIGERIAN EXPERIENCE

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ABSTRACT

This paper reviews the state of topographical maps in Nigeria vis-a-vis the status of world mapping at 1:50,000. Application of SPOT Satellite imagery for the production of 1:50,000 planimetric maps of areas not covered by the existing conventionally produced maps at this scale is presented. Methods of production, revision and metrication of parts of the national topographical maps using SPOT Satellite imagery are also presented.

KEY WORDS: Mapping, Map Revision, Space Imagery, SPOT, Remote Sensing.

1. INTRODUCTION

Topographical maps are the basic prerequisite for any meaningful planning, development and effective management of the natural resources of any nation. However the recent research conducted by United Nations Organisation (UNO) and reported by Bradenberger et al (1985), shows that only about 42% of the world land area is covered by basic 1:50,000 map series and these maps are revised at the rate of only 2% per annum. The developed countries of the world are the best mapped with Europe and North America having a coverage of 91% and 61% respectively, while Africa and South America are only mapped to 29% and 27% respectively. It is thus apparent that there is a strong correlation between development and availability of medium scale maps.

It has been estimated that using the conventional photogrammetric method it will take not less than 40 years to achieve full coverage of the world at 1:50,000; while the rate of updating cannot be less than every 40 years. It is thus apparent that the mapping needs of the world especially the developing countries, at a scale of 1:5000 and smaller scales, are not being met today by the conventional photogrammetric mapping operations. However, the increase in spatial resolution of commercial satellite images namely: Landsat MSS (1972) Landsat TM (1982) and SPOT (1986) with spatial resolution of 80m, 30m and 10m/20m respectively is fast changing the realisation of the mapping needs of the world at the 1:50,000 and smaller scales.

2. THE STATE OF BASE MAPS IN NIGERIA

Nigeria has a land form area of about 1,000.000km^2. The country is covered by about 1300 sheets of 1:50,000 map series. Up till 1989 about 90% of the country was covered at this scale. However, through the mapping commissioned by the National Population Commission (NPC), for the 1991 population census, the whole country was covered by December 1990. As laudable as this feat may seem in comparison with UNO's research finding concerning the state of world mapping, the question of spatial fidelity and completeness of most of these maps remain unresolved.

The early topographical maps of the country were produced by approximate means which included tracing from aerial photo, after control points have been supplied by slotted templates; and later by multiplex (Atilola,1986). Some of these maps produced, before the use of topographical plotters in the fifties, with limited accuraces, are still being used today without revision against the UNO's recommended revision period of 10 years for areas of high human activities and 15 years for remote areas.

Apart from the obsoleteness of the content of these base maps, most of them are still in imperial units and Modified Transverse Mercator projection system while the country has changed to metric and UTM systems.

2.1 Need for the Application of Satellite Imagery to Mapping in Nigeria.

As indicated above if the mapping of the remaining part of the country at the basic 1:50,000 scale and the revision of the existing map sheets at this scale were embarked upon using the conventional photogrammetric method, it might take not less than 40 years to complete. This is on the assumption that the whole country could be covered by the appropriate aerial photographs. From experience, production of high altitude photograph has always constituted a bottle neck in the basic mapping programme of Nigeria, as some areas in the southern and middle belt of the country are under cloud cover for most of the year. Therefore in order to produce the 1:50,000 maps, of the remaining 10% of the country that were urgently needed for delineation of Enumeration Area (EA) in the 1991 national population census and meet the basic mapping needs of the country the catographic application of SPOT satellite imagery had to be applied.

Of all the commercial satellite, SPOT satellite is unique because of the cartographic capabilities of its products, the world wide coverage and the relative ease with which the products can be obtained. Therefore in the remaining of this paper, the catographic applications of SPOT products are reviewed and the experience in the production of 1:50,000 maps for the National Population Commission (NPC) using SPOT imagery is presented. Other projects currently being carried out in the country as a result of the success of the NPC mapping are also reviewed.

3. CARTOGRAPHIC APPLICATION OF SPOT IMAGERY

Various research work and practical applications of SPOT and Thematic Mapper (TM) satellite imageries point to the fact that SPOT imagery can be

used for 1:50,000 mapping and map revision.

