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Geocoding and Census Mapping with GIS in Namibia: current status and future developments [*]

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1. Introduction

Namibia has a land area of about 824 000 square kilometres, divided into 13 administrative regions with a population of 1.8 million as per 2001 Population and Housing Census (Figure 1). The administrative regions are further divided into 107 constituencies. There are 6-12 constituencies per region depending on the regional population size. The 2001 Namibia Population and Housing Census was the second post-independence census. The lessons learned from the 1991 census provided the basis for undertaking 2001 census. Overall, it was very successful. Other than the following constraints: budget, transport, refusals during enumeration, inaccessible areas, boundary dispute problems, underestimation of number of households and payments to field staff, the whole operation was completed according to the work plan. Some of the activities were even completed ahead of schedule.

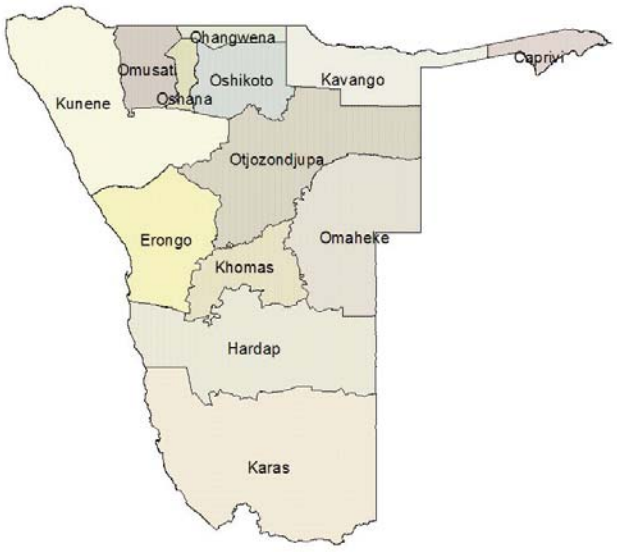

Figure 1 Namibia with 13 administrative Regions

2. GIS establishment and its use for mapping activities for 2001 census

2.1 GIS Establishment

In 1999 the Central Bureau of Statistics (CBS) of the National Planning Commission (NPC) made a decision to move away from the traditional methods of mapping for censuses and surveys to digital mapping and the development of a Geographical Information System (GIS). GIS was acknowledged as an effective tool that would enhance the capture, processing, storage and retrieval of geographical information required for national planning. To this effect, and in order to efficiently plan and prepare enumeration area maps for the 2001 Population and Housing census, CBS contracted a consulting firm (DEVINSO) from the Republic of South Africa to assist the office in putting up a GIS infrastructure. The firm was asked to assist in

developing a geographic database that would incorporate data on socio-economic infrastructure in the country.

2.2 GIS Infrastructure and data warehouses

The necessary equipment for GIS infrastructure was identified and purchased by the office through the consulting firm in order to manage the GIS Office. Since the contracted firm's main core business was not to sell and maintain GIS hardware and software, this part of the contract was sub-contracted to the relevant suppliers such as Intergraph. The following equipment was bought: 1 server, 4 workstations, 1 colour printer, 1 plotter and 1 colour photocopier/printer. Relevant GIS software such as Geomedia 4.0 was also acquired. Other equipment included 4 Differential Global Positioning Systems (GPS) and other GPS (Garmin III) were bought for use in capturing field data. Due to the workload during map creation and printing six extra computers were added to be able to handle the workload.

Currently the GIS office is using Geomedia as main GIS software but also acquired about 14 license of ArcGIS 9.2 for head office plus four of the pilot regions. Due to sustainability of expensive commercial GIS software the office is also exploring the use of Open GIS such as Postgress, Oracle will be the central database and Geomedia can directly read Oracle no need for the intermediate software.

