TOPOGRAPHIC MAPPING FROM SATTELITE IMAGES: HOW FEASIBLE IN DEVELOPING COUNTRIES ?

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ABSTRACT:

With the availability of high-resolution Landsat TM and SPOT images, space images are considered as being suitable for the production of medium scale topographic maps.
This should be very useful, particularly in developing countries, where the need for revision of the existing maps is very urgent.

The usability of SPOT imagery for the map revision of an area in Nigeria is examined in this study. An assesment of the interpretability of some cultural features such as roads and settlements is done. Few of the problems which may make the operational use of satellite images for mapping in most developing countries difficult are discussed.

KEY WORDS: Satellite Images, Mapping, Developing Countries, Feasibilty.

1. INTRODUCTION

There has been the awareness in the mapping community for some time now that images from Earth Observation Satellites could be useful for mapping activities. With the launching of the SPOT Satellite in 1986, there was the opportunity to practically test the suitability of space images for the production of topographic maps.

A great deal of work has been done in the area of investigation of the geometric fidelity of SPOT images and formulation of mathematical models for their geometric restitution (Konecny et al.,1987; Westin 1990; Jacobsen 1990). It was concluded that with SPOT images, coordinates determination could be done to an accuracy that would satisfy the requirements for topographic maps of 1:50,000, and in some cases 1:25,000.

Since map production from space images promises to be cheaper and faster, it should be of interest, particularly to developing countries whose mapping needs seem impossible to meet using the conventional method of map production from aerial photographs.

Most of the tests carried out on the potentials of SPOT images for topographic mapping were carried out in the developed countries where conditions for surveying and mapping are very favourable. It is intended in this paper to examine if the information content of SPOT images is sufficient for updating the topographic map of an area in Nigeria, with emphasis on the identification of some of the cultural features such as roads and settlements.

The status of mapping in all developing countries is not exactly the same; surveying and mapping in countries such as China, India and Brazil are more developed than in most of the countries in Africa, for example. However there a number of features common to most of the other countries; e.g lack of reliable, up-to-date maps, shortage of qualified professionals in surveying and mapping etc. The use of space imagery for mapping is examined against this general background.

2. TEST AREAS AND MATERIALS

Two test areas were chosen from a SPOT panchromatic level 1A image acquired on 20.12.88. The image, supplied in digital form, was of poor quality, having very narrow intensity range and degraded by stripes and scattered cloud.

The only topographic maps available for these areas are the 1:50,000 maps compiled in 1962.
The first test area, roughly 5km x 5km, encompasses the southern and central parts of Agbor in the Delta State of Nigeria. The area is largely urban. It has a network of main and minor roads and several paths.
The second area, measuring about 5km by 10km, is rural, comprising agricultural communities. The vegetation varies between light and thick forest. Relief variation in both areas is less than 50 meters and almost all the roads are unsurfaced and in disrepair.
The test areas were selected after part of the image had been rectified. (See Image Processing below)

Fig. 1(a): Rectified Image of Test Area 1

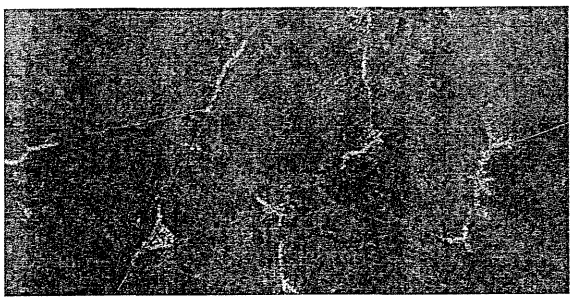

Fig. 1(b): Rectified Image of Test Area 2

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3. IMAGE PROCESSING

Contrast enhancement was done on the image before it could be used at all. Based on the image histogram, contrast stretch was done by iterative use of the MAP function on the GOP 302 image processing system. A high pass convolutional filtering by subtraction of the laplace transform from the original image was later done to sharpen the high frequency details on the rectified images of the test areas.

A part of the image was rectified using control points digitized on the Federal Surveys map sheets SW 299 and NW 299. The rectified area was approximately 27km x 25km, from which the two test areas were later selected. The rectified images of the test areas are shown in fig. 1.
Location of control points on the map and the image was a difficult task. Points, such as road intersections, which are normally used as GCP's, could not be clearly identified on the image. On the other hand, most of the well defined road intersections on the image had not existed at the time of map compilation.
In all, 19 points were identified, out of which 13 were used for a second order polynomial transformation. The mean errors on 6 check points after transformation were 1.7 & 2.5 pixels in the row and column directions respectively. Resampling was done by bilinear interpolation, pixel size being kept constant at 10 meters.

4. IMAGE INTERPRETATION

The detectability of road networks and settlements in both test areas was investigated by comparing the maps with the plots of the features.