At the launch of SPOT , 60 stereopairs were evaluated by IGN France on TRASTER analytical plotter and the results yielded standard error of about 6m in X, Y, and Z, (IGN,1986). Also, the National Research Council (NRC) of Canada Photogrammetric Research Laboratory reported that RMS values of the residuals on 80 check points for a single panchromatic image, measured on the Anaplot, ranges between 6.7m and 8.2m depending on the control configuration (Van Wijk, 1987). Similar results were reported by Gugan et al (1988) and Rodriguez et al (1988).

In the sphere of digital image processing, Rosenholm (1988) reported accuracy of 6m to 7m in height using multipoint matching technique for generating digital elevation model (DEM). Similar results were reported by Swann et al (1988).

In the area of map revision, extensive use of Landsat TM, with a resolution of 30m has been made for the operational revision of 1:250,000 maps of Canada by detecting changes on 1:50,000 map series. (Turner et al, 1987).

In general, there are two main approaches to the extraction of cartographic data from SPOT imagery viz:
-- analytical stereo-restitution or
-- digital image processing.
For both methods panchromatic stereo pairs with base to height ratio of between 0.5 to 1 are required for best results.

3.1 Analytical Stereo Restitution

Any analytical plotter equipped with necessary soft ware can be used, e.g Traster, Kern DSR, Wild Aviolyt ACI, Anaplot etc. This method has the advantage that both height and planimetric details can be plotted. However, it has the disadvantage that details are not always easily and correctly identifiable. Another major disadvantage is that films used for restitution are distorted during film writing from digital data.

3.2 Digital Image Processing

Digital stereopairs are processed to obtain digital elevation model (DEM) either by automatic image correlation or by multipoint matching (Rosenholm, 1988). Contours are then obtained by interpolation. This method is faster and has the advantage that most mapping processes like image enhancement, DEM generation, orthoimage generation, interpolation and map drafting can be automated. Final maps are obtained by superimposition of height information on planimetric details from precision corrected imagery and toponymic information. Digital image processing has the disadvantage that details cannot be plotted. However contours can be superimposed on visually interpreted and extracted details from precision corrected imagery and topographical line maps or directly on orthoimage maps.

4. NIGERIAN EXPERIENCE

The National Population Commission mapping project is a pioneering work in the application of space imagery to topographical mapping in Nigeria. It con consists of the production of:-
-- 1:50,000 annotated SPOT image maps
-- 1:50,000 planimetric line maps from SPOT imagery.
The SPOT image mosaics which were to be produced within 8 weeks of the ward of the contract was to be used as map substitutes for planning the Enumeration Area (EA), pending the time they will be replaced by line maps, which were to be delivered within nine (9) months.

The mapping covers all the areas of the country where base maps at 1:50,000 were not available. See figure 1. The total area mapped is 133,192km^2. It is covered by 177 map sheets, of size 15' x 15' of arc each. The project is divided into 7 blocks details of which are shown in Table 1. Seven survey companies participated in the project. Sola Atilola Associates carried out the mapping of Block 6.

TABLE 1: No of Map Sheets and Area Covered by Block Numbers.

Block No	No of Map Sheets	Area Km^2
1	48	36,120
2	23	17,308
3	29	21,822
4	17	12,792
5	15	11,288
6	22	16,555
7	23	17,307
Total	177	133,192

4.1 Operational Procedure

The operational procedure for executing the project included:-
-- Acquisition of SPOT (imagery) scenes
-- Provision of control points by geodetic measurement, or extraction of control points from existing topographical maps within and outside the area to be mapped.
-- Computer-base digital precision correction and (Processing) transformation of CCT data into Universal Transverse Mercator Projection system using the control points.
-- Digital combination of two or more scenes to produce digital mosaics.
-- Cutting of mosaics into map sheets and writing of films and production of bromide prints of map sheets.
-- Cartographic annotation
-- Field verification and completion
-- Preparation of final mauscripts

4.2 Acquisition and Processing of SPOT Imagery

Reception and Processing of space imagery for topographic mapping employs the state of the art "High-Tech" equipment and sophisticated softwares. Only very few organisations the world over are fully equiped to receive and process such data to high degree of geometric fidelity for mapping purposes. Other organisations depend on these few companies for imagery at required level depending on application for which they are intended. Therefore this aspect of the project was subcontracted to Sweedish Space Corporation (SSC) in order to facilitate the speedy completion of the project.