Installation of GIS equipment was followed by the development of different data warehouses, which collectively make up the database at NPC. The development of warehouses involved acquisition of already existed geographic data from various sources and manipulating it to fit the specifications required for the cartographic work for the census. The cartographic specifications was discussed and agreed between the consultancy firm and the statistics office. Some of the major sources identified below:

- Office of the Surveyor General, Ministry of Lands and Rehabilitation (responsible for updating and maintaining national maps)
- Ministry of Regional, Local Government and Housing and Rural Development
- Windhoek Municipality (City of Windhoek)
- Walvisbay Municipality

Some of the data put in the warehouse at the time include the following:

- Administrative boundaries of the country (regions, constituencies, etc.)
- 1:50 000 scanned topographic map sheets covering the whole country, at that time dating mostly from the 1970s
- 1:250 000 scanned topographic map sheets covering the whole country
- Aerial photographs covering major cities and towns
- Planimetric maps (cadastral) covering major cities and towns

The establishment of the GIS infrastructure was completed in January 2000, while the development of the data warehouses was completed in March 2000. The printing of all census maps was completed in May 2001.

3. Field mapping for additional data

3.1 Administrative order divisions and fieldwork

The administrative order divisions for which census data was collected are the National boundary, regional boundary and the constituency boundary. Other classifications considered under this category include proclaimed municipalities and towns, which mostly form the urban population.

The fieldwork mapping was done by Survey and Cartography unit at CBS while Devinso provided the most required base maps and control forms printed from the newly established GIS. However before actual fieldwork, the pilot exercise for one month aimed at assessing time-period, formulation of guidelines and field procedures was organised. The pilot was held in one constituency having a mixture of rural (both commercial and communal) and urban areas. The fieldwork activities involved capturing of geographical positions of localities and socio-economic infrastructure using GPS unit and plotting these onto the field base maps, listing heads of households and their members, capturing their addresses as well as obtaining household counts of the plotted localities.

The field teams collected the information using hand held GPS receivers and also used other map sources from municipalities and towns to complement information stored at the office. The field collected data and demarcated Enumeration Areas (EA) plus control forms were captured at the office using the GIS. The teams were deployed in one region and worked from one constituency to another within the region and this ensured quality control.

3.2 Different type of localities used in census mapping fieldwork

a) Polygon localities

These were captured during the mapping exercise such as traditional authority areas that are commonly used in the northern part of the country and King/Chief, headman or sub-headman identified these on the ground. The locality boundary and the geographical position of the King/Chief, headman or sub-headman's homesteads was captured using GPS and polygons sketched and later digitised into the GIS database.

b) Single point localities

These are common in the central and southern parts of the country where boundaries of a locality cannot be identified, particularly in the communal areas and resettled farms. Homesteads were captured and plotted as a single point coordinate localities.

c) Commercial Farms

These freehold areas are polygons as provided by the Office of Deeds under the Office of the Surveyor General, Ministry of Lands and Resettlement.

Note: For purpose of field mapping, a locality was generally understood to mean a group of households living together in a community setting. However, due to different settlement patterns obtaining in different areas, the definition loosely addressed two scenarios of polygon locality and single point locality.

3.3 NAMPLAN

This was a parallel project with the Census cartographic work and was specifically designed to collect data on socio-economic infrastructure in the country. The project's aim was that of building a National development-planning database, which thereafter became known as the NAMPLAN. Some of the facility infrastructure on which data was collected includes Health, Education, Government, Commercial, Public service, Accommodation, Banks, and Service stations. All these features and their attributes are captured using GPS and controls forms and constitute different layers in the GIS database.

3.4 Demarcation of enumeration areas

The principal objective of EA delineation was to create enumeration areas such that each one contained a population that is approximately "ideal" in size. An ideal population size is the number of people that one enumerator can enumerate in the stipulated time for data collection.

The delineation of enumeration areas was carried out in the Office by the Cartography staff. The EAs were initially demarcated onto the field maps using background topography and additional information plotted in the field. The provided estimate number of housing units in a locality was the basis for demarcating the EA population size. The problem faced when demarcating EAs in the Office is that identification of features to be used as boundaries on the ground becomes difficult because the information on the base map is scanty or inadequate.

