ADVANCES IN MAPPING IN BOTSWANA SCENARIO OF A DEVELOPING AFRICAN NATION

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ABSTRACT

The core of Spatial Data Infrastructure (SDI) is the geographic data the foundation of which is the geodetic, cadastral and topographic data. Department of Surveys and Mapping (DSM), the national surveying and mapping organization in Botswana, is mandated to produce these data sets. The topographic data is most crucial in any sustainable development. The status of topographic data/maps in Botswana is impressive in comparison to most of the African nations due to adoption of appropriate strategy after independence. This paper provides a synoptic view of induction of relevant technologies, production of topographic data, constraints faced and future trends.

After independence priority was given to aerial photography and production of topographic maps. Medium scale photography for the whole country and large scale photography for major settlements was carried out during 1988-2007. Digital Orthophoto maps (OPMs), Digital Elevation models (DEMs) and 5 m contours for the whole country were produced. These OPMs form the backbone of the medium scale mapping. Planimetric line maps are now being extracted. OPMs/line maps for a sizeable number of settlements at large scales have been produced.

The DSM developed the much needed mapping infrastructure by procuring a number of advanced surveying and photogrammetric instruments especially between 1990 and 2007. A Remote Sensing Infrastructure is being established in order to facilitate the acquisition, processing and dissemination of satellite images and thus promoting use of these images in mapmaking.

The OPMs of whole country will go a long way in serving the medium scale mapping needs. Selective revision will be carried out using satellite images with 2-5 m resolution. Large scale mapping/revision of settlements will be continued using digital aerial photographs and satellite images of ≤1 m resolution. The Remote Sensing Infrastructure will need to be continually enhanced to meet the future needs in accordance with technological changes. It is necessary to continue with capability building.

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INTRODUCTION

The Spatial Data Infrastructures (SDI) are promising initiatives intended to provide spatial data under a single platform so that it can be effectively utilized for sustainable development and environmental protection. Therefore the development of SDI is getting momentum through out the world with no exception in Botswana. The core of SDI is the geo-referenced spatial data set also known as geo-spatial data set. The foundation of this is the geodetic, cadastral and topographic data. The geodetic data includes control points on a pre-defined reference ellipsoid and its relation to international reference frames. The cadastral data includes the land parcel layouts with unique identification numbers, the ownership details etc. On the other hand the topographic data includes the transportation network, hydrography, administrative boundaries, relief etc. The topographic data is most crucial in the developmental planning related to land and water resources.

The Republic of Botswana, formerly the Bechuanaland Protectorate, became independent in 1966. Prior to this, in 1962 the Department of Surveys came into existence. In 1971 it was named as Department of Surveys and Lands and finally in 1993 the Department of Surveys and Mapping (DSM). Department of Surveys and Mapping is the premier national surveying and mapping organization in Botswana. It is mandated to produce Geodetic, Cadastral and Topographic data. Besides it produces some thematic maps. It is also mandated for acquiring Aerial photographs and Satellite Images for its own topographic mapping activities as well as to disseminate these products amongst user community in Botswana. Being the major producer of core spatial data, the Department is now spearheading the establishment of Botswana National Spatial Data Infrastructure with active co-operation of Department of Information Technology of Republic of Botswana.

The status of topographic mapping in Africa is quite unimpressive. The African nations in general are far behind the up-to-date surveying and mapping technologies that hamper the progress of mapping (1). Botswana was no exception prior to independence. The post independence era has been somehow very encouraging in this front due to adoption of appropriate strategy. The aerial photography has been the workhorse of topographic mapping. Therefore after independence thrust was given to aerial photography and topographic mapping. Besides the mapping infrastructure was established by procuring advanced photogrammetric instruments. The Global Positioning System (GPS) has been incorporated to mapping activities for providing necessary control points. Realizing the growing potentiality of satellite images in mapmaking, a Remote Sensing Infrastructure has been developed in the DSM.

Under this background, an attempt has been made in this paper to trace the growth of aerial photography, status of topographic mapping and development of mapping infrastructure and finally providing discussions on constraints, solutions and future trends to keep the mapping and mapping technology on par with the needs and advancements.

GROWTH OF AERIAL PHOTOGRAPHY IN BOTSWANA

The first aerial photomosaic of a portion of the country was available in 1925. However systematic aerial photography started from 1951. Since then, aerial photography in medium scale between 1:40, 000 between1: 80,000 and large scale between 1:3,500 and 1:20,000 have been made available for specific areas of interest. The post independence era has seen the significant growth of the aerial photography and its use in the country.

