# Geospatial Mapping and EA Database Management

* 1. **Introduction**

Cartographic mapping is a major activity conducted during the pre-enumeration phase to create Enumeration Areas (EA). Such maps are used for work allocation during census enumeration and for dissemination of geospatial referenced census data. Therefore, the quality of maps used in the census has a major influence on the quality and reliability of census data collected.

The mapping process involves the following activities: proposal development, mobilization of resources, development of tools, acquisition of equipment, publicity, piloting, recruitment, training, data collection, map production and EA map verification.

Accurately delineated EAs are essential to a successful population and housing census as they form the basis for field allocation of enumerators. However, this process can be very costly. Digital technologies offer opportunities to utilize tools and resources to reduce this cost and produce more efficient EAs, such as high-resolution satellite imagery to support the cartographic mapping. However, these digital tools also create challenges regarding the quality of mapping and the integration of maps into collection devices and data collection software. Digital mapping and cartography can also greatly increase the digital data storage requirements for a census, which has additional cost implications.

NSOs across Africa may face greater challenges in their geospatial mapping than those in other parts of the world due to limitations in the coverage and timeliness of information collected by national geospatial information agencies, including the lack of address registers. Another challenge may be the inaccessibility of some areas to allow for the creation of EAs and collection of census data (see also [Alternative Approaches](#_Alternative_Approaches)).

**Cartographic mapping during the non-digital vs digital era**

In the non-digital era, all the above activities were manually done on paper and were prone to human error and produced bulky papers for field teams to carry around. This approach limits the ability to explore location data throughout the design and implementation of the census, including in dissemination, but it also limits the usefulness of collection data as this cannot be integrated with the geospatial. The time needed to standardize, print and distribute paper-based maps is very resource intensive, both in time and money, and it reduces the re-usability of cartographic assets for other statistical and operational activities carried out by the NSO.

Digital cartographic mapping has a wide range of benefits including better quality products, reduced costs, and reduced time for development of EA maps, increased accuracy, and improved consistency etc. *(Handbook on geographic information systems and digital mapping, pg. 10-13).*

Digital cartographic mapping involves the use of digital technology for:

* map production which includes overlaying of spatial data collected in the field on satellite imageries/aerial photos, digitization of EA boundaries, preparation of EA maps
* EA map verification and quality assurance of EA delineation through either high-resolution satellite imagery or field operations by cartographers
* collecting spatial data (GPS coordinates for structures, households, features such as schools, hospitals, churches, etc.) from the field to be used in delineation of EAs
* Integration of cartographic mapping and EA boundaries into digital mobile devices used by enumerators during the census collection operation
* Integration of cartographic mapping into software monitoring collection progress during the census enumeration operation.
  1. **Considerations for digital cartographic mapping**

Transitioning to fully digital cartographic mapping for census requires NSOs to consider a number of factors and potential risks. It is first important to ensure that adequate GIS infrastructure is in place. This includes:

* A clear specification for the geospatial and cartographic data that is required from the mapping activities, including any geospatial layers
* Agreed access to the appropriate tools to carry out the digital cartographic mapping activity to the required precision, such as handheld devices equipped with Global Navigation Satellite System (GNSS) positioning technology, and/or a supply of licensed or open-source satellite imagery
* Appropriate and up-to-date GIS software
* Adequate digital storage and processing power to undertake the required digital cartographic mapping activities. This can either be physical serves or cloud-based storage
* Well-trained human resources as detailed in the manual on Geospatial Infrastructure in Support of Census Activities
* A clear understanding of how digital cartographic mapping software will integrate with the chosen data collection devices (such as the functionality and storage limitations of tablets), and the data collection software being used for the census (such as CSPro or Survey123)

During the 2020 Round of PHC, most African countries embraced digital cartographic mapping. Some countries conducted purely digital cartographic mapping where mobile devices and remote sensing products were used, while others embraced hybrid digital cartographic mapping.

This chapter points out selected country experiences, lessons learned and recommendations on what should be done during digital cartographic mapping. Areas covered include developing the proposal, pilot testing, publicity and advocacy, data collection, production, and verification of maps and issues regarding the mapping personnel.

