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SOCIAL AND DEMOGRAPHIC STATISTICS

1980 WORLD POPULATION AND HOUSING CENSUS PROGRAMME

Cartography in the work of a national statistical office

Report of the Secretary-General

SUMMARY

The importance of cartography to the work of national statistical agencies, particularly in relation to work on population censuses, has long been recognized, and the Statistical Commission's Working Group on International Statistical Programmes and Co-ordination, at its sixth session, requested that a report on this topic be considered by the Commission at its nineteenth session.

The present report, drawing largely on the experiences of the Central Bureau of Statistics of Kenya, reviews the role that cartography plays in population census and other census and survey operations (paras. 7-20) and in the analysis and presentation of statistical results (paras. 21-26) and summarizes some promising work carried out by the Central Bureau of Statistics in Kenya using imagery obtained through remote sensing of the earth by artificial satellites (paras. 27-31). On the basis of this review of the varied and specialized needs of a national statistical office for cartographic services, the report outlines the grounds for establishing a continuing cartographic capability within a statistical office and indicates some forms of international co-operation and assistance that could facilitate the creation and maintenance of this capability, particularly in developing countries (paras. 32-38).

The Commission may wish to comment on the report, bearing in mind the relevance of cartographic services to population and housing census activities and to other national statistical programmes, and to consider the suggestions for further activities, both at the national and international level, contained in the report.

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INTRODUCTION

1. Cartography has long been recognized as playing an important role in the work of national statistical offices, particularly in connexion with population censuses. For example, the United Nations Principles and Recommendations for the 1970 Population Censuses stressed the importance of cartographic work in the pre-enumeration phase of census operations to ensure effective planning and control of field operations with a view to minimizing omissions and duplications in the census enumeration, as well as to permit the development of sound and efficient sample designs for post-censal sample surveys. 1/ The importance of using maps in the presentation of census results was also noted. 2/

2. In view of the heightened interest in this topic expressed by statistical offices in a number of developing countries, the Statistical Commission's Working Group on International Statistical Programmes and Co-ordination, at its sixth session, requested that a report on this topic be considered by the Commission at its nineteenth session (E/CN.3/470, para. 19).

3. The present document, drawing largely on the experiences of the Central Bureau of Statistics of Kenya, describes the dual contribution that cartography can make in improving the statistical "product" of a government statistical agency. 3/ One aspect of cartographic input pertains to data collection, while the other concerns the presentation of results. The present report first deals in turn with each of these contributions of cartography to the work of the statistical office (paras. 7-26). It then reviews the potential contribution that the remote sensing of the earth by artificial satellites may be able to make to the work of government statistical offices, based on some promising experiments carried out in Kenya by the Central Bureau of Statistics (paras. 27-31). Finally, the report summarizes the justifications for establishing a continuing cartographic capability designed to serve the varied and specialized needs of a national statistical office in a developing country and indicates some forms of international co-operation and assistance that can facilitate the creation and maintenance of this capability (paras. 32-38).

I. ACTION BY THE COMMISSION

4. The Commission may wish to express its views on the value of national statistical agencies establishing a continuing cartographic capability, as outlined in the present report, to serve their specialized cartographic needs in connexion with census and sample survey operations and the analysis and presentation of statistical data.

1/ United Nations publication, Sales No. E.67.XVII.3, paras. 53-54, 142.

2/ Ibid., para. 90.

3/ The present report is based on materials prepared by Parmeet Singh, Director, Central Bureau of Statistics, Kenya.

5. The Commission may also wish to comment on the nature of international co-operation and assistance needed to facilitate the establishment in developing countries of cartographic services oriented to the needs of the national statistical agencies.

6. In light of the promise that imagery obtained by remote sensing of the earth by artificial satellites appears to hold for planning large-scale statistical undertakings, such as population, housing and agriculture censuses, and for certain types of statistical measurement, the Commission may wish to request the Secretary-General to bring possible applications of this new technology of relevance to national statistical agencies to the attention of the Committee on the Peaceful Uses of Outer Space with a view to ensuring that future national and international work on remote sensing will take appropriate cognizance of such applications.