4.1 Test Area 1

Figures 2 show the map of area 2 together with a plot of the features in the area. The upper part of the map was cut off so as to show exactly the same area on both map and rectified image. (See fig. 1(a))

4.1.1 Road network

Using the cursor of the GOP 302, plotting of all identifiable roads was done on one of the graphic planes. Figure 2b shows the plot for Area 1.

Main roads

According to specifications from the Federal Works Department regarding roads classification, main roads have a width of about 10 meters and are asphalted.

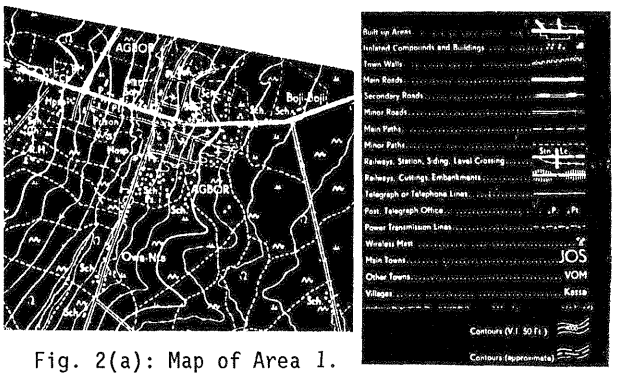

Fig. 2(a): Map of Area 1.

Map Legend

The only main road passing through this area is fully identifiable and plottable. It has a width of approximately 10 meters and is asphalted. It is labelled AB in fig. 2b.

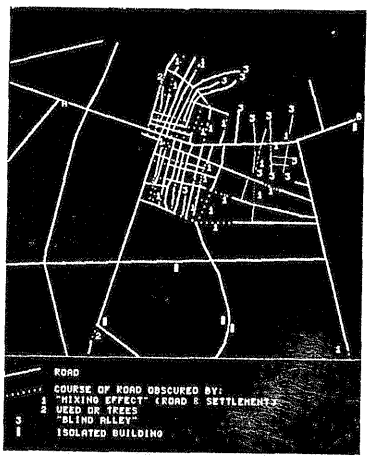

Fig. 2(b): Plot of Road network in Area 1.

Minor roads

These roads are supposed to have a width of about 8 meters and may or may not be surfaced.
It was not possible to quantitatively relate the total length of minor roads identifiable on the image to the length on the map, as only a few of the roads shown on the image existed at the time of map compilation.
For every road on the image that appears to end abruptly, it was verified on the ground whether it actually ends so or if further course of the road become unidentifiable due to some other reasons.
It was found out that:

- minor roads having width of at least 5 meters are generally identifiable.
- along sections where road widths narrow down to less than 5 meters, the course becomes difficult or impossible to identify on the image. The decrease in width may be as a result of part of the road being covered by weed or trees, as obtained at the points labelled " 2" in fig. 2(b), or it may simply be that the road no longer continues with same width after a particular point. In the latter case, it appears to come to an abrupt end.
  Such points of apparent discontinuity are labelled "3" in fig. 2(b).
- at some points, reflectance of the road and that of the adjoining buildings tend to "mix", thus making clear identification of the road impossible. These points are denoted by "1" in fig. 2(b).

It is estimated that up to 90% of the total length of minor roads having width of at least 5 meters are identifiable.

Paths (Main and minor paths)

Main paths are defined as tracks with width less than 4 meters. They may be occasionally motorable. A minor path, on the other hand, is an unmotorable track having width of less than 2 meters.
Only a few paths could be identified on the image, typical width being about 4 meters.
Identification was only possible where the paths pass through weedy areas.
Paths in built-up areas were not identifiable.

It was not possible to determine what proportion of the total length of paths was detectable, as this would involve very elaborate field work. It is estimated that not more than 10% of all the paths are identifiable on the image.

4.1.2 Settlements, compounds and buildings

Settlements can be clearly identified and adequately demarcated. Isolated buildings are also recognizable, however compounds, as isolated group of buildings are not identifiable due to the scale of the image.

4.2 Test area 2

4.2.1 Roads

The road network of the second area comprises minor roads and paths. Figures 3 show the map of this area and a plot of the identifiable roads.

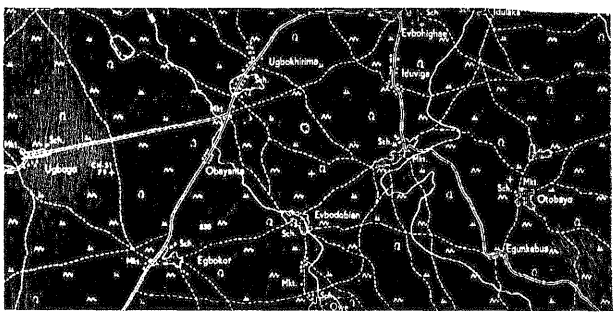

Fig. 3(a): Map of Area 2.