* 1. **Development and implementation of digital cartographic mapping instruments and tools**

Among the tools developed for digital cartographic mapping there are various forms used for sensitization, field mapping activities, verification, instructions manuals, digitization schemas, map templates as well as map editing, map production and verification. In development and finalization of these tools and instruments, most countries benchmarked and got inputs and assistance from other countries that had undertaken digital census mapping. The cartographic tools should be able to assign a unique geographical coding and identification system to avoid any omissions.

**Defining geospatial products and the information collected**

It is important to define the attributes that will need to be collected as part of the digital cartographic mapping prior to commencing other activities relating to the geospatial aspects of census. This should be informed by what may be needed to inform the census enumeration operation (such as topographic or terrain features; the expected population density) or how statistics will be disaggregated in outputs. Knowing the intended output up-front guides the choice of the best application and the questions to use in capturing data.

The digital tools used to produce maps and to collect geospatial data, and how these integrate into other digital architecture used by the NSO for census and the budget for carrying out mapping activities should also factor into how these attributes are defined.

Prioritization of the most important cartographic features is important for ensuring the scale of the digital mapping undertaken does not get too great. The inclusion of many stakeholder requests risks changing the project from a typical cartographic exercise to a statistical undertaking. This potentially slows down the mapping exercise and affects the entire timing of the census activities.

**Pilot mapping**

Pilot mapping is recommended to test the preparedness to undertake the main cartographic mapping process. The aim is to test the validity and reliability of methodology, tools, and equipment to be used in the main cartographic mapping process. The findings from the pilot inform the finalization of tools, instruments, and methodology. The pilot mapping process entails testing the suitability of the tools, logistical arrangements, assessing the workload, providing a basis for NSOs to mobilize resources and plan for an effective implementation of the process to ensure quality data is obtained.

While planning for a digital cartographic mapping pilot, it is important to consider the terrain, type of settlement patterns (urban, rural, hard to reach, arid and semi-arid lands) to enable effective testing of processes. See also [Census Testing and Pilots](#_CHAPTER_SIX:_Census).

Using base maps or cartographic resources already available can assist this process. Working with geospatial authorities in the country to adopt best practice for tools and methods can also help with reducing the cost of pilot and field operation activities while not compromising on the quality. Where newer technologies and resources are being integrated into cartographic activities, such as the use of satellite imagery, pilot mapping should include some testing of the quality of outputs and if these meet assumptions regarding the production of EAs and other geospatial content.

**Publicity and advocacy for cartographic mapping**

Publicity and advocacy for cartographic mapping is done to create awareness of the activity and seek support for the main cartographic mapping and census enumeration. During publicity NSOs seek collaboration, support, involvement, and ownership of the grassroot stakeholders and local leadership. The roles and responsibilities of all the stakeholders are also established. See also [Advocacy, Publicity and Resource Mobilization](#_CHAPTER_ELEVEN:_Post-Enumeration).

**Field data collection for cartographic mapping**

Field data collection for digital cartographic mapping entails use of mobile technology to collect spatial data (GPS coordinates for structures, households, features such as schools, hospitals, churches, etc.) to be used in delineation of EAs. Most countries embraced the use of mobile technology to capture the spatial data and transmit it to the central servers for map production.

**Map production**

After the mapping data is collected and sent to the central servers, a team of GIS technicians are engaged to undertake digitization of the EAs (EA map production). During map production, the census geo-file is developed to be used during provisioning of tablets, enumeration, and geospatial data analysis.

Map production is implemented in two stages.

**Stage 1:** Digitization of village boundaries; delineation of EAs from village polygons; creation of the EA attribute data (geography File- geo-file); preparation of EA maps (map compilation) and printing of hard copy maps for editing and verification.

**Stage 2:** Effecting changes from field verification; updating the geo-file; preparation of the final EA map (PDF format); printing of final maps for enumeration.

Delineation of EAs should consider the distance and number of households to be covered by the enumerator within the stipulated census enumeration period.

**EA Map verification**

EA map verification is the process of undertaking field verification of the boundaries of the created EAs by the local administration before the maps are finalized for census enumeration. At the end of the delineation process, it is necessary to assess the accuracy of the maps, completeness of the mapping, household size and to verify EA boundaries. EA map verification is therefore aimed at reducing the EA boundary errors before the maps can be used. The verification process provides an opportunity to review, inspect, check, audit, establish and document whether EA maps reflected the actual situation on the ground.