In order to provide thrust to medium scale topographic mapping, the first ever massive aerial photography was undertaken during 2001-02 in which the whole country has been covered at 1:80,000 scales with about 6000 photographs.

The demand of settlement maps at large scale necessitated the need of large scale photography. Systematic large scale photography in the country started from 1988 with 1:20,000 scales in black and white mode. From 1988–2000 photography for 125 settlements were available. During 2002-03 large scale photography in natural colour mode at 1:20,000 – 1:15,000 scales has been carried out for 25 settlements. Most of these photography was revision one.

Under National Mapping programme of NDP 9 priority is given to production of large scale maps for more and more settlements in order to meet the increasing demand of the user community. Accordingly another massive aerial photography exercise was carried out during 2006 covering 95 settlements. Out of this 41 are new photography whereas 54 are revision. The total number of settlements with large scale aerial photographs stands now at 169. Out of this 120 settlements have photographs from 2002. These settlements cover the cities, towns and major villages. The priority in new photography as well as revision photography is based on user requirements.

The uniqueness of this photography is that it is directly in digital form (CCD detectors in the negative plane) obtained from a state of the art digital camera (z/I Imaging Digital Mapping Camera, Intergraph) and compatible to 1:15,000 scales (15-20 cm spatial resolution). The raw images are passed through a post processing for implementing radiometric, geometric and image adjustments. The image produced is in central perspective geometry, 13824 pixels X 7860 lines, 5 bands (panchromatic, blue, green, red, infrared), 12 bit radiometric resolution. With suitable selection of flying height this camera is capable of providing spatial resolution of about 5 cm (7).

The use of satellite Remote Sensing in Botswana has been very limited. The DSM has procured few satellite images. Hard copies of LANDSAT images (1981-1988) are available for the whole country. Few such images of 1975, 1989-90 are also available. SPOT images of 1991 for some portions of the country are available. IKONOS image of Gaborne is also available. However due to resolution constraints as well as inadequacy of infrastructure, these images have not been used for mapping activities in the Department.

The Botswana Defence Force is a major user of satellite images. It uses SPOT images for defence purposes. In fact it has procured SPOT images for substantial part of the country. The Department of Agriculture uses very coarse resolution images for vegetation monitoring. However some research work has been done by Harry Openheimer Okavango Research Center of University of Botswana using remote sensing. The Department of Geological Survey has also carried out some exploration work using remote sensing images.

So far the use of satellite images as a substitute to aerial photographs could not get momentum in the country basically due to absence of suitable infrastructure and non-availability of expertise. However, the need of satellite remote sensing is rapidly increasing in the country considering the different developmental activities and thrust on science and technology. In National Development Plan 9 (NDP 9), provision has been made to develop the infrastructure, the details of which are provided in latter sections.

STATUS OF MAPPING IN BOTSWANA

The Department produces line maps and orthophoto maps on varied scales. These can be grouped into the following categories for further discussion.

Small scale Geographic Maps: 1:500,000 - 1: 2 million

Small scale Topographic Maps: 1:125,000 - 1: 350, 000

Medium Scale Topographic Maps: 1:25,000 - 1: 100,000

Large scale topographic maps for settlements: 1:5,000 -1:10,000

Small scale geographic maps on scales 1:500,000, 1:1 million and 1:1.5 million and 1:2 million are available providing full coverage of the country. These maps portray the main transport and communication net-work, settlement locations, very broad landuse/landcover and the administrative boundaries at national and international levels. Between 1965 and 1971 a series of 11 map sheets at 1:500, 000 were published by Directorate of Overseas Surveys (DOS), UK with details in black and water features in blue. There were no contours but prominent hills were depicted by form lines and some trigonometric station heights were given. This series has been revised by DSM and relief is shown by layer tinting. Most trigonometric stations are marked and heights given. A single sheet map of the country at 1: 1 million scales was produced by DSM in 1970 but was superseded by a two-sheet version in 1986. In addition, there are single sheet maps of the county at 1: 500 000 (edition 7 in 1991) and 1: 2 million (edition 3 in 1991). However the 1: 1 million sheet is now available in digital mode. This is a revised version of 2005 using the line maps generated from the 1:80,000 aerial photography of 2001-02.

In small scale topographic maps, the first series of Botswana at 1: 125 000 scale were published in 1955 by the DOS. There were no contours but form lines were used for prominent hills. This series was discontinued in 1966. The DSM 1: 250 000 series numbering 44 map sheets covers the country in various mapping styles. These maps are outdated. No contour information is available. Also there exist 1:350,000 scale topographic maps of Okavango Delta and Chobe region compiled from 1:250,000 map series during 1987.

