Needs for topographic mapping in developing countries - can space imagery deliver solutions?

G. Petrie
University of Glasgow, Scotland, U.K.

ABSTRACT: A summary of the current situation in the countries of South Eastern Asia and Eastern, Central and Southern Africa has established that most already have extensive topographic map coverage at the standard scales of 1:50,000 and 1:100,000. The main problem is that of revising and updating this coverage. The results of a number of interpretational tests carried out in several of these countries are given, followed by an account of the experience gained in a UN-funded project to update the existing topographic map coverage of Uganda. While current satellite imagery gives useful information, it is still somewhat deficient in resolution. Thus the detection of a substantial number of changes occurring in the cultural (man-made) landscape, e.g. the communications network, smaller settlements, etc., cannot be carried out in a complete fashion, so necessitating a thorough and systematic field completion. Small-scale aerial photography provides much higher resolution and is still being used extensively for re-mapping and map revision throughout the region.

1 - INTRODUCTION

The needs for Topographic Mapping in Developing Countries is a matter which receives quite a lot of attention in the literature, though most often at a policy or political level - the basic premise or underlying assumption being that the developing (Third World) countries have very little coverage at the standard scales of 1:50,000 or 1:100,000 used for nation-wide topographic mapping. In fact, it is extremely difficult to discover where exactly this presumption comes from - usually percentage figures issued by the U.N. organisation are quoted and are accepted as fact. Almost invariably, Africa is quoted as the poorest mapped continent, with strong hints that parts of Asia have none too good or none too complete cover.

2 - TOPOGRAPHIC MAP COVERAGE IN SOUTH WEST ASIA AND EASTERN AFRICA

In fact, it has been possible for the present author to build up a quite detailed picture of the situation regarding the topographic mapping of South West Asia and Eastern, Central and Southern Africa from the numerous (>50) graduate students in surveying and mapping from the different countries in this region who have completed post-graduate study programmes in Topographic Science, at the University of Glasgow. Not only have they supplied detailed information on the topographic map coverage of their respective countries but a number have also undertaken projects for their post-graduate degrees concerned specifically with topographic mapping from satellite imagery. These include projects in the Sudan (Abdalla, 1980; El Niweiri 1988); Uganda (Kajumbula 1992); Kenya (Kajumbula 1992; Liwa 1994); Tanzania (Liwa 1994); Zambia and Zimbabwe (Buka 1992); Mozambique (Ferrao 1990) and Botswana (Liwa 1994). This work has been supplemented by the present author paying a number of visits to national mapping organisations (Jordan, Sudan, Kenya, Tanzania and Zimbabwe) in the region and to the Regional Centre for Surveying, Mapping and Remote Sensing (RCSMRS) located in Nairobi. It is also worth drawing attention to some more general discussions on the possibilities, requirements and prospects for topographic mapping in Africa published recently by Leatherdale (1992); Fanta (1992) of RCSMRS; and Nino-Fluck (1993) of the UN Economic Commission for Africa.

(a) Starting with South West Asia, virtually every country in the area has complete topographic map coverage carried out using aerial photogrammetric methods either by national mapping organisations (e.g. in Israel, Jordan); by commercial survey companies on contract (e.g. in Saudi Arabia); under contract with a foreign government (e.g. Syria) or through foreign aid programmes (e.g. North and South Yemen, Oman).

(b) In North East Africa, the situation is rather different. Egypt has much of its area covered - including that between the River Nile and the Red Sea carried out under contract by Finnmap. However the countries lying to the south - Sudan (with 10% coverage), Eritrea and Ethiopia (40% coverage) have perhaps the poorest topographic map coverage in the whole region. By contrast, the former French and British Somaliland have been mapped by the former colonial powers, though the latter is really a provisional series at 1:125,000 scale.

(c) Turning next to Eastern Africa, the existing coverage is very extensive, having mostly been carried out by the UK Overseas Survey organisation over the period 1950-1980. Thus Uganda has virtually complete cover at 1:50,000 scale; Kenya has 80% coverage at 1:50,000 scale (only the desert area in the far north and northeast area of the country has still to be mapped); and Tanzania has about 70% coverage at 1:50,000 scale (the arid and semi-arid regions again being these still to be mapped).