* 1. **Selected country experiences**

**Namibia** focused its digital cartographic mapping on capturing detailed information about built-up structures and developing a Statistics Business Register and National Dwelling Unit Frame. The questionnaire gathered data on household heads, contact details, room counts, and access to services like water and electricity. The mapping application was built using ArcGIS Survey123, and a pilot exercise tested the tools and logistics. Public awareness was raised through flyers, posters, radio, and community meetings. The pilot results informed improvements in tools, planning, and resource estimation.

**Kenya** aimed to update its geographic files with detailed village and Enumeration Area (EA) data. Two household listing forms were used for rural and urban areas, collecting GPS coordinates and elevation. Initially, Open Data Kit (ODK) was used, but ArcGIS Survey123 was later adopted for its integration with map production and monitoring dashboards. A pilot tested devices, applications, and logistics. Publicity involved media campaigns and community meetings. Mapping teams were scaled up a total of 400 temporary mapping assistants in 40 teams with each team assigned specific areas. Data collection used mobile phones with GPS, and GIS technicians supported map production. The process included digitization, EA delineation, verification, and correction of errors, with 32% of EAs requiring adjustments.

**Sierra Leone** aimed to create a verified locality list with unique codes for all administrative levels. The mapping questionnaire captured building use, road types, and household details. A custom Android-based application, EA PAD 4.0, was developed by Milsat Technologies, integrating spatial and attribute data and functioning offline. The pilot mapping tested software, logistics, and field conditions. Public sensitization involved radio, community meetings, and local guides. Fieldwork included satellite imagery annotation, EA delineation, and data quality checks. Data was uploaded to a secure cloud system and processed using ArcGIS. No physical maps were printed; instead, a digital Census Pad application guided enumerators. Verification included ground trotting and system authentication.

**Senegal** built its mapping tools on previous census versions, refined through technical workshops and benchmarking visits. Tools were developed using ARCGIS and MOBAC. The cartography team included agents, team leaders, regional supervisors, and headquarters experts, each using a dedicated Android application. These apps facilitated task assignment, coordination, monitoring, and data collection, ensuring integrated management of census operations.

**Botswana** used SmartClient for Census, a web-based client-server solution with GIS architecture and a central database. It supported both online and offline functionality, enabling continuous work regardless of internet access. The system allowed real-time data synchronization and task execution by different users, streamlining data collection and management.

**Zambia** partnered with GRID3 to produce high-resolution gridded population estimates using a bottom-up modelling approach. This method integrated settlement data, building footprints, and population input data collected by the Government of Zambia. The resulting datasets provided population estimates at approximately 100-meter grid resolution, including breakdowns by age and sex. These estimates were used for microplanning in health interventions, such as malaria control and COVID-19 vaccination campaigns. The data also supported census planning and were made publicly available through GRID3’s Open Data Hub..

**South Africa** conducted its first fully digital census in 2022, using three data collection modes: face-to-face (CAPI), telephonic (CATI), and online (CAWI). To support this, Statistics South Africa (Stats SA) updated its Geo-Frame across all settlements, collecting data on dwelling units, addresses, and gatekeeper information. This update helped fieldworkers navigate enumeration areas and ensured accurate data collection. The digital census infrastructure included tools like the Digital Census Atlas and interactive mapping products, which allowed users to explore demographic data at various administrative. These innovations marked a significant shift toward integrated geospatial and statistical systems in South Africa’s census operations.

Link to case studies section

**Namibia**

Namibia aimed to provide detailed information regarding the use of built-up structures as well as develop a Statistics Business Register and the National Dwelling Unit Frame meant to provide detailed household and land use information for each Dwelling Unit.

The approach to questionnaire design focused on capturing the main elements relating to the use of a building and in the case of a dwelling unit, occupants were asked the name of the head of the household, contact details, the number of rooms, and the number of usual members residing in each dwelling unit including other basic services regarding the structure they reside in, such as the source of water, electricity, and access to sanitation. The inclusion of the many stakeholder requests changed the project from a typical cartographic exercise to a statistical undertaking.

