The Usefulness of Geo-referenced Dwelling Frames for Census Cartography during the 2010 Round of Population and Housing Census in Africa

United Nations
Economic Commission for Africa

The Usefulness of Geo-referenced Dwelling Frames for Census Cartography during the 2010 Round of Population and Housing Census in Africa

Ayenika Godheart Mbiydzenyuy1, Andre Nonguierma2
1 Economic Commission for Africa (ECA), African Centre for Statistics, Addis Ababa, Ethiopia
e-mail: AGodheart@uneca.org.
2 Economic Commission for Africa (ECA), African Centre for Statistics, Addis Ababa, Ethiopia
e-mail: ANonguierma@uneca.org.

Ordering information

To order copies of ***The Usefulness of Geo-referenced Dwelling Frames for Census Cartography during the 2010 Round of Population and Housing Census in Africa***, please contact:

Publications Section
Economic Commission for Africa
P.O. Box 3001
Addis Ababa, Ethiopia

Tel: +251 11 544-9900
Fax: +251 11 551-4416
E-mail: ecainfo@uneca.org
Web: www.uneca.org

© 2017 Economic Commission for Africa
Addis Ababa, Ethiopia
All rights reserved
First printing May 2017

Material in this publication may be freely quoted or reprinted. Acknowledgement is requested, together with a copy of the publication.

Designed and printed by the ECA Documents Publishing Unit. ISO 14001:2004 certified.
Cover photos: © Shutterstock

Abstract

The building of dwelling frames to serve as the basis for creating enumeration areas for surveys and censuses, where every building is marked by a unique geographic coordinate, is a relatively new concept in Africa as far as census cartography is concerned. The cartographic exercises of previous rounds of censuses in Africa relied much on the traditional census cartographic method. The approach to developing geo-referenced dwelling frames by some African countries in the 2010 round, has drastically changed census cartographic methodology in areas including, and not limited to: the use of mobile devices, satellite imagery and Global Positioning System; sampling frames, address register and field verification methods. The enumeration area demarcation, office demarcation, office updating and office corrections as well as distinguishing settlement types and differentiating enumeration areas has improved.

The present paper aims to raise awareness of the benefits of dwelling frames in dealing with timeliness and data quality issues, which will encourage and provide the basis for policy dialogue on the use of the technology between decision makers, geospatial information specialists, and other stakeholders. It will eventually enhance the use of census cartographic goods and services, which will improve the quality of data that are generated from censuses and surveys.

Keywords:

Census cartography, geo-referenced dwelling frame, address register system, Global Positioning System, geographic information systems, remote sensing, enumeration area, population and household listing.

1. Introduction

During the previous rounds of censuses in Africa, several errors were identified in the census monitoring and evaluation exercises conducted by the countries. Those errors included aspects such as coverage, and omissions or duplications of persons or housing units during census enumeration. The main sources of coverage and other pitfalls noticed were: incomplete or inaccurate list of dwelling units within enumeration areas; incomplete, inaccurate, or no census maps; failure by enumerators to cover all dwelling units in their work assigned areas; and duplicate counting and census mappings that were conducted on an ad hoc labour-intensive basis with the use of hard copy sketch maps. As a result, there had been inaccuracies and incompleteness in the maps needed for enumeration. Those shortcomings had prompted many countries to develop better strategies that aimed to improve census results. During the 2010 round of the population and housing census, several African countries had opted to use the Global Positioning System (GPS) and remote sensing data. The reason being, to capture the location of residential buildings in order to create dwelling frameworks that enabled the identification of dwellings and the development of enumeration areas in support of their various census operations (UNFPA-SPC, 2012).

2. Background

There are a lot of challenges relating to housing census activities in Africa. This section outlines, among others, the most obvious challenges.

2.1 Lack of standard address systems

During the previous census cartographic exercises, it was noticed that most countries in Africa lacked the address register system, which made census enumeration difficult. The creation of a geo-referenced dwelling frame with a register system, prepared countries to better monitor census operations and ensure that all dwellings in the country were covered during enumeration. In accordance with the mandate of official statistical organizations, an efficient address system is important in the provision of services, collection of statistics, and conducting censuses and surveys.

A register system must be linked to the mapping of enumeration areas – which are the smallest areas currently used in the collection of population data, and in each country. The settlement types will determine the type of enumeration area to create and address system to develop. There are different settlement types in the Africa setting, such as urban (formal) areas with a structured format of addressing; informal areas, which are unplanned settlements; traditional areas, having unstructured settlements and farm areas (Mercy, 2005).

2.2 Insistent cadastre coverage and referencing system

Developing a comprehensive registration system in urban Africa has been very challenging as most streets have no names, especially in the urban core area and sprawl settlements. There has also been the problem of mismatch of parcel identifications and property titles in the cadastral plan. Cadastral maps, which had been done at different times, also have inconsistent characteristics such as referencing systems. The lack of common standards has made data integration difficult, at a national level. The different settlement types in the urban areas require the collection of different information. Subtypes of urban settlements include individual plots, security villages, high-rise flats, town houses, institutions, central business district, industrial, and premises and recreational areas (Mercy, 2005).

Closely related to poor cadastre data coverage and referencing is the fact that most neighbourhoods in the informal sector are not officially planned, surveyed or proclaimed, and are usually not found in detail, or at all, on conventional town cadastre maps. These areas do not have official address systems and in most cases, do not have streets, and dwellings are haphazard. Some areas may seem to have an orderly network of streets and sequentially numbered dwellings along the streets, but as this level of planning is unofficial, no records of the individual structures or stands exist in the Surveyor General's office (Basson, 2008).

2.3 Poor data management capacities

Many areas, especially the rural communities, have data in different formats and stored in varying platforms. Numbers are not captured in a single database or on a digital database, and are not fully visible. One structure carries a multitude of numbers assigned by individual service providers. Numbering is only updated or maintained as a service provider identifier. Large areas for commercial farms may have a registration number, name and exact boundaries; and additional information such as ownership and subdivisions, also exist. However, the numbers used are land parcel numbers, which have no chronologic order.

The other problem is that the farms tend to be very large, and the numbers are not visibly displayed, which makes it difficult to identify one farm from the other. Also, small villages exist within the larger farm, where several workers and their families live permanently – this should be seen as a separate entity but at present, is considered under the parent farm. Traditional areas show

various data collection designs, and thus have different approaches of data storage and data access. These data sets are mostly out-dated as the picture on the ground has changed over time and are therefore not an accurate representation, (Mercy, 2005).