In medium scale front, the first sheets of the basic maps series at 1: 50 000 scales were published by DOS in 1967. These maps are with 50 ft contour interval and covered the more densely populated eastern part of the country. In the north multi-coloured enhanced photomaps without contours were produced. Production of the 1:50 000 series ceased in 1982. Out of the possible total of about 860 sheets with dimensions of each sheet as 15'*15', 220 were produced as line maps and 147 as photomaps. DSM has produced 69 monochrome conventional sheets and revised 215 sheets, some of these now have metric contours. The southern and western borders are covered by mapping produced by the Republic of South Africa and Namibia. For the remote north and northwest part of the country, 37 multi-coloured photomaps at 1: 100 000 scales were published by DOS in 1982-83. These maps are also mostly outdated. Some of these maps are having contours at 5 m interval whereas some others at 25/50 ft interval. At 1:25,000 scales only Gaborone and Francistown have been mapped.

To augment the 1:50,000 scale topographic mapping, digital orthophotomaps (OPMs), Digital Elevation Models (DEMs) and contours with 5 m interval have been produced for the whole

country during 2002-03 from the aerial photography of 1:80,000 scale. These OPMS, popularly called national OPMs, are used now as input for generating 1:50,000 line maps. Already 250 map sheets out of possible 974 map sheets of 25 km x 25 km size have been available now. These maps for the whole country will be available in next 2-3 years.

There has been a pragmatic plan from early nineties to produce large scale topographic maps on 1:5,000 scale with 2 m contours for the settlements using the modern aerial photogrammetric techniques. Digital line Maps at 1:5,000 scale for 70 settlements and orthophoto maps for about 35 settlements are available. The orthophoto mapping of another 95 settlements on the basis of recent digital aerial photography has been undertaken during the current year and expected to be completed by March 2008. These cover the cities, towns and major villages.

DEVELOPMENT OF MAPPING INFRASTRUCTURE

Prior to 1990, the Department did not have mapping infrastructure for production of topographic maps using aerial photographs. Therefore for some locations aerial photo mosaics were produced.

The Department started developing the much needed mapping infrastructure by procuring photogrammetric instruments in 1990's (4). Five analogue instruments (Wild A10, A8, B8S) were acquired and put to production of settlement maps at 1:5,000 scale with 2 m contours using hardcopy aerial photographs/films.

During National Development Plan 8 (1997 -2003), the mapping infrastructure was modernized. In 1999, a digital photogrammetric system, a photo scanner, a digital orthophoto mapping system and two analytical plotters were acquired for use in large scale mapping. The analogue instruments were upgraded with digital encoders and suitable software (SOS map) so that the maps produced could be recorded in digital form. During 2002-03 further modernization was done by procuring 5 digital photogrammetric systems, 5 digital cartographic systems, one colour photogrammetric scanner and a color management system. The digital photogrammetric system was mainly put into production of orthophotos for settlements using the large scale aerial photography whereas the digital cartographic system was engaged in production of medium scale topographic line maps (1:50,000) with the national OPMs as input. The colour scanner was used for scanning the hard copy aerial photographs those have been acquired prior to 2006. The colour management system has provided an efficient tool for enhancing and thereafter printing the so produced orthophotos in hard copy format.

The increasing demand of large scale maps and updating of medium scale maps necessitated the need of further modernization of mapping activities. Accordingly, under the National Development Plan 9 (2003-09) a project "Development of Remote Sensing Infrastructure' has been initiated. The objectives of this project has been to acquire the capacity and skill in the Department to handle the state of the art Satellite Remote Sensing images for producing/updating topographic maps. Besides, this project also aims to popularize the use of Satellite Remote Sensing in the country. Accordingly the project has three major functions: Data Acquisition and Dissemination, Digital Image Processing and Mapping (3). In addition to this, it is planned to augment the Digital Photogrammetric infrastructure to meet the increasing demand of orthophotos for settlements. The stages of implementation of this project includes: procurement of hardware and software, acquisition of satellite images, training of staff etc. The implementation of the project is ongoing. So far 5 Digital photogrammetric workstations, 4 Digital

Image Processing workstations and other necessary peripherals have been acquired. Skill development is ongoing. By end of 2008, the facilities so acquired will be fully operational. The stake-holders have been consulted in this project so that in future the Remote Sensing facility so developed can become a centre of excellence in this area in the country.

DISCUSSION & CONCLUSION

The topographic data is the most crucial one in sustainable development. The availability of this data in Botswana is quite satisfactory in terms of coverage, currency and scale. The full coverage is available in small and medium scales to meet the aspirations of the global and regional planning levels. Coverage of large scale maps for sizeable number of settlements can very well meet the micro level planning activities.