3.5 Factors that influenced demarcation of EAs

(a) Rural areas
These are areas that mostly constitute commercial farms and communal lands demarcated at the lowest level of constituency. The EAs demarcations were all based on the 1:50 000 scale field maps

(b) Urban areas
This is a category of proclaimed municipalities and towns that have Eas demarcated using cadastral maps and digital imagery of aerial photography. Initially it was thought that all municipalities and towns are classified as urban, but the non-availability of a certified definition from relevant authorities changed the approach to demarcating EAs in these areas. Only the developed part of the municipality or town and the surrounding population is demarcated as urban. The rest is classified as rural.

However, the office obtained town land boundaries after mapping so the 2011 mapping will demarcate the boundaries properly.

(c) Administrative boundaries
Observance of administrative boundaries was followed as all EAs are demarcated within the lowest administrative boundary (constituency)

(d) Physical Features
The use of well-defined visible physical features as boundaries was encouraged wherever possible

(e) Geographical area
The size of the geographical area in terms of travel distances for the enumerator was taken into consideration

(f) Estimated housing units/Population size
The estimated number of housing units making an EA varied depending on other ground features. On average the range of between eighty and one hundred (80-100) units per EA was preferred. In commercial farms and other sparsely populated areas the estimated number of housing units in an EA was kept to a minimum low of fifty (50) or less.

3.6 Settlement type

Apart from identifying the population by rural or urban, it was also decided to classify the said population by the type of settlement they live in. The settlement type of each EA appears on all EA maps in the identification box above the legend
The different settlement types are explained below.

- Formal urban: Proclaimed urban areas for which cadastral data are available
- Informal urban: Rest of the urban area and other unplanned squatter areas
- Formal rural: Mostly commercial farms for which cadastral data is available
- Informal rural: Mostly communal areas and resettled farms

3.7 Composition of enumeration areas

- Most enumeration areas in the northern part of the country are made up of polygon localities. One or more localities formed an EA while in other cases of large localities they were split up depending on the size to form enumeration areas.
- In informal rural/urban areas, which mostly cover communal lands, resettled farms and squatter areas, the estimated number of housing units was grouped into ideal sizes to form enumeration areas. However the lack of physically identifiable ground features to use as boundaries in some of the areas made the choice of EA boundaries difficult. Instead imaginary EA boundaries were drawn using household reference points falling closely inside and outside the boundary.
- In formal rural areas, individual commercial farms were combined to form enumeration areas.

3.8 Geographical codes

All enumeration areas were given unique code numbers composed of nine digits**.**
The numbers help to identify each EA by the level of administrative area. They also identify the EA by rural and urban. Rural EAs are identified with code ‘99’, while the urban EAs are coded ‘01’. A constituency with two urban centers will have the fifth

and sixth digits as '01' for the first urban center and '02' for the second urban center and so on. The structure of the EA number is shown below.

- 1st and 2nd digits represent the region
- 3rd and 4th digits represent the constituency
- 5th and 6th digits represent the rural/urban status
- 7th, 8th and 9th digits represent the EA number within the constituency.

Example of an EA number for Kavango region for rural constituency: 050199003 or for Urban constituency in Erongo region - 030401012

All administrative regions are coded in alphabetical order as well as constituencies within the region. If the constituency was added after the creation of geocoding system then it is allocated the next number from the last constituency number for consistency and updating purposes.

3.9 Data Capture and Processing

Once the CBS team completed demarcating the EAs onto the field base maps, the maps and relevant documentation were handed over to the consulting firm for onward processing and incorporation into the GIS. Processing involved digitizing polygon locality and EA boundaries and capturing geographical positions of single point data i.e. localities and socio-economic infrastructure. Single point data was captured using a data entry process the company called Nam-grabber. Most of the processing was done in South Africa where the company has its head office.

3.10 Map Creation

Map creation was an activity that involved setting standard map specifications for the final enumeration area maps. The specifications included determining the layout of the final maps and line types to be used for administrative, supervisory and enumeration area boundaries. Other map elements include content, borderlines, scale, colours, and legend etc. The paper size for the final EA map is A3 while the regional and constituency maps is A1 size. CBS staff finalized the specifications and DEVINSO implemented and applied the specifications to the final maps.