2.4 Low capacities to utilize appropriate technology

During the 2010 round of the population and housing census, few African countries such as the Gambia, Lesotho, Mauritania, Namibia and South Africa, developed dwelling frames as part of the census cartographic phase. Although the use of digital imagery and GPS has a distinct advantage in allowing the linking of geographic coordinates to physical location of dwellings, the mapping of dwellings had several limitations that required investigation. A lot of mistakes were recorded in data capture due to low proficiency in the use of GPS devices used by the field teams. There were several redundant points collected alongside with the real data because of human errors.

Also, the GPS waypoints coding system posed problems in countries where enumeration area maps were created before the development of the dwelling frame that noticed the occurrence of errors when the cartographers overstepped the enumeration boundary of the area that was allocated for mapping – overstepped the boundary by mistake or provoked by the poor accuracy of the GPS device used. Accordingly, the GPS waypoints captured adjacent areas into a different enumeration area, while the associated households belonging to a different enumeration area were incorrectly listed on another area household list.

In other countries, satellite images were used to capture and generate dwellings geo-reference data. This data was loaded into the GPS devices, and the cartographers had to retake these points in the field after identifying that the dwellings were inhabited. Other attribute data were recorded into the devices before the information was downloaded. In the office, written scripts were used to combine the double GPS points per inhabited dwelling into one. On the one hand, the whole process was time consuming and prone to errors, as closely collected GPS points of different dwellings were mistakenly swapped to represent each other. On the other, the advantage in that system depended on the fact that the speed of the fieldwork operation could be monitored as the dwelling frames were developed.

Countries also used the mobile GPS tool to collect dwelling frame data. The advantage in using the tool lies in the fact that vector and raster data, and attribute data can be downloaded into the GPS receivers. A pen is used to generate GPS points representing dwellings and other infrastructures. This system is beneficial as the error level due to poor accuracy is minimal, as the pen can generate geo-reference points by clicking a position with exact location inside the map, as displayed in the monitor of the receiver (SPC–HOPS, 2010).

2.5 Poor management of households count

The listing of households in the enumeration areas has been noted for being time-consuming in the census cartographic process. The listing process is often done in a clockwise or anti-clockwise manner; this can be done simultaneously with the development of dwelling frames in the field. The field teams have to geo-reference dwellings and other infrastructure found in the field, while at the same time, estimate the number of households in the dwellings and determine the total number of individuals living in these households – these figures are eventually used to carve out enumeration areas for both rural and urban areas.

The GPS receivers help in reducing the burden of using paper booklets containing lists of addresses or building descriptions along with a unique dwelling code, entered manually by census cartographers. At each residential building, the cartographers using the GPS devices would press a button on the receiver to acquire a positional fix as close to the front door as possible. The coordinates would be stored in the receiver's memory. The census representative would then be prompted to enter a three or four digit household number, to be associated with the building coordinate and other attribute information. However,

this is also fraught with a number of errors, which include poor data migration from the GPS to the computer system, and lack of consistency in data collection with the GPS.

Though it was expected that the uploaded data would allow supervisors to monitor progress, and serve as the eventual control file for measuring the return of questionnaires during the proper census, the mistakes made on the field make it difficult for the supervisors to tag questionnaires with the GPS field data. Also, weather conditions affect the accuracy of data collected through the GPS (Namibia Statistics Agency, 2012).

2.6 Difficulty in dealing with scattered settlements

Conducting a dwelling framework for a population scattered over a vast desert or forest territory is a laborious and very costly operation. The difficulties are compounded when it comes to a nomadic population that is in constant movement over immense territory and sometimes beyond the country's administrative borders. With regard to the behavioural pattern of the nomadic population, developing a geospatial list will succeed if the following conditions are fulfilled:

a) In desert environments, water points frequented by nomads throughout the national territory should be identified with geographic coordinates;
b) Transhumance corridors for animal movements are crucial during the census mapping operation and should be identified with geographic coordinates.

The difficulty here, is to locate and geo-reference the dwellings of a nomadic population. Using the GPS for mapping of dwellings in urban squatters and slums has been troublesome, because of settlement density and the problem of accurately positioning compact buildings. Even when satellite images are used, roofing materials of slums are often confused with markets and light industrial activity zones. Urban squatters and slums take a long time to be mapped when dwelling frames are to be developed – the listing of households is difficult as most dwellings have more than one household that use the common facilities, such as kitchens and toilets (Mbiydzenyuy, 2010).

During the 2010 census round, several conflict zones were mapped. Those areas preoccupied census planners, and several strategies were developed to map those zones. Satellite imageries were used in areas of intense conflict activities to identify and map dwellings for household identification and enumeration. The security of the cartographers and enumerators is often regarded as a priority, and maps actually help to effectively plan for these operations and guide enumerators in the field (Laldaparsad, 2007).

3. Objectives

3.1 Central objective

The overall objective of the study is to carry out an assessment on the use of geo-referenced dwelling frames for census cartography in the 2010 round of population and housing census in Africa, with the aim of guiding policies and decision-making concerning the use of the technology for enhancing the quality of data generated from censuses and surveys.

3.1.1 Specific objectives

The specific objectives of the study are to:

a) Identify the challenges associated with the current methods for developing dwelling frames for census in selected African countries;

b) Determine the new methodology for developing dwelling frames aimed at creating an address register system and the carving out of enumeration areas;

c) Establish the differences between the new and old methods for carving-out enumeration areas;

d) Assess the similarities between the new and old methods for carving-out enumeration areas;

e) From the above, propose a strategy for developing a geo-reference dwelling frame for census cartography for the subsequent census rounds in Africa.

4. Methodology

This is a cross sectional study which investigates countries that used the geo-referenced dwelling frames in the 2010 census round in Africa. Accordingly, the methodology adopted was principally to analyse the content and context of different relevant reports, and reports of missions and interactions with the technical officers on the ground, for the selected census programmes in Africa.

4.1 Scope, data collection and data analysis

The scope of the study was the entire African continent with 54 countries. From this, the 47 countries that undertook the 2010 census round were all selected. From those countries, the five countries that had used the dwelling frame in the 2010 round of population and housing census were conveniently selected.

During the advisory missions of the Economic Commission for Africa (ECA) in support of census cartographic programmes, the researcher visited two of the five selected countries – Namibia (from 9 to 18 January 2011) and Mauritania (from 5 to 9 March 2012). Reports from those field missions were used to analyse the effectiveness in the use of dwelling frames for census mapping. Census cartographic reports from the national statistics offices of the remaining countries (the Gambia, Seychelles and South Africa) were used for the analysis.