The application used to collect, transmit, store and clean mapping data was designed and developed using ArcGIS -Survey 123 by Esri.

The main objective of the pilot mapping exercise was to test whether the mapping tools (electronic data collection application and questionnaire) were adequate to provide the required data. This also involved testing the adequacy of logistics and administrative arrangements on the ground.

The results from the pilot mapping were used to review and improve on the mapping implementations in all operational areas. These included reviewing of tools, drawing up the final plans for the main mapping project, as well as providing the final estimation of resources required.

A Communication Plan focusing on advocacy and publicity of the mapping was developed. The most convenient method used was the distribution of flyers and displaying of posters to create awareness. Engaged community leaders through meetings and had the opportunity to elaborate on the objectives of

the census mapping. Mobilization was done in each selected EA before commencement of data collection exercises to ensure that local people were aware of the project and what was expected of them. Courtesy visits to constituency and local councilors were also undertaken to introduce the exercise and request them to inform their constituency inhabitants about the exercise during their respective radio announcements and community meetings. In addition, FM Radio announcements, local newspapers, television, and specific talk shows among others to announce the commencement of fieldwork.

**Kenya**

**Kenya** aimed to update her geography file for all counties and sub-counties with villages and Enumeration Areas as well as number of households.

Two household listing forms were developed: rural homestead and household listing form (F-54-5-1A and F-54-5-1B) and urban structure and household listing form (F-54-5-2) used for collecting data in rural and urban areas respectively, both collected the GPS coordinates for each household and their elevation. In addition, there was a summary form F-54-5-1A used by village elders while F-54-5-1B used by the data collection teams to compile villages and Enumeration Areas.

The Open Data Kit (ODK) a free application was used to develop and test the mapping data collection system and later the ArcGIS-Survey 123 app managed by Esri- Eastern Africa was adopted after being tested and piloted. Although ODK was easy to operate, compatible with Samsung J2 and freely available in play store, Survey 123 was introduced because it was faster to process the data in the ArcGIS environment being used in map production. Survey 123 also provided a dashboard for monitoring teams and individual MA’s. After completion of a village or block the MA would edit and upload the data to the cloud server.

The technology and instruments/tools embraced were tested before the actual cartographic mapping exercise. A pilot mapping exercise was conducted to identify the most ideal tablet for use especially one with high GPS accuracy- Samsung Galaxy J2 phone was identified as having accurate GPS readings; tested the Open Data Kit (ODK) application; tested the use of Satellite imageries and aerial photographs which were used for planning and allocation of work, plotting of boundaries and features; tested the adequacy of the data collection forms; tested the suitability of the KNBS Server and entire ICT system in undertaking the digital cartographic mapping. The pilot was also used to ascertain the type of and number of vehicles to be used as well as the resources that could be required to undertake cartographic mapping in the entire country.

The publicity and advocacy for the cartographic and mapping exercise was cascaded and done through the print media, radio, TV, social media and holding physical community mobilization meetings for the local administration who were in turn to hold community level sensitization meetings. Sensitization of the local administrative leadership was done by NSO staff sensitizing the local administrative officers in each county. The sensitization meetings were held, and the administrative officers were taken through the importance of census and the activities involved in the census process, inform how the village elders were to fill the mapping form 1 provided to them in the rural villages. Due to lack of clear understanding of mapping concepts in Kenya, there was a variance in number of villages provided and the actual number of EAs during the sensitization exercise.

In Kenya, the exercise started with 12 teams with each team comprising of a team leader and 7 mapping assistants. There were also coordinators in charge of several teams. The number of teams was later increased to 40 with a total of 400 temporary Mapping Assistants (MAs) who were recruited and trained to speed up the mapping process.

A team was allocated between 2 and 3 vehicles depending on the number of MAs. All teams were working either in one or two counties at a given time. A team was allocated several sub locations to map the homesteads, structures, households, and points of interest. Each MA was assigned a village or a block to work in at any given time and they would move around the entire village with the help of a village elder. The MA would use the form earlier filled in by the village elder to confirm the details listed and pick coordinates for the structures, households, and features. Data was collected using mobile phones with an in-built Global Positioning System (GPS).