(d) In Central Africa, a similar situation exists. Thus both Malawi and Zimbabwe have complete topographic map cover at 1:50,000 scale, while Zambia has a 70% coverage, with mainly the arid western part of the country still to be mapped.

(e) In Southern Africa, Mozambique has almost complete cover carried out under the Portuguese colonial authorities, except for the far north of the country. The Republic of South Africa has complete coverage, as has Lesotho (carried out by the UK Overseas Surveys organisation). Botswana has partial cover, again provided by the UK.

In summary, one can say that the provision of original topographic mapping is not the main problem over this vast region. Basic topographic map cover based on aerial photogrammetric methods exists, except in one or two specific countries such as Sudan, Ethiopia and Eritrea where the coverage is very far from complete. Elsewhere, the areas where the coverage has not been completed comprise desert and semi-arid areas with little population and economic activity.

It is also apparent that the main problem which exists is that of map revision. Much of the topographic mapping was carried out over the 30 year period between 1950 and 1980, either by the former colonial powers (UK, Portugal, France) or under aid programmes, especially those undertaken by the UK, but also by Canada (in Zimbabwe and Tanzania), Japan (in Kenya and Tanzania) and the Scandinavian countries (in Egypt, Tanzania, Zambia). But since the withdrawal of the colonial powers, there have been immense changes in the landscape. These include the effects of (i) civil war (e.g. in Yemen, Sudan, Ethiopia, Eritrea, Somalia, Uganda, Zimbabwe, Mozambique); (ii) famine arising from civil war, drought, etc.; (iii) political policies (e.g. the break-up of large European style farms and plantations in certain countries or the forced villagization in Tanzania); and (iv) large-scale agricultural and other development projects. The results of all these major events have been vast shifts in population, causing huge changes in the rural landscape and the rapid and uncontrolled growth of the cities. In many areas, when inspecting the rural landscape in the field, it is immediately apparent that, while the basic topography (as represented by the heights and contours shown on the map) has not changed, the man-made cultural landscape in the form of settlement, communication networks, cultivated land, etc. has altered radically, as has the natural environment, in particular the forest cover. Thus for most countries, the most pressing problem in the topographic mapping area is not that of acquiring basic map coverage, but is that of revising and bringing up-to-date large numbers of existing topographic maps in the light of the very rapid changes that have been and are taking place in this vast region. Even if this objective can be achieved, there will be a continuing demand to keep the topographic map coverage up-to-date, since it is most likely that rapid changes in the landscape will continue for the foreseeable future.

3 - CAN SPACE IMAGERY DELIVER SOLUTIONS?

The task is obviously a daunting one in terms of the effort and resources which will be required both to update the topographic map coverage and to keep it current. An obvious question which has to be asked is whether space imagery can indeed deliver solutions to the problem and can do so in a cost-effective manner.

The available space imagery may conveniently be sub-divided into three categories: - (a) scanner imagery; (b) photographic imagery; and (c) SAR (radar) imagery.

(a) Scanner Imagery

The characteristics and availability of the various types of scanner imagery are well known, with that from the Landsat and SPOT programmes used on a world- wide basis. Less well-known are the Russian MSU-E scanner operated from the RESURS-O-N2 satellite; the LISS-I and II scanners mounted in the Indian IRS 1A and 1B satellites; and the MESSR scanner operated from the Japanese MOS-1 satellite. Till now, these have been used largely on their respective national programmes and have not had wide currency outside their countries of origin.

In terms of topographic mapping, attention has to be concentrated on Landsat TM and the SPOT Pan and XS images with their better resolution and widespread availability. The newest type of scanner is the MOMS-02 device flown on the Space Shuttle flight STS-55 in April 1993 and scheduled to be orbited again in the PRIRODA module of the Russian MIR satellite in 1995 (Seige, 1993). Its high resolution pushbroom scanner (13.5m or 4.5m pixel) seems to have obvious potential for topographic mapping. A great deal of imagery of North and North Eastern Africa was acquired during the MOMS-02 mission and should soon become available for tests.

In practical terms, stereo-imagery (which may be used for height determination) is, at the present time, really only feasible using SPOT with its side-pointing capability, which produces varying base:height ratios in terms of stereo-viewing and measurement. Again the MOMS-02 device promises along-track stereo capability to overcome the difficulties experiences with SPOT's side-pointing images (e.g. those arising from the images being taken in different seasons, etc.).