Between 2010 and 2013, the researchers visited Botswana, Cameroon, the Democratic Republic of the Congo, Djibouti, Mauritania, Namibia and Senegal, through the technical field mission programme of the ECA office – the African Centre for Statistics on census cartography and data processing. During those visits, census cartographic data were collected from national reports and other supporting documents from responsible agencies in the countries. The content analysis technique was performed on the reports and anecdotal documents to identify similarities, and lessons learned from the selected countries. Some of the reports that were content analysed included:

a) Reports of ECA advisory missions and country specific reports on census methodology;

b) Reports of ECA advisory missions and country specific reports on establishment demarcation, re-demarcation, updating and correction of the census dwelling frame;

c) Reports of ECA advisory missions and country specific reports on the concepts and definitions used in census cartography;

d) Reports on strategy for putting in place a geo-reference dwelling frame for census cartography for the 2020 census round in Africa.

Other primary data were collected through interviews, focus group discussions, observations and documentary analysis. The in situ data sets collected through the above methods, were also content analysed to identify processes and strategies adopted by the selected countries.

5. Results and discussion

5.1 Challenges of the current census methodology in African countries

According to the findings, countries such as the Gambia, Namibia, Seychelles and South Africa, had enumeration area digital data sets generated from hard copy maps of previous censuses (see table 1).

Table 1
Current census methodology

Countries	Similarities	Differences	Traditional census cartography (selected countries and Africa)
The Gambia, Mauritania, Namibia, Seychelles and South Africa	The Gambia, Namibia, Seychelles and South Africa had EA digital data sets.	Mauritania had to develop a new EA digital data set	The Gambia, Namibia, Seychelles and South Africa had to scan geo-reference and digitalized EAs used in their previous censuses
EA updating	EA updating methodologies for the Gambia, Namibia, Seychelles, and South Africa consisted of EA boundary modifications and updating using fundamental data sets The fieldwork exercise for the creation of the geo-referenced dwelling frame, which included verifying or updating EA boundaries and capturing new information, has been completed	Creation of new EAs and capturing dwelling frames in the EAs.	Hand designs of EAs were carried out – the delineation of boundaries was difficult as natural and human features were rarely used to carve out EAs. Each census required the complete cartographic exercise of drawing new maps; countries lacked digital data sets that could easily be updated

Note: *EA – enumeration area.*

The methodologies developed for updating the enumeration areas by the Gambia, Namibia, Seychelles and South Africa, were almost similar. The area boundaries were modified after fundamental data sets were updated with satellite imagery being used as a back drop. The fieldwork exercises for the creation of the geo-referenced dwelling frame included, the verification, updating of enumeration area boundaries, and the capturing of new information. The differences were noticed when Mauritania had to develop a new enumeration area digital data set for the entire country. Those methods indicated a departure from the traditional census cartographic method in which hand designs of enumeration areas were used in the delineation of boundaries. The method made it difficult for natural and human features to be used in carving out the areas. Each census required the complete cartographic exercise, which involved the creation of new maps as countries lacked digital data sets that could easily be updated.

Due to the fact that most censuses conducted before the 2000 round had used the analogue method of carving out enumeration areas, most countries that conducted the census in the 2010 round lacked a digital spatial database for updating. Many countries had to scan geo-reference and digitize the old census EA maps. The digitized maps had several limitations in terms of accuracy, correctness, reliability etc., and rectifying those maps required a lot of human and financial resources. According to the Gambia Bureau of Statistics (2008), with using new technology, a new methodology had to be developed to better update the current data set.

5.2 Imagery coverage and base map

High resolution satellite and photogrammetry imagery were used by the Gambia, Namibia, Seychelles and South Africa (see table 2). Mauritania did not use high resolution satellite imagery in developing the geo-referenced dwelling frame, and as far as the traditional census cartographic method was concerned, no imageries were used – with major landmarks indicated manually on paper maps, which made utilization difficult and led to several errors.

The Gambia, Namibia and South Africa all found discrepancies and inefficiencies in the following areas: the desired area of coverage; the types of base imagery; obtaining quotes and determining cost; and the ordering, receiving, processing and storing of imagery in appropriate format steps. As a result, those countries were faced with limitations in the implementation of their census programmes.

5.3 Creation of an accurate geographic frame

The Gambia, Mauritania, Namibia, Seychelles and South Africa had similarities in that their enumeration areas represented the smallest building block of the geographic frame (see table 3). The enumeration area boundaries had to be corrected in order to fit the corresponding features on the imagery, and the collected data from the field. Since the current enumeration area and administrative boundaries were derived from old topographic map sheets, the accuracy was not sufficient.

In Mauritania, the cartographers in the field clearly identified the lowest administrative units and carved out the units as geospatial digital polygons. A combination of those units built up the entire administrative hierarchy and the urban and rural limits of the country, and the enumeration areas were carved out following those established limits, which permitted for data disaggregation (by geography) to the lowest administrative division.

Table 2
Imagery coverage

Countries	Similarities	Differences	Traditional census cartography (selected countries and Africa)
The Gambia, Namibia, Seychelles, and South Africa	High resolution satellite and photogrammetry imagery were used by the Gambia, Namibia, Seychelles and South Africa	Mauritania did not use high-resolution satellite and photogrammetry imagery	No imageries were used – with major landmarks indicated manually on paper maps, which made utilization difficult and led to several errors

Table 3
Creation of accurate geographic frame

Countries	Similarities	Differences	Traditional census cartography (selected countries and Africa)
The Gambia, Mauritania, Namibia, Seychelles and South Africa	EAs represented the smallest building block of the geographic frame EA boundaries had to be corrected in order to fit the corresponding features on the imagery and the collected data from the field	EAs were developed in accordance with the different administrative set-ups in the different countries. That respected the census tabulation plans developed by those countries	Field verification, with regard to the accuracy of the frame, was rarely conducted as the hand drawn maps made it difficult to verify errors. At present, it is easier to use satellite images and GPS technology to verify the geographic frames created

5.4 Field verification

In Mauritania, the necessary selected spatial data layers were transferred to the GPS personal digital assistant (PDA) devices, using the transfer software – manager for Windows mobile devices – which helped to accomplish the field verification and data collection tasks. The methods for estimating the population involved assessing the population of each locality through a complete enumeration of all housing units in the localities. The cartographic agents carried out a house to house evaluation of the population, asking how many people usually resided in the dwelling, and that information was immediately captured into the mobile geographic information system (GIS) environment (see table 4).