II. CARTOGRAPHY IN THE WORK OF A NATIONAL STATISTICAL OFFICE

A. Contributions to improved data collection

7. An accurate and a well-documented population census is a basic prerequisite for the creation of a statistical information system capable of providing urgently needed data on socio-economic trends in the population, particularly for the rural poor. This is so because the only realistic way of obtaining information on such trends is through an integrated programme of sample surveys based on clusters of "households/holdings" as the ultimate unit of enumeration, with locations of such area clusters precisely identified on the ground. Adequately documented census data provide the frame for developing the sample for such a programme of household sample surveys. Furthermore, the required precision in definition of the sample units should be achieved in a manner which can be easily understood by an enumerator with only a partial secondary education.

8. This facet of survey methodology, although basic, is often overlooked or given inadequate attention. As a result, in many situations, a certain amount of vagueness prevails on the part of the enumerator as to the number and precise location of units to be surveyed. This, in time, shifts control of a vital element of the design process from the survey planner to the enumerator, thus often leading to biased samples and various forms of non-sampling error. The magnitudes of these biases and errors are usually unknown and may, in many situations, have a serious impact on the usefulness of the results.

9. Development of good cartographic base materials for use in conducting censuses and sample surveys is an important prerequisite for controlling the quality of census or survey results. Maps can contribute to the control of census and survey operations in various ways: (a) they show the location of each enumeration area or sample cluster, as well as the travel routes to and from each area; (b) they provide a record of the boundaries of each enumeration or sample area and thus help to prevent omissions or duplications in census operations or mistakes in coverage in surveys; (c) they help in the allocation

and control of work assignments by showing landmarks, natural features, convenient travel paths etc. and (d) they facilitate better coverage of isolated households, efficient planning of required call-backs, and more frequent and effective supervisory visits.

10. Although the provision of the enumerators and field supervisors with appropriate cartographic materials is important in any country, the contribution these materials can make to improving the quality and efficiency of field work is particularly significant in developing countries. Often, sizable proportions of the rural population in these countries and, hence, many enumeration or sample areas, are at a considerable distance from public communications facilities and transportation services. This means, for example, that supervisory visits to the enumerator in the field may be difficult to arrange and that it is often impossible to obtain guidance from senior technical staff about problems that arise in the field before the enumerator has left the area. Consequently, much of the data-collection process may proceed in comparative isolation from direct supervision and control. In this context, maps are an important instrument for guiding the field staff as they move from dwelling to dwelling and area to area in the course of their work.

11. Cartographic materials thus serve to provide the highly scattered and isolated field staff of the statistical office - the staff charged with the responsibility of gathering the data to be used to guide national policy and action - with a clear description of the location and contents of each enumerator's and supervisor's assignment in accordance with the census plan or survey design.

12. If the cartographic materials provided to the field staff are to serve this important purpose, they must be carefully planned, prepared and reproduced. Such maps have a number of features that distinguish them from other types of maps. These relate to the functions they serve, the conditions in which they will be used and the type of persons who will use them. To illustrate the quite specialized nature of the maps required for work in a population census, six general characteristics of such maps are listed below:

> "(1) Distance is slightly less important than the portrayal of features which are in proper relationship to each other. Whether a structure lies 50 or 70 metres from the road is relatively less significant than whether it is located on the correct side of the road.
>
> "(2) All boundaries which define areas for which data are to be reported must be shown as clearly and accurately as possible in relationship to other features of the landscape.
>
> "(3) Maps should be simple and contain little information which is not pertinent to the work and needs of the user. A detailed and complicated map may only serve to confuse the user, since most individuals involved in census work are not trained in map use.

"(4) It is essential that features and names be shown clearly, since many copies will be made of most maps. If copies are blurred, the utility of the map will decrease sharply.

"(5) Map distance should be shown by means of a graphic scale since it does not have to be altered in the event that the map is enlarged or reduced in size.