Mapping for the first 27 counties was carried out using Open Data Kit (ODK) App while the rest were mapped using ArcGIS survey123.

A team of GIS technicians were recruited to support the GIS team in undertaking map production.

**Stage 1**

• Digitization was carried out by first downloading the spatial data collected from the cloud server. ArcGIS software was used to overlay spatial data on satellite imagery for rural areas or aerial photographs for urban areas. The data would be symbolized by village name to determine the extent of a village. Digitization of village boundaries was guided by already generated schema.

• Delineation of EAs was done based on measure of size which is between 50 and 149 households making an average of 100 households. A village with more than 149 households was subdivided to create more than one EA whereas one with less than 50 households was merged with another next to it. An EA was therefore either part of a village, an entire village or several villages combined.

• The EA polygons were cleaned by creating topologies to show where overlaps and gaps exist. Each EA was described by its administrative and political units, type (rural or urban), status (informal or formal) and universal (special or conventional). The information was added on the EA polygons attribute table to create the census geo-file.

• A 13-digit code was generated from administrative units to uniquely identify each EA. Maps were prepared using templates generated during development of tools. Two maps were created, a sub-location map with all the EAs or several EAs in that sub-location and every individual EA map.

**Stage 2**

• The maps were printed for editing guided by the editing forms and later printed for use during verification. Rural maps were printed on A3 size paper while urban maps were printed on A2 size paper.

• Maps returned from verification were returned to map production for the GIS technicians to effect changes from the field. After effecting the changes, final PDF maps and geo-files were forwarded by counties to uploaded on the tablets to be used during census enumeration.

• Hard copy maps were also printed for training and EA identification.

The EA map verification exercise was undertaken by trained verification officers and coordinators who worked with the National Government Administration Officers (NGAO) with a collective role of confirming that all the maps and geo- file for their respective administrative units were available and that they were in their correct geographic locations and had correct spellings. During verification, several NGAOs were brought together.

Additionally, the verification process identified missing features/facilities, spelling mistakes, confirmed the number of villages and boundaries, etc. The key tools were therefore the sub-location map and geo- file. The exercise started after several EA maps were produced for several counties. It was conducted in phases where in each phase several counties were covered.

Verified maps and verification forms were forwarded to the map production office to effect the changes documented before final production of maps. Major errors noted during verification included: spelling errors, wrong village/EA naming, incorrect EA numbering, disjointed/fragmented (Flying) villages, omission of features, gaps where some households had not been mapped, unclear boundaries, incomplete naming of features. 32% of the EAs had one or more of the above errors.

**Sierra Leone**

**Sierra Leone** aimed to achieve a verified and categorized nationwide locality list of all administrative levels showing the name of each locality, district, chiefdom, and section with a unique code.

The cartographic mapping questionnaire was developed to capture information on, building use, locality class, classes of roads, water bodies and expected drainage type etc. The questionnaire was mainly designed to enable the head of the household to give information about the structure and number of members in the household. Other information was obtained using observation methods by the field staff.

An android-based mapping PAD application with a data acquisition package was built by Milsat Technologies to be used for the cartographic mapping exercise to fit all the data needs in a robust manner. The application was able to prompt the mapper when it reaches a minimum threshold of an EA to be delineated. It also ensured that the mapper is within the confines of the structure wanting to collect information about as seen on the satellite imagery. The application integrated both the spatial dataset and the data attributes collected on the same platform. The application has provision to work both offline and online that ensured that work is continuous even where there is no internet coverage. These innovations made it possible to achieve a sustainable national geographic frame for Censuses and Surveys.

The pilot mapping was done in two phases and the section administrative boundary shape file was used:

- The first phase was done in the capital city to: assess the cartographic mapping software EA PAD 4.0 and the means of data transmission; assess the use of ARCGIS software in processing the data from EA PAD 4.0 for EA delineation; test the entire systems and processes including logistical requirements, deployments, average time spent to complete an EA in both rural and urban areas; and identify likely problems to be faced by mappers in the field.

- In the second phase, the coverage was increased beyond the capital city with diversified prevailing conditions including hard to reach areas and poor internet connectivity. Three sections were randomly selected across the country.

the Communication and Publicity division within the NSOs led the campaigns to sensitize and educate the public on the need to cooperate and support the mapping teams before the start and during the cartographic mapping process. The key tools used included Community sensitization meetings, radio discussions in both local and national languages, use of megaphones, providing local guards by the communities as part of the process to lead field staff for hard-to-reach areas and ensuring all communities are reached.