3.11 Map printing

Once the specifications were set, printing of final maps was automated through a Geo-media software application developed by the consultancy company called the PLOTTING TOOL. In order to speed up the process of printing the maps, only one set of all EA maps covering the country was printed through the PLOTTING TOOL. The remainder of the maps was copied four times over in order to equal the number required for the census count. In all, about six thousand (6000) enumeration area maps were printed for the actual count. In addition, about three hundred and six (306) A1 size constituency maps showing the position of EAs within the constituency were printed.

4. *Lessons learned (difficulties, Successful achievements etc) in developing and implementing a digital census-mapping program*

4.1 Successful Achievements

a) Pilot Exercise

It was good to conduct a pilot because it revealed that the work done during the exercise showed that the teams were spending more time than expected on collecting household attribute data. It was therefore decided to streamline the procedures in order to speed up work during the main mapping exercise. It was recommended that:

- The number of teams to be increased in order to complete the work on time
- Listing of head of households and their members be discontinued because it was time consuming
- A quick count of housing units in a given locality be conducted for purpose of obtaining figures to facilitate the demarcation of enumeration areas

b) Establishment of GIS

The GIS made it faster to update and reprint maps instead of make copies of the more cumbersome manually sketched maps. GIS made it possible to answer to spatial data requests on time and also to share spatial data with other users and producers to avoid duplications of data collection and wasting of resources.

By using the GIS the census indicators were linked to spatial data and a GIS census dissemination Tool was created for the planners at all levels. Other spatial data was also disseminated using the same tool. The National Sampling Frame layer was added to the GIS database and made it possible to update and maintain. The merging and splitting of the EAs after the census was done using the GIS and all Primary Sampling Units (PSUs) were created with GIS. The GIS environment made it easier to generate PSU maps needed for any survey/study fieldwork.

In addition, having a fully-fledged GIS in place, it is possible to support other office initiatives for data dissemination purposes such as supplying shape files to DevInfo (renamed as NamInfo) a dissemination database for its mapping component. The statistical office is busy implementing NamInfo at both national and regional level.

4.2 Problems Encountered during mapping activities

a) Problem encountered during fieldwork

Problems experienced at the beginning of the mapping programme include the following mentioned below:

- There wasn't enough publicity about the mapping program taking place through out the country because many local people did not know about it.
- There was a general lack of adequate transport to move the teams around
- The number of teams at the beginning of the exercise was insufficient to complete the work within the set time frame.

- Regional and constituency boundaries shown on the field maps were not very clear on the ground especially in the areas of imaginary straight lines
- Maps with Town/Municipality boundaries were not easily available from the local authorities during fieldwork
- The eastern most part of Kabe constituency (Caprivi Region) did not have base maps for use as field maps during fieldwork.
- At the beginning of fieldwork, teams working in constituencies with a rough terrain did not have suitable 4x4 vehicles.
- In some constituencies refueling of vehicles was difficult because of non-availability of service stations and inadequate fuel tank capacities of some vehicles.
- Some constituencies mapped during the beginning of the year 2001 experienced floods, as such teams spent days waiting for the floods to subside.

b) Problems Encountered During Demarcation

As mentioned earlier in the paper, demarcation of enumeration areas was carried out in the Office, and some difficulties were experienced during this time. One of the major reasons is that during mapping, teams were more concerned with capturing and recording housing units' estimates in a locality. At the time they did not worry about what features would be used for demarcating EAs. So collection of information and factors relating to EA boundary descriptions was not accomplished while the teams were still in the field. As such, teams working on demarcation of EAs in the Office made a lot of assumptions as to what the real ground situation was.

Some of the problems include the following:

- EA demarcation was based on information found on the base maps, which had not been updated in a long time. Some current ground features are not shown on the maps and the ones appearing on the map may have undergone some change or have all together disappeared.
- After fieldwork was done and demarcation of EAs completed in some constituencies, it was discovered that some administrative boundaries the field teams used during fieldwork were not correct. Some boundaries were cutting across localities. Office verifications were later made and correct administrative boundaries applied, the estimated number of housing units in the affected EAs was resized and the boundaries redrawn.
- Reference features (localities in or out) to support boundary descriptions of imaginary constituency and enumeration area boundaries were mostly insufficient or not available at all during demarcation. Field teams were made to go back to the field to collect more information to support description of boundaries.