"(6) It is important that all names be spelled correctly and reflect any recent change. Names used on a census map should be those which are commonly recognized by local people." 4/

13. Provision of the requisite cartographic materials for the enumerator is not a simple task in developing countries - particularly since the cartographic base in these countries is rather weak, if not non-existent. It entails a great deal of effort, investment in human material resources and co-ordination between professionals from various fields. The initial task, of course, involves determining and assessing the cartographic materials currently available to form the base from which the required field maps for enumerators can be developed. Such materials, if at all available, are usually out of date and more often than not are detailed only down to the level of the smallest administrative unit of the country.

14. For statistical work in connexion with censuses and surveys, such materials need to be further detailed to the level of "enumeration areas" well beyond the detail to which the smallest administrative unit is identified. In fact, in most instances, the cartographic materials available form only the starting point for the development of the required cartographic base. A thorough investigation needs to be undertaken of all the available maps, air photos and other cartographic materials from such national agencies as the government central mapping/survey office, local government agencies (e.g., provincial, district or municipal authorities) and sources, such as university departments of geography and agencies executing projects of the nature of malaria eradication programmes or geological surveys. Such investigation, accumulation and indexing of available material are time consuming but essential. In many instances, a single source may cover only part of the country. It also takes perseverance and ingenuity to fit the various "bits and pieces" into a meaningful base to cover comprehensively the particular universe of interest.

15. A cartographic base, having thus been established, the material needs to be transformed into a form usable by the enumerator. This task of providing field maps for the enumerator entails co-ordination between the cartographer and census and survey statistician. More often than not, extensive field operations need to be conducted at this stage to fill the missing gaps in the cartographic coverage and to undertake the necessary "ground truthing", particularly if the base materials happen to be out of date. The problems of establishing the cartographic base for statistical work can be illustrated with a summary of some work recently carried out in Kenya by the Central Bureau of Statistics.

4/ Marvin Gordon, "Cartography for census purposes", World Cartography, Volume XIII (United Nations publication, Sales No. E.75.I.6), p.8

16. In Kenya, the need for an effective cartographic coverage of the area of interest was felt when maps were being compiled for a national multipurpose area sample to be utilized over the next four years to collect data on population changes, socio-economic trends covering rural households/holdings, human fertility, labour force and possibly other characteristics. It is intended that, after the cartographic work for this national sample is completed, more extensive work will be initiated on the cartographic base that needs to be established for the next population census, due in 1979. In establishing the national sample, for reasons noted above, emphasis was placed on the need to ensure that each sample cluster of households/holdings could be identified by distinct boundaries which could be easily observed by the enumerator on the ground. These boundaries were to be defined by features such as roads, rivers and permanent streams and foot-paths.

17. In developing the cluster maps for the national sample, consideration was first given to utilizing the enumeration area maps which had been prepared for the last population census, undertaken in 1969. Unfortunately, these maps had deficiencies which rendered them unsuitable for the requiremenss of the national sample. A large number of census enumeration areas could not be identified by easily recognizable boundaries. Since little or no effort had been made to keep the cartographic materials up to date by correcting errors subsequently discovered in the maps and recording changes that had occurred in the seven years since the last population census, a major effort would have been required to up-date the maps. It was, therefore,,decided to develop entirely new geographical enumeration units for the national sample.

18. Kenya was fortunate in that the Survey of Kenya (the central government mapping/survey office) had already effected an extensive map coverage, at a scale of 1:50,000, of the densely settled areas of the country. This provided a suitable cartographic base from which enumerator maps of sample clusters could be developed. Additionally, air photo coverage of most of the rural areas in the national sample was also available, at a scale of 1:12,500. For most of the urban areas, the local authorities had established large-scale city maps and/or town planning maps at scales of 1:5,000 and 1:2,500. Some of these maps were quite recent while others were 15 to 20 years old. However, in most cases, easily recognizable physical features which could be adopted for delineation of sample area boundaries had not changed significantly between the time when the aerial photographs were taken and the time when the currently available maps were drawn.

