REVISION OF 1:50,000 TOPOGRAPHIC SHEET USING SATELLITE IMAGERY PRELIMINARY STUDIES

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ABSTRACT

Topographic map coverage of Ghana is a costly project, considering both acquisition of the aerial photographs and the mapping that covers the entire country. It has therefore often gone as a bilateral project. It becomes therefore imperative, considering the rate of development in the country, to revise these ageing maps consistently rather than allow them to get out-dated and unattended to. Though revision by aerial photographs would have been the best method by reason of their resolution, reflying large areas for revision would be a costly project. Reflying to obtain new aerial photographs for revision is also costly.

Considering the fact that revision must often be selective, the use of satellite imagery may be a good alternative and must be exploited. The study limits itself in this stage to the Landsat TM with a pixel size of 30m and the SPOT XS also with a pixel size of 20m.

In this paper, a level IB SPOT XS imagery at 20 m pixel and a Landsat Thematic Mapper of pixel size of 30m are rectified to a Transverse Mercator Projection using control points (Map coordinates) and a digitizer with a resolution of 0.03mm. Performance of the imagery with regard to accuracy (geometric fidelity) feature identification and the economic implications are discussed. Alternative proposals are also outlined.

Keywords: Satellite imagery, revision, economy, rectification, mapping identification

INTRODUCTION

The method of mapping in the country in recent times has been with the use of aerial photographs (photo grammetric) after the departure from the tedious ground surveying method.

The Survey Department, the sole mapping agency in the country, however, encounters problems in respect of maintenance of equipment for mapping, finances (hard currency) and staff remuneration (problem of the civil service) which results in the drift of trained personnel towards private sectors and expatriation.

Left on its own, the complete coverage of the 1:50,000 map sheets of the country after the acquisition of the aerial photographs in 1972 would have taken several years to complete. The Survey Department, after all these problems is still grappling with the problem of revision.

With the limited facilities at the disposal of the Survey Department of Ghana, conventional surveys have become slow, labour intensive and expensive [1]. Reflying large areas to acquire new aerial photographs is expensive and a limiting factor in the maintenance of topographic mapping.

Fortunately, and with the assistance from the World Bank, the Survey Department is gradually settling down with the digitisation of all its 1:50,000 series map topographic map[1].

The Ghana Environmental Resource Management Project (GERMP) which precipitated the digitisation process has therefore brought into focus the need for digital revision which will be compatible with the database and will be quicker, more flexible and more economic.

Though the present production line and the existing database is graphical the situation promotes the

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gradual transition from graphical into digital form and therefore making digital revision very appropriate and welcome. With digital data efficient use can now be made of satellite data and the techniques of image processing and automation in this revision process. Data from satellite imagery could be integrated into the 'old' data from digitised map in a form of partial revision.

This will clear the difference between the updating and re-mapping even when more than 50% of the information has changed. The proliferation of companies exploring for and exploiting minerals, constructional materials, timber (resulting in the depletion of the forest), and several other developmental activities in the country calls for careful planning and monitoring.

There is the need therefore not only to accelerate mapping but also to update them. The question of mapping and revision without doubt must be carefully addressed for it offers an effective means of planning and is a means by which natural resources can be exploited and the economy of a country developed.

THE STUDY AREA

The study area lies between Latitude 10° 30' N-10° 45' N and Longitude 0° 05'W - 0° 30'W and stretches between Nakpanduri and Gambaga with the Gambaga scarp in the northern part of it (See Fig. la).

The range stretches South-South-West to North-North-East direction serving as a watershed with elevation between 520m and 170m. The White Volta and the Morago river border the northern part of the range and both the Gambaga Scarp East Forest Reserve and the Morago East Forest Reserve stretch along the SSW-NNE direction over the peak of the scarp.

The area has both forest cover and the guinea grassland interspersed with towns at the southern part of the scarp, hence a representative region of the northern part of Ghana (in respect of ground cover). However planimetric features are minimal. See Fig. la, b.