In addition to cartographic, the census mapping operation was an opportunity to collect a range of rich and varied information on socioeconomic, infrastructure and community facilities. To that end, several questionnaire forms were designed to support the collection of that information. The following information were captured through the questionnaire ***form e.*** Questions on locality, which included: the geo-referencing of the locality; name of locality; primary and secondary languages; economic activities; types of infrastructure; and estimated population of the locality.

The data on infrastructure provided information on features and detailed specifications on the infrastructure at each location. Additional information included: location locality; code of locality; category of infrastructure and type of infrastructure; name of the infrastructure; and state of the infrastructure.

Sheets on water points were intended to identify key information and feature a water point aimed

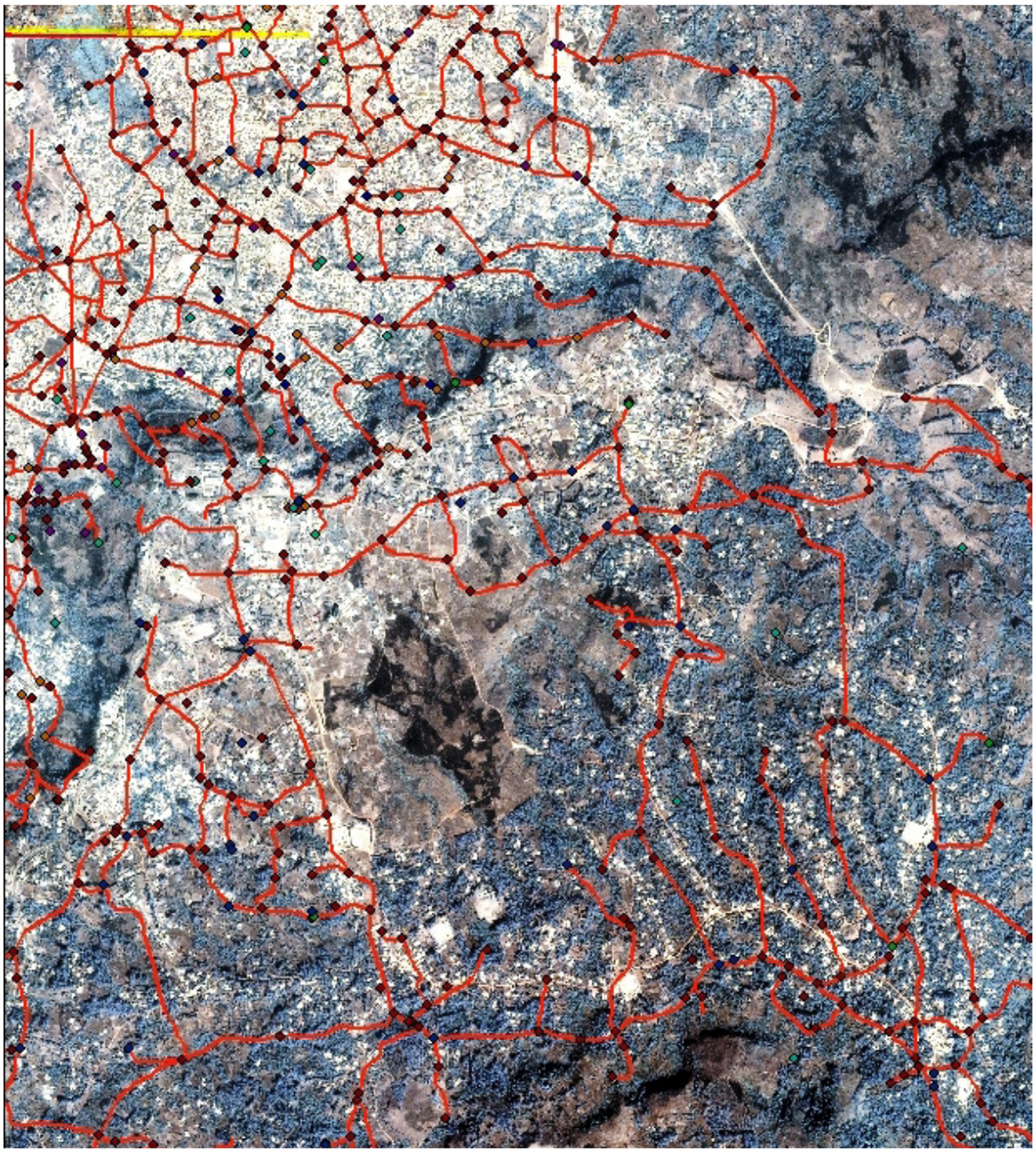
Table 4
Field verification

Countries	Similarities	Differences	Traditional census cartography (selected countries and Africa)
The Gambia, Mauritania, Namibia, Seychelles and South Africa	All field verifications were conducted using new technologies (GPS) receptors	Mauritania carried out a house to house evaluation of the number inhabitants in order to determine the size of EAs, both in rural and urban areas. Whereas, the Gambia, Namibia, Seychelles and South Africa counted the number of dwellings in order to determine the EAs	Traditional field verification methods involved a house to house evaluation of the number inhabitants in order to determine the size of EAs both in rural and urban areas
	Geo-referencing of socioeconomic infrastructure and other landmarks		No geo-referencing of socioeconomic infrastructure and other landmarks
	Listing of dwellings and households were conducted during cartographic phase		Listing of dwellings and households were conducted during enumeration phase
	No development of sketch maps in the field (automatic recording of updates in GPS receptors)		Hand development of sketch maps in the field

at collecting information from the nomadic population. That information included: code, name of water and geographic coordinates; nature and number of water points, water quality, and number of water; average operating time and usage of water point; and season of the presence of nomads, and period of the presence of nomads. In order to equip field staffs in the performance of the assignment in Mauritania, manuals were developed and delivered to team leader, cartographic agents and supervisors.

In the Gambia, Namibia, Seychelles and South Africa, field verification of data was carried out through systematic procedures by which the information captured and created in the GIS office, was verified and updated in the field. That included the enumeration area data, geo-referenced compound

Figure 1
Mismatch between Global Positioning System waypoints and track logs with satellite images



Source: *ECA 2014, Map generated from the Cameroon 2005 census digital data.*

data, landmarks, and topographical features such as roads and rivers. Maps were printed for the fieldworkers to use in the field. The enumeration area boundary, size and shape were verified against the set criteria. The current data were verified and updated and any new data were captured. Other information, such as landmarks, were also verified and captured, and any changes were annotated.