4.3 Lack of relevant staff and training during GIS establishment

When the GIS was established at CBS, there were not existing officials who had previous training in the area of GIS and no GIS unit was created. This made it hard for the allocated staff to work and learn from the consultancy as expected because they were totally at different levels. The consultancy firm did not train the local staff as anticipated due to time delivery plan and also due to limited staff that were

allocated to the GIS project as well as their level in GIS. Therefore limited training was done with an understanding that training can be done after the project by the same company but this did not happen even afterwards. However, the office was fortunate to be given a GIS Expert for three years from Swedes Survey through Statistics Sweden funded the Swedish Government.

4.4 Recommendations

Now that the CBS has gone digital in mapping and provision of map products, mapping activities will no longer be done as a once in a while program as it used to be in the past. It now requires that data in the databases be kept as up to date as possibly can because as we all know spatial data has 'lifetime', it is dynamic. In order to achieve this, it is recommended that an on-going map-updating program be made an integral part of the Statistical Office. The program will be crucial in minimizing the amount of work expected during preparation of EA/PSU maps for censuses or surveys. Continued updates will also ensure that map products issued out to clients are of higher quality and always up to date.

- It is recommended that CBS as a provider of statistics at the lowest level of administration should initiate consultations with other mapping agencies, stakeholders, and major users of the master sample frame. This is with a view to encourage harmonization of issues pertaining to the provision of descriptive boundaries, map definitions of political and administrative boundaries. This will bring about the use of standardized concepts and definitions and lead to the formation of a national geo-coding system.

- It is often said that a well-publicized census or survey is almost halfway done because respondents become aware and are willing participants in the exercise. It is therefore recommended that future-mapping activities be well and widely publicized.

- It is suggested that collection of reference features to support constituency and EA boundary descriptions and area identification inside PSUs should be part of the long-term program of updating the master sample.

- Straight lines representing constituency boundaries that cut across localities are not particularly practical on the ground. This was evident during the demarcation of EAs and during the joint field trip undertaken for the third delimitation commission by CBS and the Office of the Surveyor General. The trip was aimed at verifying the constituency boundaries of proposed new constituencies. It is recommended that since CBS is frequently on the ground conducting censuses and surveys and encountering the same problems, they should follow up the issue with Elections Commission.

Finally, it is recommended that dedicated officials are assigned at the beginning of GIS establishment and proper training is given during the duration of the project for sustainability of what was done during the project. It is also further recommended to create a GIS division or unit within the structure of the statistical office rather than adding its activities to the existing staff hence it will ensure that personnel with relevant qualification are employed which makes training a lot easier. GIS is a field of

its own therefore it should be treated as such with the complement of Information Technology (IT) professionals given that IT and GI activities are more linked in order to produce expected results.

5. Future Developments

5.1 Mapping for 2011 census

The preparatory work for the 2011 census will start with the pre-enumeration phase such as fieldwork in 2008 hence the planning is already in progress. The mapping exercise will demarcate the PSUs that are based on the 2001 census enumeration areas into manageable size as per urban and rural areas using a GIS database. The mapping exercise will start with demarcating larger PSUs in the GIS office. This will be based on updated maps of demarcated areas and on the basis of digitising dwellings on recent remote sensing products in less formalised and communal land. Once the office work is done such demarcations will be verified on the ground by field teams in order to come up with boundary descriptions. The pilot to test guidelines and logistics is also envisaged before the main fieldwork. Since the mapping activities will not list households in an EA but dwelling units, the sizes of the EAs by type will be reduced as follows: Urban EAs from 80 to 100 dwelling units; Commercial areas from 50 to 60 dwelling units too long travelling distances between farms while communal areas will have 60 to 80 dwelling units due to distance as well.