4.2.1 Choice of SPOT Imagery For cartographic applications, panchromatic imagery with a high resolution of 10m is most appropriate. However at the beginning of the project no panchromatic scenes of the project areas were available both at Kiruna and Toulouse. Programming SPOT for Panchromatic imagery would also take a few weeks. Therefore in view of the urgency of the project, the available multispectral (XS) scenes had to be used.

4.2.2 Precision Correction of SPOT Imagery
The selected scenes were precision corrected to level 2 product. For the geometric rectification, about 4 to 6 control points are required per scene.

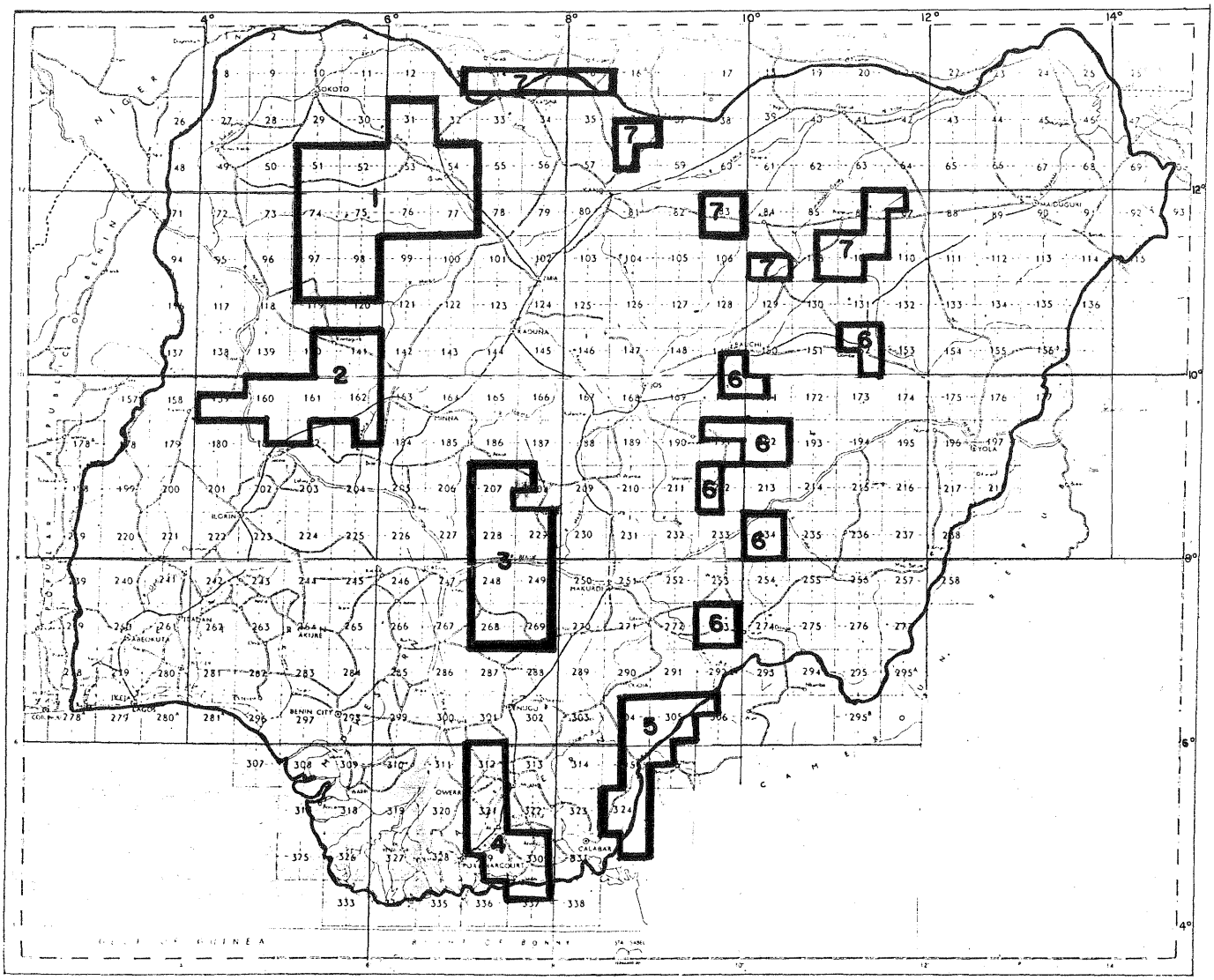

Figure 1 : Map of Nigeria Showing Areas Covered by the National Population Commission Mapping Project

These are better obtained by geodetic measurements but could also be obtained from available topographical maps within or outside the area to be mapped, if these maps are of sufficient accuracy. In this project, because of the urgency of the job, existing controls from existing maps around the project area were used as basic controls. Taking advantage of the satellite orbit and optimization in the data processing, additional control points were provided for relevant scenes by space triangulation using points on the scenes that overlap the scenes on which control points were required.