In Sierra Leone, the actual field work started with annotation of Satellite imagery, updating of verified locality list, deployment of field staff with required logistics and delineation of EAs using the satellite imagery.

The Data quality assurance officers and Assistants were busy with the required quality checks. The National quality officer was supervising all the quality assurance officers also used a customized application to ensure that data from the field mappers shows a true representation of the real information on the ground and in addition do ground trotting for randomly selected delineated EAs.

• Mappers were in the field collecting data and creating temporary Enumeration Area boundaries and saving the data into the cloud. The GIS Officers and assistants who were in the respective District Offices downloaded data as sent from the field via google cloud. The EAs were digitized and delineated using ArcGIS Mapping software tool.

• The mapping PAD remote submission process utilizes a top-level security cloud system to scan and safely deliver uploaded tasks to GIS portal. GIS portal can only be opened by registered and verified GIS Officers.

• No physical maps were printed for actual census enumeration instead a Census Pad application was used with online resources like Open Street based on cartographic enumeration area boundary shapefiles, and the spatial data collected. These facilitated the census staff to locate their Enumeration areas without hard copy maps.

The verification process was followed up with a ground trotting exercise. To ensure that only accredited functionaries use the App, the mapping PAD periodically runs system authentication on every phone the App is installed.

**Senegal**

The design of the Mapping tools was a build up from versions of the previous census. They were finalized in technical workshops and benching marking at INECV Cape Verde (for Cartography) and INSD Burkina Faso (for enumeration).

The software used for development of the RGPH-5 Mapping tools were: ARCGIS and MOBAC

The cartography team included: mapping agents, team leaders, regional supervisors, and headquarters experts. Each of these had a functional mobile application under Android set up centrally for an integrated management of census operations. The supervisor application was used to ensure coordination and monitoring of field operations. The regional supervisor application was used to manage team composition, assign work, check completeness, and send to the server. Team leader application allowed the team leaders to assign tasks to team members and coordinate field work. The cartographer agent application was used to carry out cartographic data collection on the localities.

**Botswana**

SmartClient for Census a WEB-based Client-Server software solution was used to collect, transmit, store and clean mapping data. SmartClient for Census enables different users to log into the system to execute tasks allocated to them and has GIS architecture with one central database for office and field work, which ensures easy access to data. This ensured that through unique workflows the data capturing was viewed and managed as soon as data was synchronized into the server and field work was ongoing. SmartClient for Census also has online and offline functionality, that ensured that work is continuous even where there is no internet coverage.

**Zambia**

Zambia partnered with GRID3 to produce high-resolution gridded population estimates using a bottom-up modelling approach. This method integrated settlement data, building footprints, and population input data collected by the Government of Zambia. The resulting datasets provided population estimates at approximately 100-meter grid resolution, including breakdowns by age and sex. These estimates were used for microplanning in health interventions, such as malaria control and COVID-19 vaccination campaigns. The data also supported census planning and were made publicly available through GRID3’s Open Data Hub.

**South Africa**

South Africa conducted its first fully digital census in 2022, using three data collection modes: face-to-face (CAPI), telephonic (CATI), and online (CAWI). To support this, Statistics South Africa (Stats SA) updated its Geo-Frame across all settlements, collecting data on dwelling units, addresses, and gatekeeper information. This update helped fieldworkers navigate enumeration areas and ensured accurate data collection. The digital census infrastructure included tools like the Digital Census Atlas and interactive mapping products, which allowed users to explore demographic data at various administrative levels. These innovations marked a significant shift toward integrated geospatial and statistical systems in South Africa’s census operations.