(b) Photographic Imagery

The main sources of imagery available in this category are those acquired by the cameras (KFA-1000, KATE 200 and MK-4) mounted in the Russian RESURS and MIR satellites. The KFA-1000 photographs have somewhat unusual characteristics - a twin-camera fan (i.e. tilted) configuration ; a large format (30x30cm); and a narrow-angled camera (f=1 metre) which gives rise to a poor base:height ratio in terms of stereo-coverage. However, its comparatively large scale (1:270,000) and high resolution (8 to 10m) are favourable characteristics in terms of topographic map compilation and revision.

The corresponding cameras flown in the Space Shuttle are the ESA Metric Camera (MC) and the NASA Large Format Camera (LFC). However the photography taken with these cameras (at 1:800,000 scale), although much experimented with for topographic mapping in the mid-1980s, has not been extended since the Shuttle disaster in 1986. Thus the MC and LFC coverage is both fragmented and rather old.

(c) Radar Imagery

Following on from the experimental SAR images of the Seasat and SIR-A and -B missions of the late 1970s and early 1980s, a more production oriented mission has been ESA's ERS-1 SAR. While many of its objectives are concerned with the systematic and repetitive coverage of oceanic areas, it is of course available for land applications. In general terms, little use has been made of SAR imagery for topographic mapping in spite of the apparent advantages of its all-weather imaging capabilities. This is due to the shortcomings of the imagery in terms of its background clutter or speckle; the foreshortening, layover and shadowing experienced in areas of high relief; and the extreme variability in the detection of ground features, which is so highly dependent in the orientation of the object with respect to the look direction of the sensor.

Currently a great deal of attention is being paid by the research sector of the remote sensing community to the revival of an old technique - radar interferometry. This is based on the combination of two SAR data sets to provide information, via interferometric techniques, on the height differences existing on the ground. As yet, this is still in the research stage, but undoubtedly given its European dimension, it will get much attention at the present EARSeL meeting. Till now, no results have been published to confirm that the heights and contours produced by satellite radar-interferometric methods do indeed meet the accuracy standards and specifications for 1:50,000 and 1:100,000 scale topographic maps.

3.1 *Mapping Specifications*

As noted above, the basic scales of nation-wide topographic mapping are 1:50,000 (for most countries) and 1:100,000 (for a few, e.g. Sudan and North East Kenya). Typical basic map specifications are as shown in Table I.

Table I -Topographic Map Specifications

Scale	Plan Resolution (at 0.1mm)	Plan Accuracy (±0.3mm)	Spot Height Accuracy	Contour Interval (m)
1:50,000	5m	±15m	3m	10 to 20m
1:100,000	10m	±30m	6m	20m +

3.2 *Results of Accuracy and Interpretation Tests*

The results of numerous tests, show that, by-and-large, the planimetric accuracy specifications for topographic maps can be met using satellite imagery. A representative sample of those tests carried out in African countries is given in Table II.

Table II - Results of Accuracy Tests

	PLAN (m)			HEIGHT (m)		
Sensor	m_x	m_y	m_{pl}	m_z	CI	Source
TM	14	13	20	-	-	Petrie/El Niweiri
SPOT	11	11	15/18	10/12	? 30	OS/IGN
MC	7	19	25	25	? 50	Petrie/El Niweiri
LFC	14	12	18	18/20	? 50	Petrie/El Niweiri
KFA-1000	7	7	10	36	?100	Jacobsen

It can be seen that the main shortcomings in purely measurement/accuracy terms lie in the area of heighting, where there is a real shortfall, both in the spot height accuracy and possible contour interval. In general terms, these are incompatible with standard topographic map specifications. It is also worth noting the quite frequent references (e.g. Jacobsen 1993, Jobre 1993) to the difficulties experienced in height measurement with stereo-SPOT imagery, mostly due to the changes in vegetation, hydrology, etc. occurring over the time interval which had elapsed between the acquisition of the individual side-pointing images making up the stereo-pair.