The 1:1 million scale map (small scale geographic map) with 1 km grid for digital version is useful in global studies. However some items such as relief, landuse have to be revised.

The medium scale topographic map at 1:50,000 scales is the main frame work of the topographic data for any developmental activities. The world average of updates of this scale is about 50 years (5). However the situation is quite pleasant in this front for Botswana. The whole country has a fairly accurate digital Orthophto map base (the national OPMS) with 5 m contour interval on the basis of 1:80,000 scale aerial photography of year 2001-2002. This can provide information compatible between 1:25,000 and 1:50,000 scale mapping. Digital line maps compatible to 1:50,000 scales from this are being produced/updated. This meets the requirement of the medium scale mapping. Considering the nature of the terrain, where about 70% of the area or more is under Kalahari deserts, the scope of development is very limited. Therefore this base need not be updated even in next 20 years. However some limited areas may undergo development and selective revision of those areas may be undertaken using satellite images with 2 – 5 m resolution (e.g. SPOT 5). The thematic mapping at such scale such as land use/land cover can go ahead with relatively coarse resolution multi-spectral data of 20-30 m depending upon the requirement. The revision cycle for this can be set according to need. Areas having high environmental and economic significance could be revised at 10 years interval. The production/revision 1:250,000 scale topographic maps can be linked to the 1:50,000 scale.

In large scale mapping front, about 130 settlements will be covered under orthophoto maps by March 2008. These maps are based on aerial photography of 2002-06 and therefore can be assumed nearly updated for the purpose of developmental planning. There are also settlement maps for a number of settlements based on aerial photography prior to 2000. However the number of settlements in the country having potentiality of developments is about 300 Therefore there will be a further need to provide large scale line maps/orthophoto maps for more and more settlements and update the existing old maps. This mapping will largely depend on the digital aerial photography. Very high resolution satellite images of the order of 1 m or better available from a number of commercial satellites such as QUICKBIRD, IKONOS, KOMPSAT, IRS – CARTOSAT RESURS – DK1, World View 1 (0.5 m), Geo Eye1 (0.4 m in multi spectral mode) etc. could be used as a trade off for updating/generating the village maps. The utility of these data in mapping the urban environment has been well established (6).

The digital aerial photographs and high resolution satellite images along with digital photogrammetric/imagegrammetric techniques is now replacing the conventional aerial photogrammetry. Popular products generated from this are Digital Elevation Models (DEM),

Digital contours and Digital orthophotos. The digital orthophtos are increasingly forming the basis to extract the attributed planimetric topographic mapping in interactive mode (called 2D line mapping) thus reducing the cumbersome process of such mapping using sophisticated stereoscopic models (called 3D mapping). The digital contours are integrated with planimetric details finally to provide the digital version of the topographic map.

The Remote Sensing Infrastructure so developed will accelerate the map production in the Department. This Infrastructure will need further up-grading in the next 4-5 years in tune with technological advancements.

Botswana is a country with an area of 582000 sq km but a small population of less than 2 million. Mapping such a vast area is really a daunting task. Besides, this also invites financial constraints. However prudent selection of satellite images for mapping is expected to reduce the cost of data acquisition. For example the 1 m resolution data from the Russian satellite RESURS DK1 costs about 10 USA$ per sq. km. This is about half of the cost of similar data from other commercial satellites

Data sharing among the users in Botswana is likely to increase significantly. The establishment of Botswana National Spatial Data Infrastructure is going to play a major role. Satellite images will be fully integrated into this. However the problem of multi-user license of this data has to be settled. The authorization to re-distribute LANDSAT data once purchased is an excellent example in this direction (2). The data from the Russian Satellite 'RESURS DK1' is too provides opportunities for further commercial distribution .

Another point to be looked into is the capacity building/skill development. The largest number of workforce in Geomatics comes from DSM. A sufficient amount of work force also exists in Land Boards, few other Government Departments and the private sector. The area of Geomatic is gradually becoming more flexible in terms of application areas such as Landuse planning, Watershed Management etc. and getting wider acceptability among developmental planning experts. The formal education and training needs in this area is totally inadequate considering the demand of the industry. The University of Botswana (UB), the Botswana Surveying and Mapping Association (BSMA) and the DSM should initiate steps so that this opportunity increases significantly within the country. Besides, the digital technology in mapmaking is changing very fast necessitating replacement of hardware and software in every 4-5 years. The DSM being the pioneer in this field may look into conducting short term refresher courses at regular intervals for updating its own staff as well as staff from other sectors.

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