METHODOLOGY

Source of information

a) Level 1B mage of Spot - multispectral imagery. Date: 31/01/94.

b) Landsat Thematic Mapper image - multispec tral imagery of Ghana 21/12/92 (generated 21/6/93).

c) A Topographic map of scale 1:50,000 published in 1963 which served in this preliminary studies as the ground truth.

Image Treatment

Both images were enhanced using histogram equalization over the entire range since the histogram approached the normal distribution curve. They were both rectified to a Transverse Mercator projection using a first order transformation (affine).

Comparative Study

The areas for the comparative study are the following:

i) Metric Accuracy (image geometry with respect to the 'fit')
ii) Semantic Accuracy
iii) Cost

METRIC ACCURACY (LANDSAT TM)

The planimetric accuracy of 1.7 pixels (50 m) was obtained.
(See Appendix Ib).

SEMANTIC ACCURACY

Feature identification:

Linear features

Major roads: These could easily be seen or identified but could not be classified except by the extent of their visibility on the imagery. As they moved over the scarp they often got missing due to shadow cast by some parts of the scarp and also the forest cover.

Secondary roads: Their identification on the imagery varied depending on the environment. They were not easily traced on the scarp but on the southern portion some were visible. New routes could not be found.

Tracks: These were virtually non-existent. Edge of reserve could be located.

Point Features

Buildings: Those within the towns could be seen as white spots, possibly due to reflection of their roofs. They could not be seen individually.

Township: They could be traced without difficulty due to the presence of the buildings and for their extent by the reflection of the bare ground.

STUDY AREA

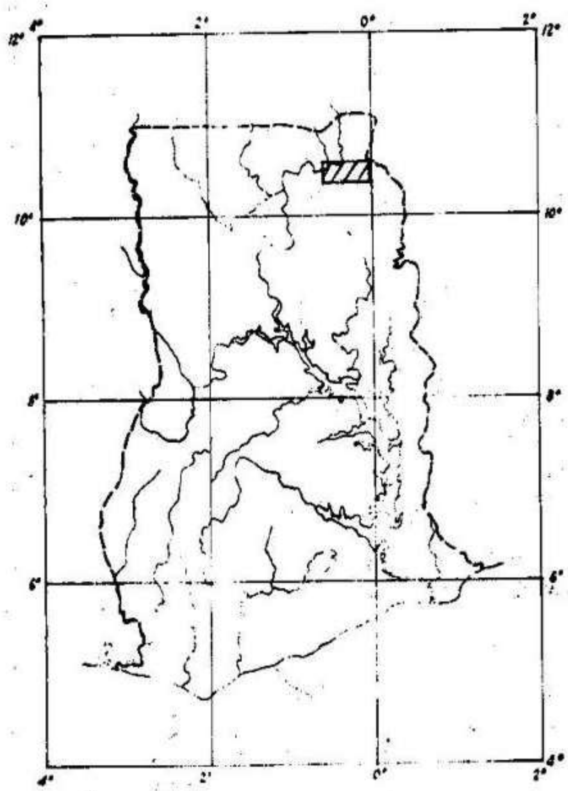


Figure 1a
Outline Map of Ghana and the Study Area

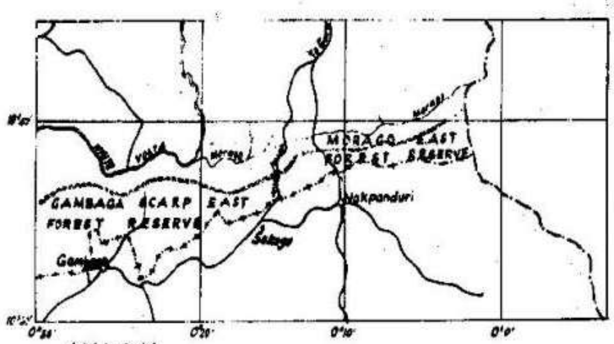


Figure 1b
(detail of shaded area in Fig.1a).