The other major problem lies in the shortfall in the resolution of the images. The 10 and 20m pixel sizes of the SPOT XS and Pan images translate to smaller values - ? 15 and 30m respectively - in terms of ground resolution. In practice, these values are not too substantially different to the ground resolution values of the MC (16 to 20m) and LFC (10 to 14m) respectively. Obviously these resolution values result in difficulties in the detection of the smaller objects present on the ground, especially isolated or individual buildings, footpaths and tracks, streams and other drainage features, etc. These objects will often have dimensions (<10m) which are smaller than these quoted figures for ground resolution and may exhibit poor contrast with the surrounding terrain, especially in arid and semi-arid areas. The inability to detect such objects means that the map detail is then seriously deficient or incomplete. In turn, this results in the need for a thorough and systematic field completion procedure to be executed on the ground to locate missing features and to incorporate local knowledge, e.g. names, building classification, etc. This has been done quite successfully for 1:50,000 scale map revision in Canada (Genest and Boisvert 1993) using hard-copy SPOT images to help identify and position these smaller missing features in the field.

There is of course an emphasis in topographic map compilation and revision on the detection, interpretation and measurement and plotting of point and line features. This requires good resolution and the need for good contrast in the imagery used for mapping. Also since automatic feature extraction is still in the research stage, the extraction of the required information will have to be carried out visually and manually - in contrast to the extraction of land use/land cover types and areas for thematic mapping, often carried out using automated or semi-automated machine classification techniques.

3.3 *Topographic Map Compilation from Stereo-SPOT Images*

The main areas in the region of South Western Asia and Eastern, Central and Southern Africa which have been mapped topographically using satellite imagery are parts of North Yemen (Hartley 1988, Murray & Farrow 1988 and Murray & Newby 1990) and Djibouti (former French Somaliland) (Veillet 1990). These involved the plotting of 18 and 16 SPOT stereo-models respectively at 1:50,000 and 1:100,000 scales in the case of North Yemen and 1:50,000 and 1:200,000 scales for Djibouti. Both projects required a thorough field completion to pick up missing features. A 40m contour interval was used in North Yemen.

It is of course worth noting that both of these mapping projects have been carried out by well endowed, and technically highly competent European national mapping agencies - the British Ordnance Survey (OS) and French Institut Geographique National (IGN) - under aid programmes. For this purpose, they have been able to deploy analytical plotters with appropriate software plus experienced and expert photogrammetrists to execute this demanding work. These are resources that are simply not available in most of the countries within the region.

The exception to these remarks is the Ethiopian Mapping Agency (EMA) which has carried out topographic mapping from stereo-SPOT hard-copy images processed to Level 1A, using a Wild BC-2 analytical plotter in conjunction with a Wild OR-1 computer-controlled orthophotoprinter (Jobre 1993). This work started with a pilot project covering the Addis Ababa area using well-defined features on the existing 1:50,000 scale maps as ground control points (GCPs). The result from this pilot project was an ortho-image map with contours derived from a DTM produced by manual/visual measurement along break lines and major rivers besides grid-based sampling. The results were judged to be acceptable and so EMA has gone ahead with the plotting of a further seven SPOT stereo-pairs with the GCPs provided by field survey utilizing GPS receivers (Medhin 1993). A further 21 SPOT stereo-pairs are now on order for the continuation of this work.

Specific difficulties have included those arising from the individual SPOT images comprising a stereo-pair being taken three months apart at the beginning and the end of the rainy season, resulting in the very different appearance of vegetation and water features in the two images. This caused difficulties with stereo-viewing and measurement. Jacobsen (1993) has also commented in similar terms on experiences in trying to measure SPOT stereo-images in Germany where the individual SPOT images had been taken at different points in the growing season. Of course, such difficulties also preclude the use of automatic correlation (image matching) techniques for height measurement.

In the arid and semi-arid areas of Saudi Arabia, Yemen and Djibouti, these difficulties resulting from seasonal differences in vegetation and hydrology are either not present or considerably reduced. However, even then, automatic correlation has not been found successful on desert areas due to the inability of the software to match images which exhibit little texture (Donnelly 1994). Thus, in Saudi Arabia, the spot heights required for a DTM in such areas are measured visually by an operator, again using hard-copy stereo-SPOT images in an Intergraph IMA analytical plotter.

3.4 *Tests of Map Revision from Satellite Imagery*

As discussed earlier in this paper, the main problem for most countries in the region lies in the revision of the existing, very extensive topographic map coverage completed using aerial photogrammetric methods during the period 1950-1980. As noted above, the planimetric accuracies attainable with most types of space imagery are quite compatible with those specified for 1:50,000 and 1:100,000 scale topographic maps. The main problem lies instead with the detection, interpretation and depiction of those features which have changed since the compilation and publication of the original edition of each map.