19. The process of selecting and defining a sample cluster in the national sample involved cartographers, sampling statisticians and field mappers. It consisted of eight steps, which were followed in each of the 64 rural primary sampling units (PSU). These are detailed below:

(a) Each PSU was first subdivided into "chunks" - an intermediate step between selection of the first-stage and the second-stage sampling units. This subdivision was based on an up-dated population count of the 1969 census by enumeration areas and the most recent topographic maps drawn to a scale of 1:50,000. Each chunk was approximately 2 to 4 clusters in size and had easily recognizable boundaries;

(b) Two chunks were then selected randomly within each PSU;

(c) A photographic mosaic was prepared for each of the selected chunks. This mosaic was covered with a clear plastic overlay and the outer boundaries of the chunk and the "count area" (i.e. a small area within a chunk for which household counts could be conveniently made in the field) were marked on the overlay. Care was taken to ensure that each count area within a chunk also had well-defined boundaries;

(d) The photographic mosaics of the chunks were taken to the field for "ground truthing" and for a "quick count" of the households in each count area;

(e) On the basis of the current household counts in the count areas, each chunk was divided into an appropriate number of equal-sized clusters, one of which was randomly selected as the national sample cluster. Care was again taken to ensure that clusters had easily recognizable boundaries;

(f) The next step was to draw enlarged cluster maps. Although these were drawn mostly to a scale of 1:5,000, the scale was varied according to the densities of population in certain parts of the country. The enlargement was drawn from the aerial photos (when available) using pantographs;

(g) The enlarged cluster map and the photographic mosaic were again taken to the field so that:

(i) Each structure (dwelling unit) could be physically numbered and the location of the structure, as well as its number, plotted on the cluster map;

(ii) Names and terms of reference for the physical features on the map could be verified and physical features within or on the periphery plotted onto the maps;

(h) The up-dated details on the cluster maps were then entered on transparencies ready for final reproduction of the maps.

20. This process entailed a considerable investment of resources for the development of the national area sample. However, it was felt that the pay-off from this investment in terms of improved quality of data justified the cost.

B. Contributions to improved data presentation

21. Applications of cartographic techniques to the presentation of data are as pertinent as their application to data collection. For many purposes, data in tabular form are sufficiently revealing in themselves or provide a basis for further analysis. On the other hand, column after column of tabular data can be

discouraging, especially for the layman or administrator with no professional training in statistics. Moreover, it is often difficult to perceive spatial patterns of survey data in such tabular form and more effective graphic techniques of data are often required.

22. Cartography at the preeentation stage, therefore, attempts to employ principles of good map design and symbolization to display census and survey results or to reveal more complex spatial relationships. Good, clear cartography, using appropriate symbolization, can display census or survey results in an interesting and immediately understandable manner, and can do so in a limited amount of space. If the statistical agency requires its data to be translated into forms easily comprehended by the public and by decision makers elsewhere in Government, the map is often a most effective means of communication.

23. A wide range of cartographic techniques is available to the statistical office, depending on the skill and imagination of its cartographic staff. Point, line, area and volume symbols have been developed to show quantitative distributions of virtually any locationally specific set of statistics. Simple display of single-category data, measures of central tendency, ratios, proportions, percentages, densities and a variety of other indices can be effectively presented through cartography.

24. In the past two decades, conventional cartography has been supplemented by computer graphics, which enable locationally specific survey and census data to be processed rapidly by high-speed electronic computers. Programmes such as SYMAP and CALCOMP produce a pictorial computer output from raw statistical information. Point, line, area and volume maps are rapidly turned out with these programmes, enabling almost instantaneous spatial analysis of survey data. Data collected in a population census or survey, for example, can be processed using such programmes to produce choropleth or isopleth output about as rapidly as the corresponding tabular output is generated.

25. Both conventional and automated cartography are also invaluable tools for assisting the various government ministries which the national statistical organization serves in the analysis of census and survey results. For example, spatial presentation of employment data and related social and economic data, using incisive cartography, can lead to better understanding of prevailing regional patterns of employment and unemployment.

26. To summarize, although not the only tool available to the national statistical office for presenting data, cartography ranks as a highly effective means of succinctly communicating census and survey results to a wide variety of users.