In South Africa, the limitations of field verification were evident during field data capture. Enumerators were assigned areas where the social and administrative boundaries did not correspond with the physical boundaries or feature such as roads, rivers, rail lines, etc. Given the importance of tribal boundaries to the local people, their cooperation was constrained because they felt that the census programme was imposing new boundaries from the original tribal jurisdictions. The same challenge was recorded in Cameroon (see map). A number of mismatches between the GPS waypoints and the physical boundaries were observed.

5.5 Office desktop demarcation, re-demarcation, updating and correction of enumeration area

The Gambia, Namibia, Seychelles and South Africa, used imagery to generate dwelling units, through the desktop capture of geo-referenced coordinate points digitized from the satellite images with each point representing a structure or dwelling. Those points, which were given attribute numbers, were overlaid with the satellite images for printing colour maps and for use in the field.

The fieldworkers used the Trimble GPS PDA device to recapture the already identified dwelling units as a quality control measure to ensure that all identified points were visited by the fieldworkers (see table 5). Equally, dwellings not identified in the image were captured, and wrongly identified dwellings were deleted. That process allowed for field editing of the data generated from the acquired images. It equally facilitated staffs assessment in the field, as each dwelling was required to have two geo-referenced points, one generated

Table 5
Office demarcation, re-demarcation, updating and correction

Countries	Similarities	Differences	Traditional census cartography (selected countries and Africa)
The Gambia, Mauritania, Namibia, Seychelles and South Africa	Desktop capture of geo-referenced coordinate points digitized from the satellite images with each point representing a structure or dwelling		Drawings of EAs were done manually and updating or corrections involved constructing new maps entirely
	The fieldworkers use the Trimble GPS PDA device to recapture the already identified dwelling units		No use of the latest technology in delineating EAs
	spatial data bases linked to software, were used to develop digital maps		No data bases were used. Most of the captured information were stored in paper form
	Information technology and geographic information staffs worked in the demarcation process		No information technology and geographic information staffs worked in the demarcation process
	Updating and corrections were done simultaneously with fieldwork.		Updating and corrections were done after fieldwork is completed.

in the field and the other in the field. The process was instrumental in the carving out of enumeration areas as a certain quantity of dwelling units constituted an enumeration area, and the collection of additional information on dwelling characteristics.

While evaluating the enumeration area creation process, it was noticed that the field enumerators were not carrying out population estimation simultaneously with the dwelling units identification process in most of the countries evaluated. This was a serious error as the estimated household size would have been used to determine the size of each enumeration area to be established. Equally, information on the number of persons living in collective households was left out, which made it difficult to carve out enumeration areas as those populations could be left out during enumeration.

The field visits identified several problems, with the most serious of them being the inability of fieldworkers designating sketch enumeration areas after counting the dwellings. The process was important to be carried out in the field as the staffs in the office did not have knowledge on the topographical huddles each enumerator would face while counting in each enumeration area.

The sketch enumeration area maps helps in identifying specific requirements or needs for each enumeration area during the counting phase, for example, the number of required bicycles and boats. In Mauritania, the available technologies were optimally used and integrated as a part of the total census mapping project, and the advantages were obvious for census cartographers. Equally, the office had lacked the know-how to interpret and effectively use those images when acquired.

5.6 Development of geographic frame and census administrative boundaries

Administratively, the following countries were divided into the following boundaries:

a) The Gambia had 8 local government areas, 40 districts within the 8 local government areas, and those districts were divided into supervisor areas and enumerator areas. The basic geocode used was constructed according to the geographic frame;

b) Seychelles was made up of 5 regions, 25 districts, census supervisor areas and standard enumerator areas;

c) Namibia was divided into 14 regions; the regions were divided into constituencies for electoral purposes. Local authorities were established in urban areas, and the regions covered the rural areas;

d) South Africa was divided into nine provinces that were split into district, municipalities, local government, main place name, sub place name, small area, enumeration area, and dwelling frame;

e) Mauritania was divided into 13 wilayas (regions), including the Nouakchott Capital District. Each wilaya constituted a decentralized administrative area. The wilayas were divided into moughataa (departments) and the moughataa into districts. The smallest administrative unit was the commune.

The parameters that informed the development of the geographic frame and the boundaries of the enumeration area are succinctly presented in the following sections:

5.6.1 Settlement types

Demarcation in the Gambia and Namibia were according to the following settlement types: gazetted urban areas; rural traditional and other areas not gazetted as urban; and large institutional settlements such as hotels. For the demarcation of enumeration areas in Seychelles, no distinction was made between settlement types. Institutions were part of an enumeration area already present. Although no distinctions were made between urban and rural settlement types, care was taken when the enumeration areas were demarcated to

ensure that settlements areas with similar densities or patterns were demarcated together.

The geocoding in Mauritania was done according to the 13 wilayas, including the Nouakchott Capital District. There were 53 moughataa and 208 communes in the country. All localities were geo-referenced with each locality linked to an administrative unit. Mauritania mapped the nomadic transit corridors and water points.

5.6.2 Main enumeration area types

In the Gambia, Namibia, Seychelles and South Africa, the demarcation followed:

Large vacant areas, demarcated as separate entities, which were added to the credibility and relevancy of GIS analysis and dissemination. The attribute data indicated the type of vacant enumeration area and name;

Urban enumeration areas were predominantly residential enumeration areas within proclaimed and gazetted urban settlements, which consisted of low-cost or shack housing, and medium and high-cost housing;

Rural enumeration areas were predominantly residential type enumeration areas within rural settlements, and agricultural enumeration areas covered predominantly agricultural land and settlements.

5.6.3 Enumeration area subtypes

An enumeration area subtype is a further definition to illustrate any subordinate-type aspects of the enumeration area (for example, if there is an institution present as part of the larger enumeration area). The subtype will be captured as part of the attribute information of the area. Two subtypes have been identified and will be used where relevant: no subtype and part institution – where a small institution is part of the enumeration area.

5.6.4 Enumeration area size parameters

The enumeration area size parameters have been chosen to ensure a balance between geographical size, topography, drainage and population size, while keeping in mind that the enumerator should be comfortably able to visit all households in the enumeration area within the specified enumeration time frame. Enumeration areas are demarcated from digital imagery using modern GIS techniques. The geo-referenced dwelling frame households have been used as size indicators.