A very detailed series of interpretational tests covering MSS, TM, MOMS-01, RBV, MC and LFC imagery over the Red Sea Hills and Khartoum areas in the Sudan have already been carried out at the University of Glasgow and the results published in Petrie and El Niweiri (1992). These showed the superiority of the MC and LFC photographic images over the other (scanner) images in terms of the detection and interpretation of the required features. However much of the communications network and many smaller settlements could not be detected in this arid region, even with the LFC photography. This points to the need for a comprehensive field completion if space imagery is to be used either for the compilation of original maps or the revision of existing topographic maps.

Since this work, a further series of interpretational tests have been carried out in Glasgow for a number of countries in the region, with an emphasis on SPOT Pan and XS imagery (which had not been available for the Sudanese test areas), but including also some TM images. A summary table shows the test areas and material (Table III). It will be seen that they cover a great variety of landscapes in Eastern, Central and Southern Africa ranging from desert to heavily vegetated areas and from urban and suburban areas to heavily cultivated rural areas (Figure 1).

Besides the satellite imagery, the opportunity was also taken to include in the tests, small scale (mostly 1:60,000 to 1:80,000 scale) aerial photography. This has been done for comparative purposes since a number of the countries (e.g. Kenya, Tanzania and Zimbabwe) in the region are continuing to use this type of photography taken from high-flying aircraft specifically for 1:50,000 or 1:100,000 scale topographic mapping or map revision. It will be apparent immediately that the ground resolution of these photographic images is very high - at 40lp/mm, it will range between 1.5m (@ 1:60,000 scale) and 2m (@ 1:80,000 scale)

A summary table (Table IV) gives the results of some of these interpretational tests carried out on certain of the areas located in Kenya and Tanzania. These included Naivasha in the Rift Valley of Kenya and Thika in the Kakuzi Hills, north-east of Nairobi; while the Tanzanian areas comprised Korogwe in North East Tanzania and the western suburban/peri-urban area of Dar-es-Salaam. This particular test was executed by Mr. Liwa of the Ardhi Institute, Dar-es-Salaam, who is familiar with both of the Tanzanian test areas. Use was made of both hard-copy and digital versions of the SPOT images, the former being measured on a tablet digitizer equipped with a large aperture magnifier and the latter on a PC-based DIAD image processing system. The detail extracted from the aerial photographs was compiled on a Kern PG-2 stereo-plotting instrument equipped with

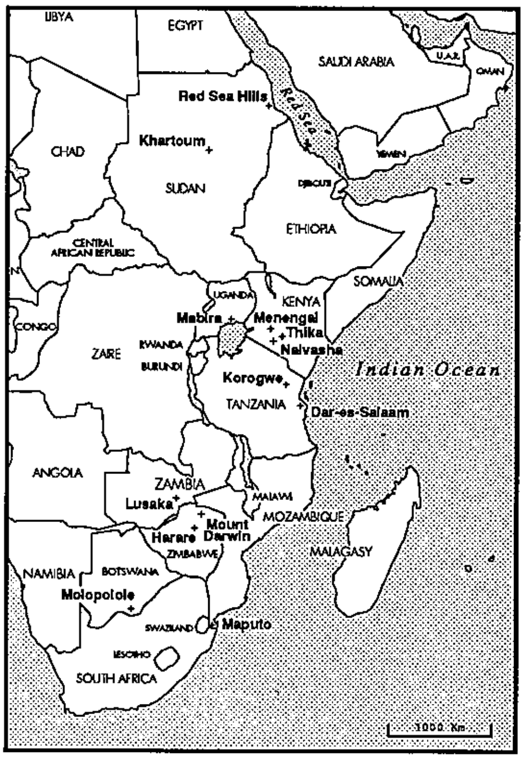

Figure 1

encoders and PC-based RPLOT software. All the sets of measured digital data from the satellite images and aerial photography were processed using Intergraph's MicroStation software and plotted as overlays on the 1:50,000 scale maps of the test area dating from the 1950s and 1970s.