4.3 Production of Annotated Mosaics

4.3.1 Mosaiking After the precision correction the scenes were digitally mosaiked by combining two or more scenes. One scene is introduced at a time as a master, and image edge is digitally smoothened by the method of histogram equalization. The mosaic was then digitally cut into sheet size and border information added to the digital data. The digital images are then transformed into diapositives and paper (bromide) prints.

4.3.2 Cartographic Annotation The diapositive and bromide prints of the colour mosaics supplied by the SSC were not directly useful for any field work especially for the delineation of settlements. They had to be reproduced on a more suitable form and base with other information added. The procedure for the annotation included:
-- Identification and delineation of settlements.
-- Enhancement of road network.
-- Field verification of place names.
-- Drafting of road network and place names on film.
-- Half-tone screening of the multispectral mosaics.
-- Combination of the half-tone screened mosaics with road network and feature names.

4.3.3 Screening of the XS Mosaics Initially the screening of the multispectral image to produce black and white mosaic posed problems. Forest and some water body area appear red on a multispectral image. Using ordinary screen, the red areas will appear black. This problem could be solved by using magenta screen, or appropriate filter and screen with autochromatic or panchromatic film. It was found out that the use of panchromatic film and 54 lines/cm screen produced the best result and gave very good contrast and tonal range. This enhanced the recognition of details, especially linear features.

The main problem with the use of panchromatic film is that both screening and the photographic process have to take place in complete darkness. This is very messy and therefore a very good laboratory and highly skilled technician are required for the screening and film processing. Another difficulty in the use of panchromatic film is that the film is difficult to come by in the standard map sheet size.

The drafted film containing cultural details toponyms, road network and boarder information was combined with the screened negative to obtain a single annotated half-tone film positive. Experience shows that when working with multispectral imagery it is better and more accurate to screen the film positive rather than the bromide print.

4.4 Production of Line Maps

The production of intermediate material for other components of map production such as compilation, field completion and fair drawing is as described in section 4.1, steps 1 to 5. The production of mosaics can be omitted if it is not required and replaced with the production of films and paper prints of individual precision corrected scenes from which maps can be compiled. This approach is particularly suitable for map revision.

4.4.1 Map Compilation The mosaics produced in section 4.3 is an image map with cartographic accuracy. Since in this project only planimetric information is required it was possible to handle the compilation using relatively simple equipment like enhanced Transfer Scope with digitizer or PROCOM -2 with digitizer or ordinary light table with appropriate magnifier. In a "high-tech" enviroment direct digitization of planimetric details could be done from the digital data. In this project the use of PROCOM -2 with digitizer proved efficient. The compilation was then followed by extensive field verification and completion.

4.4.2 Field Verification and Completion Multispectral SPOT imagery contains a walth of information that can be recognised and positively identified with experience and ground truthing. However some details like footpaths and small settlements may not be positively identified and classified but their presence can sometimes be inferred from the associated surrounding details. Therefore in order to ensure a high fidelity of details content of the maps, extensive field completion and verification had to be carried out.

The field completion was carried out to:-
-- Obtain the names of all settlements on the map
-- Classify the road networks
-- Classify vegetation and land use types
-- Obtain names of rivers and identify dry valleys and areas liable to flooding
-- Obtain names of hills, mountains and other cultural details, and
-- Carry out the addition or deletion of natural, cultural and infrastructural details as enumerated above.

4.4.3 Map Production After the field completion cartographic drafting, pasting and photo-lithographic works were carried out to produce the final maps.

4.5 Accuracy of Mapping from SPOT Imagery

Map accuracy can be measured either quantitatively or qualitatively. The qualitative accuracy can be measured by comparing map edge details with the existing maps of the surrounding areas; or by comparing content of a map of a scene obtained from a different source e.g aerial photographs. The quantitative accuracy can be determined by measuring displacement of image points from their expected positions. From the edge comparison exercise carried out after map compilation, most details especially line features like roads, rivers and paths, fit very well with existing maps especially where there had been no alignment. Random qualitative checks were also carried out on parts of the project area.