* 1. **Challenges and lessons learnt**
* When balancing stakeholder requests, be sure to prioritize what is needed for census and be realistic about what the available tools allow.
* There is a need to provide clear guidelines on the definition of villages and EAs during the sensitization meetings and for the mappers.
* Illiteracy of village elders made training and signing of documents difficult and time-consuming during sensitization meetings in Kenya.
* Fragmented and disputed administrative units make it difficult to determine the village boundaries, therefore this needs to be addressed before the mapping teams get to the respective villages. Otherwise, this can lead to failure in identifying some boundaries and creation of overlapping boundaries which should be explicitly avoided for all the areas across the country.
* The introduction of new mapping tools midway through the exercise slowed the fieldwork because some mapping assistants could not cope with the changes immediately. This implies that early determination of the end products and testing of all the possible applications is vital.
* Unclear definition and demarcation of boundaries between urban and rural EAs made it difficult to get accurate data.
* Lack of prior planning for mapping of mobile populations like nomads and pastoralists, who can be missed or double counted.
* NSOs did not plan for adequate server space to accommodate the arising huge geo spatial data.
* There was insufficient planning about the required number and quality of editing personnel for map production.
* The GIS licenses to enable map production were either unavailable, expired and yet too costly.
* There was a lack of sufficient computer machines with adequate processing capacity.
* In most cases, the map production process started late causing delays in concluding the mapping phase.
* New administrative units may come up after mapping and these interfere with the geo-file, several points of interest were missed out by the mapping assistants therefore not reflecting the actual picture on the ground.
* Insufficient communication given to the community leaders during sensitization led to having absent Chiefs and Assistant Chiefs that made verification of their area maps difficult because the team had to make alternative arrangements to use other people or come back later.
* Allowances for some levels of NGAOs were not factored in the census payment guidelines and rates therefore created a challenge on how to compensate them when they attended the verification meetings. This calls for comprehensive planning and budgeting along the mapping business process.
* Politics and insecurity can affect map verification: political and partisan interests on the ground tended to interfere with the workflow. Insecurity in some areas led to the team requiring special security arrangements that necessitated rescheduling of the programme.
* Illiterate administrators in some areas made interpretation of the map and geo-file difficult.
  1. **Recommendations**
* Given the existing internet challenges in some parts of the continent, the choice of software should take into consideration the ability to work both online and offline.
* Benchmarking with countries that have already undertaken digital cartographic mapping is key in informing the mapping methodology and especially the choice of software.
* Countries should develop their mapping tools and applications using internal capacity at the NSO like in Kenya, Namibia, Uganda among others especially with the choice of simple and tried software such as ArcGIS-survey 123 with minimal support from Esri.
* The use of open-source software should be explored given that it proved to work and saves on costs. e.g. SmartClient that was used in Botswana saves on costs.
* Have a clear selection criterion of who should be part of the sensitization meetings, usually the most influential persons in the community are ideal and use trainers/facilitators who are conversant with the local language of the community so that they can translate the message and not use English to avoid any information loss.
* There is a need to provide timely communication for sensitization meetings to reduce absenteeism of community leaders due to poor cellphone network and short notices.
* During recruitment, adequate reserve mapping assistants should be recruited to stand in when those engaged exit given that the exercise takes a long period.
* Cascading and segmenting the mapping application among the field teams with their respective duties is a good practice to ensure quality control.
* It is important to have a field work manual and instructions for mapping assistants with clear definitions of concepts especially the delineation between urban and rural EAs.
* Clear cartographic mapping plans should be put in place for mapping of mobile populations like nomads and pastoralists otherwise, they can be missed or double counted.
* Collecting accurate GPS coordinates for the structures, households and features during the mapping is a good practice to ensure completeness and enhance spatial data analysis. However, it may slow down the mapping exercise during times when the internet is unstable due to weather etc. Therefore, mechanisms should be put in place to control for displacement of GPS coordinates because of tall buildings and congested structures especially in urban centers.
* It is recommended that proper training and supervision of mapping assistants should be done to avoid the creation of gaps that could delay completion of delineation of EA boundaries.
* NSOs should plan for adequate server space to accommodate the huge geo spatial data such as satellite imageries and aerial photographs.
* There is a need to plan for adequate editing personnel to avoid delaying the EA map editing process.
* NSOs should opt for opensource software as much as possible or plan for adequate GIS licenses and workstations to facilitate faster digitization process.
* NSOs should purchase adequate computer machines with adequate capacity to process the complex and huge geospatial data.
* It is important to start map production in time to enable earlier finalization to inform other census processes.
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