To avoid overlap in dense informal urban areas, it is envisaged that coordinates of digitised dwellings forming an EA will be downloaded to handheld GPS to be used by the enumerator to locate the dwellings.

To address the need for more disaggregated data, due to advances in computer technology able to handle larger amounts of data it is proposed to use traditional authority boundaries in communal land and code these accordingly. Similarly, it is proposed to include codes for suburbs in municipalities and towns.

Due to the fact that in rapidly developing countries most EAs change with each census or survey it becomes difficult to compare changes between censuses at more disaggregated levels while this is more and more required. It will be therefore investigated to attach coordinates to each questionnaire to be able to compare population and related attribute data at more disaggregated levels.

To improve the display of population densities by means of choropleth maps, the settled areas (ecumen) will be mapped. This will allow the production of more representative density maps, as vast areas of Namibia are largely unpopulated.

The current process of decentralising of GIS and statistical activities in CBS regional offices in line with CBS restructuring opens new avenues for data capture. With improving of Internet connection speeds, it becomes possible to link the head office with regional offices through web-GIS and this approach is under development. Regional offices will have better local knowledge and will be more able to address the requirement for more suitable boundaries of EAs, while also well located to raise awareness about the 2011 population census.

5.2 Using GIS as a tool to for national and regional development planning

The office is busy implementing a Geographic Information System (GIS) to support development planning in regions. For this purpose a Project NAM/342: "GIS Based Development Planning and Implementation for Regions in Namibia [GISIII]", which is funded by Grand Duchy of Luxembourg is being implemented with assistance of Lux-Development as the implementing Agency for Luxembourg. The overall objective of the new GIS III Project is to improve the Namibian Government's national-regional planning and development processes, in line with the framework of the Decentralisation Policy, to contribute to the achievement of the National Development Plan (NDP) objectives within the framework of Vision 2030. The Project aims to create and provide spatial and non-spatial information for the implementation and monitoring of regional development based on National-Regional dialogue, inter-departmental cooperation, community participation and the application **of web-based GIS tools** in the framework NDPs. This will result in a streamlined and highly participatory planning and development process, assisted by computer technology and GIS tools, which will lead to realistic national and regional programmes, which in turn will help deal with issues of poverty and inequality in the nation.

There is a lot of digital geospatial data in the country, but there is a lack of coordination in almost all aspects resulting in the lack of metadata, low accuracy, double work and all other problems associated with low coordination. CBS will support the creation of a Spatial Data Infrastructure in line with other initiatives in Africa. While CBS is using ORACLE as its central database, it is also investigating the use of open source GIS and database software for smaller municipalities and other urbanised areas that can ill afford expensive commercial GIS but nevertheless require their own databases for various purposes. It is envisaged that by more decentralised data capturing, more accurate and more up-to-data information will available for future censuses and surveys.

6. Conclusion

In conclusion for the countries that are planning to establish their GIS, it is advisable to do that during census project. It has an added advantage because census mapping fieldwork is already covering the whole country and financial input are part of the census budget given that GIS infrastructure mighty be costly. ***However, the planning of GIS establishment and its inclusion in census mapping activities has to be done in advance to avoid the risk of failing or postponing the census which will have negative implication for the statistical agency.*** Any other further development on the GIS can be done with normal funding which is not expensive. GIS is a must have in all statistical agencies since it efficient in generating and printing of maps for the census and survey fieldwork plus there is more demand for digital spatial data. Hence the GIS will assist the statistical offices to respond to the user needs by using GIS technology tools. Furthermore updating and maintaining of EA maps is very easier comparing to traditional methods that is time consuming. Geographic information (GI) and GIS have become powerful tools for governments in assessing and implementing development goals. Therefore integrated statistical and geographical data provides information on the current economic and socio-economic situation in

any country and it is used at all levels for decision-making. Therefore, statistical offices are encouraged to take such advantages of using new technologies such as Geographical Information technology (GIT) and their tools that are easy to use and more cost effective if fully utilised at all level of planning and development for effective decision making by the planners and the policy makers.