5.6.5 Enumeration area attribute table

Since enumeration areas are demarcated from digital imagery using modern GIS techniques, dwelling units are used as size indicators instead of households. The following sizes have been specified: less than or equal to 500 people per EA; urban areas: 70 compounds; and rural areas: 30 – 50 compounds.

Table 6
Main enumeration area types

Countries	Similarities	Differences	Traditional census cartography (selected countries and Africa)
The Gambia, Mauritania, Namibia, Seychelles and South Africa	The demarcation following EA type and urban EAs, agricultural EAs, rural EAs and vacant EAs		Predominantly urban and rural EAs
	EA types failed to follow the tabulation plan		EA types failed to follow the tabulation plan
	VACANT (STATE/PARKS/AGRICULTURAL)=<100 Square km URBAN= 70 Compounds (+-500 people) RURAL= 30 – 50 Compounds (+-500 people)		

6. Census practices outside Africa

The United Nations Statistics Division (2010) conducted a survey on census methods used by countries in the 2010 census round. Tables 7 and 8 show the use of census maps by regions, globally, during the 2010 census round.

The survey was conducted in 122 countries, and it was noticed that about 89 countries in developing regions used census maps as compared to 33 countries in developed regions. Most developed regions were well mapped with an effective address register system, as compared to developing regions with an ineffective mapping and address register system. The survey indicated that the continents of Asia and Africa used more census maps (37 and 27 respectively), while 4 countries in Oceania used maps for their census during the 2010 round. Africa used 62 per cent of digital maps as compared to Asia with 59 per cent, and Europe with 48 per cent.

About 30 Asian countries used the GPS GIS technology followed by Africa with 25 countries. More European and Asian counties did not use the

Table 7
Countries using census mapping – by region

Region	Number of countries or areas using census maps	Type of map		
		Digitized map only	Sketch map only	Several types [i]
		Number		
All regions	122	71	13	38
Developed regions	33	15	3	15
Developing regions	89	56	10	23
Africa	29	18	4	7
Asia	37	22	5	10
Europe	27	13	3	11
Latin America and the Caribbean	22	15	0	7
Caribbean	8	5	0	3
Latin America	14	10	0	4
Northern America	3	1	0	2
Oceania	4	2	1	1
		Percentage		
All regions	100	58	11	31
Developed regions	100	45	9	45
Developing regions	100	63	11	26
Africa	100	62	14	24
Asia	100	59	14	27
Europe	100	48	11	41
Latin America and the Caribbean	100	68	0	32
Caribbean	100	63	0	38
Latin America	100	71	0	29
Northern America	100	33	0	67
Oceania	100	50	25	25

Note: i) A combination of sketch, digitised maps and maps based on aerial photography and satellite imagery.

technology as compared to Africa, where only 4 countries did not use the GPS GIS technology (see table 8). The definitions and concepts on the parameters have been presented in appendix 1.

Table 8
Technology used for census mapping on a global scale

Region	Number of responding countries	Use GPS/GIS technology	Not use GPS/GIS	Not applicable (i)
		Number		
All countries/areas	138	102	23	13
Developed countries/areas	46	26	8	12
Developing countries/areas	92	76	15	1
Africa	29	25	4	0
Asia	39	30	8	1
Europe	39	20	8	11
Latin America and the Caribbean	22	22	0	0
Caribbean	8	8	0	0
Latin America	14	14	0	0
Northern America	4	3	0	1
Oceania	5	2	3	0
		Percentage		
All countries/areas	100	74	17	9
Developed countries/areas	100	57	17	26
Developing countries/areas	100	83	16	1
Africa	100	86	14	0
Asia	100	77	21	3
Europe	100	51	21	28
Latin America and the Caribbean	100	100	0	0
Caribbean	100	100	0	0
Latin America	100	100	0	0
Northern America	100	75	0	25
Oceania	100	40	60	0

Note: i) Most of the countries or areas in the "Not applicable" column conduct register-based censuses and do not need to demarcate census enumeration areas.

7. Summary of findings and strategy for geo-reference dwelling frame for census cartography during the 2020 census round in Africa

The strategy is primarily based on leveraging the facilitating capabilities of geospatial information technologies in census data collection, processing, analysis and dissemination, while ensuring that spatial information infrastructures are harmonized with national statistical development strategies. Geospatial information and technologies are pervasively making our societies spatially aware in every aspect, because of their capacity to improve informed decision-making. Geospatial information is developed, used, maintained and shared in a wide range of census processes to facilitate spatial analysis and the locational management of information.

7.1 Vision, mission, objectives and strategies

The vision is to facilitate the use of a geo-reference dwelling frame for census cartography during the 2020 census round and other rounds in Africa. The mission is to enhance the quality of census cartographic products and services aimed at producing quality demographic data for decision-making and policymaking in Africa. The objective is to enhance the putting in place of a geo-reference dwelling frame for census cartography during the 2020 census round in Africa. The strategies are to: setup a management mechanism for putting in place a geo-reference dwelling frame for census cartography during the 2020 census round in Africa; conduct a country need assessment – technical assistance, training and research; develop a data management mechanism; and develop a monitoring, evaluation and reporting mechanism.

7.2 Regional and national governance mechanisms

The Statistical Commission for Africa was established in 2005 by the ECA Conference of Ministers of Finance, Planning and Economic Development. It acts under the United Nations policies and procedures framework, and is subject to the general supervision of the ECA Conference of Ministers of Finance, Planning and Economic Development. Its members are composed of African countries represented by heads of their national statistics offices. It is also a forum where the African Symposium on Statistical Development, the Forum on African Statistical Development, and other initiatives report on their progress. The Statistical Commission for Africa meets on a biennial basis.

The United Nations Initiative on Global Geospatial Information Management for Africa (UN-GGIM Africa) is a regional subset to coordinate African GGIM activities. It will propose the formal establishment of the body to replace CODIST-Geo[1] and decide upon the main challenges and issues pertaining to geospatial information in Africa. UN-GGIM: Africa will facilitate the global movement of integrating geospatial technology into national statistics offices. The correlation between geospatial information and statistics are strong and globally acknowledged as necessary. There is, therefore, the need to link the putting in place of a geo-reference dwelling frame for census cartography during the 2020 round of censuses in Africa, to the Statistical Commission for Africa and GGIM: Africa.