The results given in Table IV show the %age of each class of data which could be discerned on the respective images. In other words, they show the completeness of the mapping from the SPOT Pan and XS images and

Table III - Test Areas & Materials

Country /Area	Imagery	TM	SPOT PAN	SPOT XS	MC	MOMS	LFC	Air Photo (Scale)
Sudan -	Red Sea Hills/ Pt. Sudan	√	-	-	√	√	√	√ (1:60,000
	Khartoum	-	-	-	√	-	-	√ (1:40,000)
Kenya -	Menengai	-	√	√	-	-	-	-
	Naivasha	-	-	√	-	-	-	-
	Thika	-	-	√	-	-	-	-
Uganda -	Mabira	√	-	-	-	-	-	√ (1:30,000)
Tanzania -	Korogwe	-	√	√	-	-	-	√ (1:65,000)
	Dar-es-Salaam	-	√	-	-	-	-	√ (1:75,000)
Zambia -	Lusaka	-	√	-	-	-	-	-
Zimbabwe -	Mt. Darwin	√	-	-	-	-	-	-
	Harare	√	-	-	-	-	-	√ (1:65,000)
Mozambique -	Maputo	-	-	√	-	-	-	√ (1:40,000)
Botswana -	Molopolole	-	√	-	-	-	-	-

Table IV - Results - Interpretation/Information Content of SPOT Imagery & Small Scale Air Photos, Tanzania & Kenya

% Completeness of Features Extracted from the Images.

Area / Image Type	Dar PAN	Korogwe PAN	Korogwe XS/FC	Korogwe XS/2	Naivasha XS/FC	Naivasha XS/3	Thika XS	Dar/Kor Air Photo
Communications	%	%	%	%	%	%	%	%
Hard-surfaced Roads	100	100	100	100	100	100	100	100
Unsurfaced Roads	100	100	50	80	80	70	80	100
Motorable tracks	75	60	50	80	60	70	70	100
Footpaths	5	5	5	10	10	5	0	80
Streets	50	10	2	10	0	0	30	100
Bridges	0	5	5	5	0	0	0	50
Railway Lines	80	100	80	100	75	70	70	100
Cultural Features								
Towns	40	60	50	50	100	100	100	100
Smaller Villages	-	50	40	40	20	20	0	100
Isolated Buildings	40	60	15	15	20	20	0	100
Pipelines	0	0	0	0	0	0	0	0
Power Lines (HV)	100	100	0	0	0	0	0	90
Wells	0	0	0	0	0	0	0	0
Storage Tanks	100	0	0	0	0	0	0	100
Cemeteries	0	0	0	0	0	0	0	0
Vegetation / Land Cover								
Cultivated Land	20	50	90	60	90	85	70	100
Forest/Woodland	100	85	100	80	100	100	100	100
Scattered Trees	0	0	0	0	0	0	0	0
Scrub	0	0	0	0	0	0	0	0
Hydrology								
Rivers	70	65	90	30	40	40	100	100
Streams	0	0	80	25	0	50	80	100
Irrigation channels	-	0	0	0	0	0	0	50
Water Bodies/ Reservoirs	-	90	100	70	80	80	95	100
Geomorphology								
Large Rocky Areas	0	20	60	20	0	0	0	100
Gravel Beds	70	70	5	5	0	0	0	100

from the small-scale aerial photography - all of which date from the same period (in the late 1980s).

It goes virtually without saying that a major defect of all the SPOT images lies in the failure to detect a substantial proportion of the communication features, especially the unsurfaced roads, motorable tracks and footpaths, which form the main elements of the communications network in these areas. This experience is backed up by another study of the Korogwe area carried out by Dowman & Peacegood (1988). Their published figures for the communications features which could be extracted from TM and SPOT images are given in terms of %age errors of commission (i.e. wrongly plotted or identified features) or omission (i.e. features left out) as shown in Table V.

Comparing the data extracted from one of the Landsat TM images and the SPOT Pan image with the data contained in the 1984 photogrammetric plot, the results were as shown in Table VI.

Another major deficiency lies in the difficulties found in detecting the settlement pattern, especially the smaller villages, small clusters of dwellings and isolated buildings, of which there are many existing in the test areas Again as Dowman & Peacegood have also noted, "this probably reflects the natural building materials more widely used in this area". Furthermore certain of the rivers and many of the streams were not detectable,

Table V

	Road (%)	Rail (%)	Track (%)	Road+ Rail+Track
TM (3+2+1)	28/31	50/48	90/90	59/59
TM (5+3+2)	38/51	54/51	88/78	59/48
TM (6+4+3)	34/46	48/51	83/74	60/50
SPOT	51/46	47/47	97/88	75/47

Table VI

	Road (%)	Rail (%)	Track (%)	Road+ Rail+Track
TM (3+2+1)	-	-	-	33/33
SPOT Pan	-	-	-	37/17

even when known to exist from the maps and the aerial photographs.