5. OTHER MAPPING PROJECTS EMPLOYING THE REMOTE SENSING TECHNIQUE

As noted earlier the application of SPOT imagery for the production of maps for the National Population Commission (NPC) was a pioneering work in the catographic application of satellite imagery in Nigeria. Initially the method was therefore

approached with scepticism and caution. However after the completion of the NPC mapping, and the maps were checked and found to meet the standard specifications for the 1:50,000 mapping, the technique has now been fully embraced, Currently, the technique is being used by the Federal Surveys Department to revise and metricate some of the obsolate maps of the country covering about 240,000km^2 which is about 25% the total land area of the country. Also the Shell Petroleum Development Corporation of Nigeria is currently revising the 1:100,000, 1:50,000 and 1:25,000 map series covering its areas of operation from latitude 4^{o}N to 7^{o}N. The project consists of using SPOT imagery for the revision of 1:100,00 and 1:50,000 map series; and the 1:25,000 with a combination of aerial photographs and satellite imagery. At the current rate of application of satellite imagery, it is expected that the whole of the 1:50,000 map series would have been revised and metricated by the close of the century.

6. REVISION OF 1:50,000 MAPS USING SPOT IMAGERY

The immense wealth of image content and the high spatial resolution of SPOT imagery makes it a useful tool for monitoring enviromental and thematic changes and for revision of maps at 1:50,000 or smaller scales. SPOT imagery is economical for map revision because of the large area coverage and the relative ease with which it can be obtained. For revision, SPOT scenes precision corrected and transformed to selected projection system are used. The diapositive of the scene is the superimposed on the existing maps using optical mechanical equipment like Transfer Scope or PROCOM -2. Changes are then detected, traced off or digitized. In revising the 1:50,000 maps of Nigeria, advantage will be taken to convert all the existing maps into the UTM system and change units of measurements to meter. This will make the task a little bit more involving, since the contours will have to be digitized and DEM created from which the maps will be recompiled.

A procedure similar to the following could be followed using equipment like PROCOM - 2 with digitizer (Turner 1987), (Atilola, 1990).

-- Superimpose SPOT data on the existing map.
-- Detect and mark areas of changes on the map on small grid bases.
-- Identify the changes on the SPOT image and digitize
-- Digitize the 1:50,000 base maps excluding the areas of changes marked, and convert data to UTM system.
-- Digitize the contours onto a separate file and create DEM.
-- Combine the digitized map file and the image changes and plot the map in the UTM system.

Alternatively, the SPOT scene could be transformed into NTM projection system and the map revised in NTM. The revised maps are later digitized for conversion to UTM.

7. SUMMARY AND CONCLUSION

Up-to-date and accurate maps are basic tool for any meaningful planning, systematic development and effective management of the natural resource of any nation. The topographical base map needs of the world in general is not being met by classical photogrammetric mapping method. The increase in spatial resolution of commercial satellite imageries is fast revolutionising the production and revision of 1:50,000 and smaller scale maps. The developing countries of the world that need maps most for their development and which are the least mapped should take advantage of this technology. Mapping with space imagery may become operational the world over in the nearest future.

It had been possible to complete the 1:50,000 planimetric mapping of about 14% of Nigeria, covering an area of about 133300km^2 within a period of 12 months as a result of the application of SPOT imagery. Some of these areas had hither-to defied all attempts to map them because of the mountainous nature of the terrain and the near permanent cloud cover. The same project could have taken at least 36 months to complete using photogrammetric method, assuming adequate aerial photo coverage.

As a fallout of the success of the NPC mapping project, the revision and metrication of some of the 1:50,000 maps of the country is being carried out by the Federal Surveys Department and oil exploration companies using SPOT Satellite Imagery suplemented with aerial photographs.

The optimization of the processing of SPOT imagery, its high resolution, low cost, low control requirement and relative ease with which the products could be obtained make it attractive and suitable for the 1:50,000 and smaller scale mapping and map revision . SPOT imagery contains a wealth of information also useful to other users like foresters, geologists, geographers, hydrologists, agriculturists and others. Acquired imageries could be passed on to these users. The sharing of data will thus make space imagery acquisition and application very economical on national basis, especially for developing countries

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