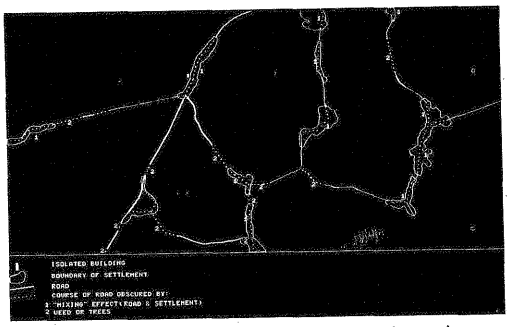

Fig. 3(b): Plot of Road network and boundary of settlement in Area 2.

Minor roads

An overlay of the map with the plotted roads shows that only about 50% of the total length of minor roads is detectable in this area.
Part of the reason for the poor result here is the state of the roads which is much worse than in the first area. Portions of the roads are overgrown with weeds, while parts are occluded by trees above. The course of the roads in such sections are usually unrecognizable on the image.
Also, where roads pass through or follow boundaries of settlements, the course becomes undetectable.

Paths

Except for some of the old paths which now appears to have been "upgraded" to minor roads, no paths are detectable on the image of this area.

4.2.2 Settlements, Compounds and Buildings

Due to their high reflectance in contrast to the surrounding vegetation, settlements and isolated buildings can be identified. On the other hand, compounds are not recognizable.

5. OVERALL ASSESSMENT

The image is suitable for identification of main roads.
Minor roads are identifiable provided they are at least 5 meters wide.

Paths are generally not detectable on the image. This is partly due to the fact that the width is too small for the spatial resolution of the sensor, and partly to the fact that some of these tracks often run through woods and can therefore not be seen from above.
Pathways are sometimes the only communication links between rural communities and are therefore important features on topographic maps of such areas. Detail survey of these tracks have to be done by ground survey.

Settlements can be clearly recognized on the image and their boundaries sufficiently demarcated. Isolated buildings can also be identified. Identification of compounds is however not possible.
Change detection of settlements can be adequately done out using the image.

Apart from deficiencies in the detection of some map details as seen above, the use of space images for topographic mapping may not become popular in most developing countries for some time to come due to some operational problems peculiar to these countries.

In most developing countries, ground controls for geometric restitution of the images would, almost invariably, have to be provided through ground survey methods since large scale maps are generally not available.
Provision of ground controls by the traditional methods of land surveying (traversing etc) for a full image scene may take a long time considering that the geodetic control nets are in most cases poorly densified.
The cost of GPS positioning equipment, with which control points can be more easily and quickly established, restricts their use in most developing countries.

Since the available maps are usually too old to be used as reliable references, very extensive and time-consuming field verification woud be required to assess the amount of omission commision errors in the image interpretation and plotting. Ground verification with satellite images is a very tedious task because of the small scale of the images. In most cases, such checks have to be supported by the use of aerial photographs which are not always available.

The instrumentation requirements for mapping from satellite images is likely to discourage the use of this method in most developing countries. The available analogue plotters are unsuitable because of the image geometry. Analytical plotters are beyond the reach of many survey departments because of their costs. Even where they are available, maintenance poses a great problem as breakdown is very frequent due to power fluctuations and bad handling.

If the use of space images for mapping is to be fully operational in developing countries, there must be the possibility of carring out projects using the locally available manpower.
Experience has shown that there is a dearth of qualified personnel in photogrammetry and cartography in most of the countries, with the result that most of the operations involved in map pro-

duction, even from aerial photographs, still have to be carried out by foreign mapping organizations. Since a much greater skill is required when using space images, it is very doubtful whether mapping projects involving the use of these images can be executed with the current manpower capability of most of the countries.

6. CONCLUSION

The information content of the SPOT image used in this study would not be sufficient for full revision of the 1:50,000 topographic maps of the test areas. Road tracks, for example, are generally not detectable on the image.

Although the situation in the test areas may not be representative of all areas in developing countries, it no doubt provides an insight into typical problems of undermapped areas. Where areal development is rapid and unplanned, as is the case in most developing countries, space images, at their present spatial resolutions, may be unsuitable for revision of any map more than 5 years old, otherwise, the ground verification would be too tedious.

There are a couple of other problems mentioned above which may make operational use of space images difficult in most developing countries. However, if the importance of maps to development could be fully appreciated, and more effort made to enhance the practice of surveying and mapping, these problems would be significantly reduced.

With the launching of SPOT, there is a general awareness of the potentials of space images. If future sensors could combine the geometric quality of SPOT with an improved spatial resolution, most developing countries could be in the position to take advantage of mapping from space imagery in future.

7. REFERENCES

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