Zonal Features

Vegetation: The forest reserve and their edge could be easily identified due to variation in height of vegetation. About three zonal areas could be delineated.

These are:

i) The forest reserves
ii) The grassland
iii) The bare land

METRIC ACCURACY (SPOT XS)

A planimetric accuracy of 1.5 pixel (30 m) was achievable (see Appendix Ia).

SEMANTIC ACCURACY

Generally speaking there seemed to be some haze which ramained over the imagery. This could possibly be explained as smoke resulting from the constant burning of the grassland in the area. The scattering effect of dust particles (during harmattan) cannot be ruled out. This will affect the longer wavelength and especially Band 3 (0.79 - 0.89 μm) in the SPOT XS imagery though this will not completely scatter it. The combination of the smoke and the effect of harmattan is not conducive to good interpretation due to low contrast.

However, green vegetation and bare soil have enough contrast even in Band 2 (0.61 - μm) to be easily distinguished one from another. But where vegetation is without vigour (dry) confusion may occur. See Fig. 2. This poses a problem because it hinders identification of the features under investigation.

Road: Major roads could be traced. However, as the road moved south westwards from Sakogu it got missing perhaps among the vegetation and smoke.

Except for zonal features which could still be seen, the secondary routes, tracks, buildings/townships could not be identified. The alternative was to use the Band 3 (NIR) for the analysis.

In relation to atmospheric interaction (transmission of ozone, water vapour, dust particles etc.) with radiation the two bands, Band 1 and Band 2 (0.50-0.59 μm and 0.61-0.68 μm respectively) are strongly correlated [2].

Therefore for a study that relate to vegetation, bare ground (including surfaced and non surfaced roads) and water Band 3 will do well.

Linear Features (on Band 3)

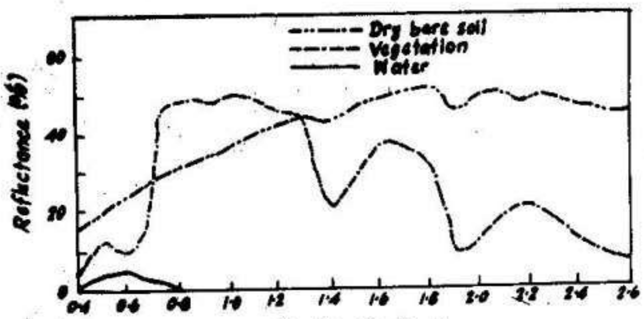
Roads: Major roads could all be traced. Being a black and white imagery there was a problem of identification when the road reached areas which were bare ground. These areas had high reflectance characteristics.

Minor roads over the scarp (towards Garu) which otherwise could not be traced from the landsat MSS were identified. Here often shadows over the scarp and vegetation (forest cover) obscured some features.

Tracks: These were not easily identifiable, though some could be seen.

Point Features

Building/township: These were not easily identi-



REFLECTANCE CURVES FOR VEGETATION, SOIL AND WATER

Adopted from [7]

Fig. 2

fied by reason of reflectance characteristics of the bare ground (lack of contrast).

Area/Zonal features: Fortunately the forest reserve outline could be seen and can be traced. The three zonal areas could also be seen.

Cost Aspect

Here in this preliminary study, the cost aspect is limited to the cost of imagery and does not involve that of compilation.

The size of Landsat TM full scene (185km x 170km) is about 9 times the size of SPOT imagery (60km x 60km). However, SPOT covers approximately 128 models of 1:40,000 photography [9].
For a topographic map at 1:50,000 (15' x 15') the SPOT scene covers approximately 5 sheets,

(i.e. 60km x 60km)
(27.6km x 27.6km)

The Landsat TM costs approximately $5000 for a full scene of seven channels while the SPOT for a full scene of three channels costs about $3,500.

Both imageries unfortunately align themselves in such a way that their orbital paths begin approximately from the middle of the map sheet. This would mean that about 2¼ SPOT scenes may have to be purchased to cover this map sheet. The Landsat TM, in this particular case may need 1¼ scenes even though the full scene covers other adjoining map sheets east of the map under consideration.