1 CODIST-Geo: Committee on Development Information, Science and Technology– geoinformation subcommittee.

7.3 Linkages

7.3.1 Linkages to the national mapping agencies in Africa

The critical role of mapping and cartographic production in national and regional planning, and in the programming of international assistance are important components to be underscored in linking national statistics offices and national mapping agencies in Africa. The agencies in Africa should coordinate their activities and work with different partners in terms of putting in place a geo-reference dwelling frame for census cartography during the 2020 census round in Africa.

7.3.2 Linkages to the national statistics offices in Africa

At a national level, the national statistics offices are the main players within the national statistical system and the African Statistics System. They are the ones that government agencies entrusted with the development and management of official statistics. It is also their role to make data accessible to government organs, the business community, and the public at large. Census cartography is conducted at an ad hoc basis and the collaboration with the mapping agencies are usually poor results in poor census cartographic products and services.

7.3.3 Linkages with mapping institutions in Africa

Most countries lack functioning spatial data infrastructures and their activities are not linked to statistics in areas not limited to the putting in place an effective geo-reference dwelling frame for census cartography. There is need to build a coordinating mechanism to build the synergy among various actors in the domain.

7.4 Interdependent linkages of components of the strategy

7.4.1 Need for country assessment, technical assistance, training and research

There is need for a country assessment to be conducted on the feasibility of putting in place a geo-reference dwelling frame for census cartography. This study will facilitate the adaptation of the proposed mechanism for putting in place the dwelling frame. The assessment can be conducted at a macro- (nationwide) and micro-institutional levels. The assessment outcomes will identify the various gap areas for technical assistance in support of putting in place a dwelling frame and those identified gaps can also be used as areas of research to foster the implementation of the dwelling frame.

7.4.2 Technical components and their interlinkages

The need for country assessment, technical assistance and training and research components must be linked to the management mechanism of the strategy. The stakeholders involved in management, should be part of the implementation of management components of putting in place a geo-reference dwelling frame for census cartography. Equally, the monitoring and evaluation, and the funding mechanisms of the strategy have to be an integral part in developing a robust system for creating dwelling frames in Africa.

8. Conclusion and recommendations

As noticed in the study, visible benefits have been accomplished through the adoption and sound application of new technologies such as GIS, GPS and high resolution satellite imagery in census mapping and household listings. Although there are several limitations, countries that have used the dwelling frames during the 2010 round have well developed tools and experience essential to improving coverage and quality of fieldwork in the actual enumeration phase of a Census. Invariably, GIS have modified the way in which data from national statistics offices are collected and stored and are produced for census purposes. These countries have integrated GIS into their census mapping processes and household listings in some regard, and most now have developed a solid geo-referenced (GPS) database of dwelling locations, clearly delineated enumeration area boundaries and a complimentary set of high-resolution satellite imagery.

Recommendations

- The reinforcement of the recommendations of a satellite communications unit-II (SATCOM II), which encourages the bringing together of geoinformation and statistics, is necessary. This has to be accomplished by working together with national mapping agencies, national statistics offices and other partners, in order to improve coordination in the 2020 census round and other rounds.

- In the 2010 census round, there was little collaboration among the mapping and statistical institutions in the country, which led to poor mapping and eventually poor quality of data collected from censuses and surveys. It is therefore imperative that the institutions work hand in hand to enhance the quality of census cartography and the entire census process as a whole.

- The geo-referenced data, collected during the household listing exercise, involved the use of high-resolution satellite imagery, and the registration of the physical location of households. The physically located households should be linked to their respective scanned image of the census questionnaire produced during data processing. This process is known as hot-linking. The technique can identify where there are serious problems with coverage of the census enumeration and facilitate investigations for individual problems, as compared to a census listing which identifies vacant households or families that have moved households.

- Canvassing involves going through an enumeration area to identify all buildings or structures that are used as dwelling units. Identified dwelling units from the listing should correspond to household interviews at the time of enumeration. Many countries have mentioned the need to improve workflow and found the process to be very slow, and hence, dragging out the work on the field. An assessment on the canvassing procedure should be conducted to facilitate the development of proper procedures or mechanisms that can expedite the canvassing process.

- Comprehensive methods and procedures of collecting data on dwelling frame and registration should be instituted in order to gather and compile an effective and efficient address database. Deciding on updating or redesigning the current database, identifying gaps, and drawing some intelligence on available coverage, should be integral parts of the mapping process.

- Addresses should be captured as they filter into the system and their validity should be verified. The postal directory should also be used to update records, and current updates from metropolitan councils should be used.

- Establish a continuous maintenance and update system of the compiled data sets. Develop and maintain an address system that will be of use to the occupants of informal and traditional settlements. Investigate the possibility of capturing a location for each structure, alternatively, the total or partial area with multiple structures. Ideally, capture accurate coordinates of each housing unit or the area that it is built on, in the settlements. Capture the popular place names of the settlement areas. Accurately capture the information in a GIS. Have the numbers visibly displayed to mark the individual units – be it a structure or area.

- Establish and ensure continuous maintenance and update of the address system. Some decisions should be taken on the address format: urban formal – will follow the street number, street name and suburb format; informal areas – consist of the dwelling number and locality name; traditional areas – dwelling number

and village name and farm settlements (farm name and district name).

- National statistics offices need to undertake evaluations of the GPS technology and equipment to be used before factoring it as technology change for the development of dwelling frames. Equally, the offices should be encouraged to develop procurement strategies and funding options for new technologies such as GPS, and this should be linked with training. The management of GPS units should be factored in the census planning. The reason for using new technologies is based on life expectancy, and possibilities for sharing data between national statistics offices and other stakeholders. The national statistics offices must develop relationships with other mapping providers in other countries (NSB, 2007) in order to:

  - Share technical expertise;
  - Share costs of software and training;
  - Share GPS coordinates - linked to other service providers;
  - Share best practice examples;
  - Integrate GIS into the entire census operation, including dissemination and other surveys;
  - Encourage regional standardization of concepts and application software, and jointly develop the capacities of staff in order to avert high staff turnover and poor quality mapping.

References

Basson, Carel (2008). ***The use of Geographical Information Systems, Global Positioning Systems and automated demarcation technologies in surveys and census mapping at Statistics South Africa***. The Regional Workshop on Census Cartography and Management**,** 8–12 October 2007. Lusaka: Statistics South Africa, pp. 1–23.

Gambia Bureau of Statistics (2008). ***Census mapping methodology using remote sensing and GIS technology.*** Gambia Bureau of Statistics and Geospace International.