The superiority of the small-scale aerial photography in terms of the information which it can supply for the map revision task is obvious. When this is combined with the fact that all the African countries are fairly well supplied with analogue stereo-plotting instruments that can utilize this photography (- EMA possess the only analytical plotters in the region -), then the continued use of this traditional aerial photogrammetric approach can be understood.

3.5 *Topographic Map Revision from SPOT Imagery in Uganda*

The political, economic and security problems experienced in Uganda as an aftermath of the Idi Amin regime have been enormous. In particular, from the mapping point of view, there have been massive movements of population, such that certain areas have been substantially depopulated or deserted. At the same time, the main towns and certain rural areas have had huge increases in population and large-scale expansion of settlement. In connection with the last item, very large areas of forest, including designated national forests, have been felled and cleared to accommodate numerous new settlers and allow many new farms to be created. The landscapes shown in the 1:50,000 scale topographic map series completed by DOS in the early 1970s have been greatly altered and the series badly needs revision.

A UNDP funded project is seeking to update the 1:50,000 scale topographic maps using SPOT XS satellite imagery with 20m pixel (Jansen 1993). A contract for this work has been awarded to the Norwegian VIAK company which carries out the image processing operations at its Arendal office in Norway using a MicroVAX-based Teragon image processing system and outputting the results in the form of stable hard-copy transparencies and paper via a film writer. The geometrically corrected raw image data is supplied by the Swedish Space Corporation/Satellitbild in Kiruna. The final processed images correspond to the individual sheets of the Ugandan 1:50,000 scale topographic map series.

So far, 72 SPOT scenes (out of 86 to cover the whole country) have been processed corresponding to 233 map sheets. Data for 80 sheets have still to be acquired, mostly for areas in the south-west of the country, which have persistent cloud cover.

The interpretation and updating of the 1:50,000 scale maps is done visually, manually and graphically on light tables to produce revision overlays at the Department of Survey & Mapping in Uganda (Figure 2). The resulting cartographic work and the printing of the new maps is also the responsibility of the national mapping organisation. Very similar procedures based on the use of hard-copy SPOT satellite images have also been employed in the Philippines, Malaysia and Nigeria to update their existing 1:50,000 scale topographic map series (Rosenholm 1993).

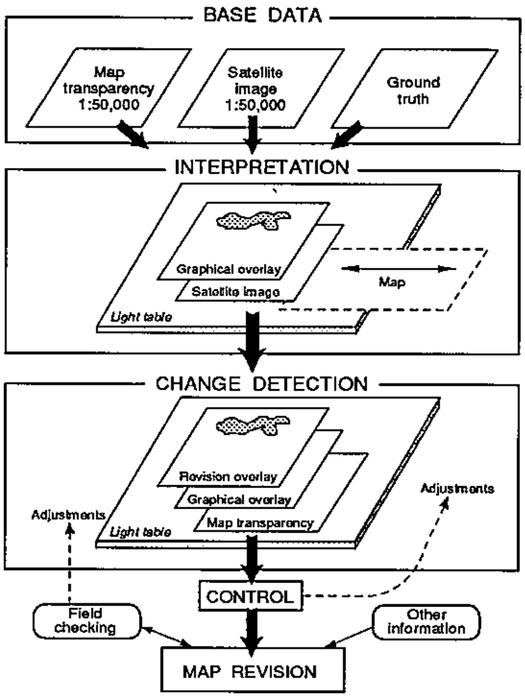

Figure 2

It is interesting to quote Jansen of VIAK on his experiences with this Ugandan project, - "Problems encountered include the interpretation of small features (buildings, etc.) which is limited by the SPOT satellite's geometric resolution - 20x20m pixel. Seasonal swamps may be hard to detect on images taken in the dry season. Roads are recognised as lineaments. Main roads are easy to detect, minor roads may be partly invisible and motorable tracks are sometimes not recognised at all. Roads should be interpreted in close interaction with the existing map. Forests are usually clearly defined with a distinct outline, but problems may occur in areas with forest/woodland mosaics and in transitional zones towards vigorous bush or thickets."