Cost, however, will also increase with the use of additional materials when resolution of imagery makes identification difficult, especially in the 1:50,000 map sheet where information content requirement is exacting.

Stereo overlap capability found only in SPOT imagery may ease identification of features and make contouring possible when needed, but this is costly and will affect gains made in savings. It should however, be noted that satellite mapping cannot be justified except on the grounds of gains in economy.

ANALYSIS

Metric Accuracy:

Of the two images both achieved planimetric accuracies (position) which were below the expected (<20 m). This can be explained by the age of the map and the possible changes in width of rivers over the years (lack of well defined test points). Points used for the rectification were mainly river branches (intersections) and river/road intersections. Digitizing and possible identification errors could also be contributing factors.

Information Content:

Though the Landsat (TM) portrayed townships and the major road of the area, several other information like secondary roads and tracks could not be found. Though useful for the 1:50,000 topographic map of such an area of less planimetric features it will do better for a 1:100,000 map.

The Single Band (XS_3) used for later analysis (because of smoke over the SPOT XS) was rather much helpful for the 1:50,000 topographic map in respect of features identified. The information content in this band was satisfactory.

CONCLUSION

Though the expected metric accuracy of the Landsat TM was not achieved, the information content was comparatively very useful. The SPOT XS encountered a basic problem relating to the environment and not of the imagery itself. The performance of the Band 3 in this case points to a problem which the spot panchromatic imagery may have as it comes into areas that are bare. The reflectance characteristics may make feature identification difficult. Nevertheless it raises our expectation for the potential use of the SPOT panchromatic imagery (0.51-0.73μm) with ground resolution of 10m.

Band width of this panchromatic imagery has been carefully chosen in such a way as to reduce confusion between dry vegetation (as occurring in the north during the dry season), bare soil, paved and unpaved roads and rocks [5]. This will be helpful in the existing situation when contrast for example between bare soil and dry grass (and shrubs) may be very much reduced.

It is hopeful that in the extended study, the SPOT panchromatic imagery may do well if it is combined with the multispectral imagery, since it is possible that imagery not identified on the panchromatic may be found on the multispectral.

The rectification problems due to lack of well-defined points can be resolved by the provision of these controls using Global Positioning System (GPS).

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APPENDIX 1a. Computed results of the matrix for image rectification for SPOT XS

Point Count	Point Number	Image X Pixel	X Pixel Residual	Image Y Pixel	Y Pixel Residual
1	7	453.02	-0.1983E+01	502.18	0.1770E+00
2	10	425.41	0.1407E+01	65.22	0.2197E+00
3	3	71.60	-0.1398E+01	143.95	-0.5129E+01
4	4	173.57	0.1573E+01	574.08	0.1084E+01
5	5	210.24	0.2430E+00	500.78	-0.1216E+01
6	6	480.16	0.1570E+00	511.79	-0.2133E+00

X RMS Error = 1.31805 Y RMS Error 0.68101

Total RMS Error 1.48359

APPENDIX 1b. Computed results of the matrix for image rectification for TM

Point Count	Point Number	Image X Pixel	X Pixel Residual	Image Y Pixel	Y Pixel Residual
1	1	1411.25	0.2471E+00	733.67	-0.1334E+01
2	2	1388.96	-0.1045E+01	778.86	0.8570+00
3	3	1429.97	0.9682E+00	791.03	0.285E-01
4	4	1475.90	-0.1026E+00	832.45	0.4479E+00
5	10	1307.99	-0.2009E+01	923.80	-0.1965E+00
6	6	1508.30	0.3011E+00	1025.84	-0.1604E+00
7	7	1279.83	-0.1172E+01	873.44	0.2439E+01
8	8	1260.93	0.2934E+01	897.24	-0.1757E+01
9	9	1283.88	-0.1219E+00	899.68	-0.3248E+00

X RMS Error = 1.34277 Y RMS Error = 1.15083

Total RMS Error = 1.76846