Laldaparsad, Sharthi (2007). "A Geo-referenced Census Frame of Dwellings for the 2011 Census of the Republic of South Africa." Paper presented at the Satellite Meeting on Innovative Methodologies for Censuses in the New Millennium,of the fifty-sixth session of the International Statistical Institute, Lisbon, Portugal, 30 August – 1 September. Statistics South Africa, pp. 1–8.

Mbiydzenyuy, Ayenika (2012). Advisory Services on Census Cartography to the Islamic Republic of Mauritania. ***African Statistical Newsletter***, vol. 6, No. 2 (June), pp. 25–31. African Centre for Statistics – Economic Commission for Africa.

Matheri, Mercy (2005). Challenges facing the creation of a standard South African address system. ***FIG working week 2005 and GSDI-8.*** Statistics South Africa, pp. 1–5.

Noongo, Emma, N. (2007). ***The Implementation of Geographic Information Systems in Namibia***, University of Joensuu, Publications in Social Sciences, pp. 1–250.

Seychelles National Statistics Bureau and Geospace International (2007). ***Census mapping methodology using remote sensing and GIS technology.***

Secretariat of the Pacific Community–Heads of Planning and Heads of Statistics (2010). ***Statistics 2020 – Developing sustainable national and regional statistical capacities***. Regional meeting of the Heads of Planning and Heads of Statistics. SPC/HOPS 2010/Information Paper 4, July, pp. 1–5.

United Nations Population Fund–Secretariat of the Pacific Community (2012). ***Experience from the Pacific – Lessons learned for 2020***. UNFPA-SPC regional workshop reviewing the 2010 round of population and housing censuses in the pacific. Noumea, New Caledonia, 21–25 May 2012. UNFPA-SPC/Census Review 2012/Working paper 2, pp. 1–7.

United Nations Statistics Division (2010). ***Report on the Results of a Survey on Census Methods used by Countries in the 2010 Census Round.*** Working Paper, UNSD/DSSB/1. Available from http://unstats.un.org/unsd/census2010.htm.

Appendix I

Concepts and definitions used in census cartography

Enumerator areas

In the Gambia, Namibia, Seychelles and South Africa, an enumeration area is a small unit of about equal population size, each of which will be assigned to a single enumerator to enumerate its total population. An enumeration area has distinct boundaries that are describable. Its size is determined by a number of factors, among which the most important are, but not limited to, and not in order of priority: a number of dwelling units, easily manageable by at least one enumerator for the specified period of enumeration, topographically accessible, unique in that it should not cut through any administrative boundary, enumeration areas do not and should not overlap, and an enumeration area should have a unique number. An enumerator area number is a unique digit number given to an area for the purposes of record keeping and coding.

Household

A one-person household, defined as an arrangement in which one person provides his or her own food or other essentials for living without combining with any other person to form part of a multi-person household, OR, a multi-person household defined as a group of two or more persons living together who make common provisions for food or other essentials for living –persons in a group may pool their incomes and have a common budget to a greater or lesser extent; they may be related or unrelated persons or a combination of persons both related and unrelated.

Head of household

A head of household is the person that the household regards as such, and is usually the person who assumes responsibility for decision-making in the household. The head could be either a male or female. Please note – there should be one head of a household. Where property is equally owned and responsibilities of both the husband and the wife are seen as equal, then age should be considered to determine who the head of the household. This concept has traditionally remained the same although, increasingly, children and women are becoming heads of households in Africa.

Head of household, acting

A person, who assumes decision-making responsibility of the head of household in the absence of the designated head, is regarded as the acting head of household, sometimes referred to as reference person.

Dwelling(s)

Dwelling refers to various types of structures used for accommodation. Such structures include: houses, townhouses, flats or apartments, hostels, huts, shacks, semi-detached houses, and sometimes structures that are not intended for human occupation. The difference emerges when each dwelling is geo-referenced creating an address register, etc. Dwellings are used to determine the number of households and individuals living in these structures, and recently, the address system has been added in the definition of dwellings in census cartography.

Dwelling unit

A dwelling unit is a unit of accommodation of a household that may be vacant or shared by more than one household. Dwelling unit, housing unit, living quarters and stands can be used interchangeably. The difference emerges when each dwelling is geo-referenced creating an address register, etc. More information on dwelling units are being collected in the new census cartographic methodology, the characteristics of dwelling are identified and registered as part of the questionnaire loaded in to GPS devices.

Physical address

A physical address is a physical location of a dwelling unit of household(s). It consists of a number and street name. In the old system, physical addresses containing the physical location of a

dwelling unit of household(s) were not registered. The physical address system is a new concept in census cartography. For this system to be successful, it should be tied to the cadastral system of countries. The cadastral system is essential for the regular updating of the developed address system.

Household number

In the Gambia, Mauritania, Namibia, Seychelles, and South Africa, a house number is a number indicated on the house. This number is often written on the walls of dwelling units, the nomenclature differs from one country to another.

Compounds

In the Gambia, Mauritania, Namibia, Seychelles and South Africa, a compound is a group of households that can easily be identified as such. Usually, a compound will have a head of the compound that is appointed by the occupants of the households. The concept of a compound was used in the Gambia and Seychelles.

Enumeration area boundaries

An enumeration area should be delineated within the lowest order of administrative divisions, and in consideration of other subdivision or social structures for which the census data are to be reported. As far as possible, the boundaries of enumeration areas should be made identifiable by delineating along some permanent (preferably physical) feature such as rivers, ridges, a street. Where such features are non-existent, the imaginary boundary lines may be drawn and identified with reference to prominent buildings or other bench mark features. An enumeration area, delineated within the urban areas, should not extend over the adjoining rural areas. All enumeration areas have to be demarcated within the defined geographic and social boundary framework. The concept of enumeration area delineation has not changed significantly, only the technology in delineating the areas has changed drastically over the years.

Size and shape

Enumeration areas in an administrative area should cover its entire space in an exhaustive and mutually exclusive manner. That is, every parcel of land area should be allocated to one or the other enumeration area and no gaps or overlaps must occur. It should be of a compact size, to the possible extent and it must not have any outlying pockets. In the areas of sparse population distribution, the territorial size of enumeration areas should be such that the respective enumerators can cover them by walking, during the specified period of enumeration. As far as possible the enumeration areas should have population closer to the prescribed size. It should be demarcated as closed, contiguous polygons, without any gaps or overlaps, and within the specified size. The shape and size of the areas are determined by the milieu (urban or rural), rural areas are vast in nature, permitting for large enumeration areas and urban areas are smaller in nature with smaller enumeration areas with high population concentration.