It is also of value to note Jansen"s final conclusions - "Experience from the project shows that SPOT satellite data is a useful tool for updating topographic maps, if accuracy and detail criteria are reduced compared with traditional mapping procedures. The updating should be considered as being temporary since a complete updating of all details would require the use of aerial photographs."

This view has indeed been confirmed by the experience of Kajumbula (1992) of the Ugandan Department, who has carried out comparative tests of satellite imagery and 1:30,000 scale air photos over the Mabira forest area and found that the missing communications and settlement features can indeed be picked up readily on the aerial photography and plotted using conventional analogue stereo-plotters or the digital monoplotting technique.

However the SPOT satellite imagery does have the advantage of availability and speed, even if it is deficient in the details needed for a full map revision. Also multiple use and cost-sharing is another plus point - in this case, in Uganda, the National Biomass Group has also used the SPOT XS images to generate the location and distribution of land use/land cover classes to calculate the areas of woody biomass in Uganda.

4 - CONCLUSION

An overall conclusion arising from the survey of mapping requirements in the region of South West Asia and Eastern, Central and Southern Africa covered by this paper is that the compilation of original topographic maps on a national scale is a major issue only in a few countries - Sudan, Ethiopia and Eritrea being obvious examples. Elsewhere, topographic map coverage is fairly complete, but in many areas, it is now out-of-date, having been compiled in the period 1950-1980. Thus the main problem for many countries is map revision. The topography, as represented by height contours, is of course largely unchanged, but the man-made cultural landscape and parts of the natural landscape, e,g, the forest cover, have often changed drastically as a result of the wars, drought, famine and political policies and changes that have afflicted so many of the countries in the region.

From the account given above, the following points may be made as a result of experiences with satellite mapping in Eastern Africa.

(i) Experience in virtually all of the Easter and Central African countries points to the fact that satellite imagery is still deficient in resolution and hence in its information content in terms of being used for topographic mapping, re-mapping or map revision. Deficiencies are particularly noticeable in the mapping of man-made objects in the landscape - especially communications, smaller settlements, etc. This results in the need for a very extensive and expensive field completion to remove these deficiencies.

(ii) The use of satellite imagery for contouring - 10m is often needed in flatter areas - is not possible with presently available systems.

(iii) There is very strong competition for satellite mapping from small-scale aerial photography (at scales between 1:60,000 and 80,000) taken from high-flying jet aircraft such as the Learjet. This type of coverage is being used extensively for topographic mapping in Kenya, Tanzania and Zimbabwe. The ground resolution at 1.5 to 2m is an order of magnitude (i.e. 8 to 10x) better than the best satellite imagery taken by SPOT, LFC, etc.

(iv) Contouring specifications, e.g. for 10m interval, can easily be met from the aerial photography and the extensive analogue photogrammetric instrumentation available in the region can be used for the mapping.

(v) Satellite images can be used for topographic mapping, re-mapping and map revision only if the normal specifications regarding accuracy and content are relaxed and the resulting product is still acceptable. Those satellite image maps produced at 1:50,000 and 1:100,000 scales for countries in the region often fall into the category of reconnaissance maps, especially if they are not subjected to a field completion procedure.

(vi) In the context of topographic mapping or map revision, digital image processing systems have been used mainly used for pre-processing operations; for rectification of the image to a given scale or for processing to ensure that the final satellite images or image maps delivered to the users correspond to the sheet boundaries of the established national topographic series at 1:50,000 or 1:100,000 scale. However most of this pre-processing work has been carried out by the image suppliers, in particular by SSC/Satellitbild and SPOT-Image.

(vii) The use of satellite images for topographic mapping or map revision in the region is mainly carried out using monoscopic hard copy images overlayed on an existing map with visual interpretation and either manual drafting or the use of tablet digitizers to produce a plot of the compiled detail. This procedure is easier to integrate with the existing repromat available in national mapping agencies in developing countries. Rosenholm (1993) reports a similar concentration on using hard-copy satellite images for topographic map revision and for land use and vegetation mapping in many countries in both Africa and Asia.

(viii) The national remote sensing centres established in almost all of the Eastern, Central and Southern African countries are concerned almost exclusively with low resolution land cover mapping and the application of satellite imagery to help solve specific environmental problems.

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