C. The potential contribution of remote sensing

27. Many technological innovations have had a profound impact on the work of national statistical offices. Some, such as the punch card and the digital

computer, were associated with the work of the statistical office from the time of their invention. Others, such as the automobile and off-set printing were used by national statistical offices only after their potential contribution to the work of gathering and disseminating data was perceived and the contribution justified in terms of cost effectiveness. Currently, considerable national and international attention is being given to the utilization of remote-sensing capabilities of artificial earth satellites to provide important information in many fields 5/ but few statistical offices and statisticians have yet begun to examine the potential impact of this new technology on national statistical operations. 6/

28, Remote sensing is detecting the nature of an object without actually touching it. The exercise involves both image and numerical analysis. An example of an image-oriented remote-sensing system is an aerial camera and a photo-interpreter. Photographic film is used to measure the spatial variations of the electro-magnetic fields and the photo-interpreter relates these variations to specific classes of the earth's surface cover. Numerically oriented remote sensing systems, on the other hand, involve computers. Analysis of a scene photographed through different portions of the spectrum are made and patterns based on spectral differences in the image are established. The patterns so made facilitate easy definition of the classes into which observable information can be categorized.

29. In Kenya, work on the investigation into statistical application of remote sensing was initiated in the Central Bureau of Statistics in September 1974 as a result of an agreement between the Ministry of Finance and Planning and the United States Agency for International Development. A major objective of this agreement was to develop Kenya's institutional ability to utilize remote-sensing technology in connexion with the gathering of demographic and other related statistical data. Satellite imagery and the most up-to-date equipment to interpret the imagery have been made available for this exercise. Preliminary work, using both satellite imagery and conventional aerial photography, indicates that the available space and aerial photography provides the Central Bureau of Statistics with invaluable information required for more effective planning and control of field data-collection operations. The two land-surveying satellites launched by the United States of America: LANDSAT-1 (formerly ERTS-1) and LANDSAT-2 are the sources of space photography. LANDSAT-1 provides imagery for the same spot on the earth's surface at 18-day intervals. However, supplemental aerial photographs can be taken as often as is desirable and economically feasible.

5/ See, for example, "User needs for satellite remote sensing data" (A/AC.105/157).

6/ Some exceptions are: "Statistical application of remote sensing", Kenya Statistical Digest, vol. XIII, No. 1, pp. 1-2 (March 1975); Robert C. Durland, "Potential uses of ERTS satellite imagery for population studies and census activities", U.S. Bureau of the Census, paper presented at the Population Tribune, Bucharest, 18-30 August 1974; H. F. Huddleston and W. H. Wigton, "Uses of remote sensing in sampling for agricultural data", paper presented at the 40th session of the International Statistical Institute, Warsaw, 1-9 September 1975.

30. It is envisaged that, in Kenya and elsewhere, remote sensing may be able to assist in the process of keeping the cartographic base up to date both for ongoing work on sample surveys and for preparing the cartographic materials for subsequent censuses. Moreover, it is possible that satellite imagery may be able to help in the demarcation of boundaries of urbanized areas for census purposes using objective criteria and, in some countries, assist in the enumeration of certain types of nomadic populations.

31. It must be stressed, however, that satellite imagery can only supplement data-gathering activities on the ground. Most data that statistical offices gather on the economic, social and demographic characteristics of persons, households and establishments are not amenable to collection by satellites. Nevertheless, once this important qualification is well understood, satellites hold considerable promise for the cartographic work of a national statistical office because of their wide and regular geographic coverage and the ease with which objectively defined and standardized classifications can be implemented.

D. A continuing cartographic capability within the statistical office

32. In the light of the considerations raised above, it is pertinent to review briefly the value of establishing a cartographic unit as an integral part of the national statistical organization. Three major considerations point to the conclusion that the cartographic needs of most national statistical offices are most effectively and efficiently served by means of a continuing cartographic capability within the national statistical office.

33. First, it will be recalled that the cartographic operations described above require a capability that is highly specialized and integrally linked with other operations both in data collection and the processing of census and survey results. The establishment of a cartographic unit within the statistical office facilitates the technical and logistical co-ordination required between the cartographers, sampling statisticians, computer programmers and field survey staff to ensure that essential statistical operations proceed in a proper and timely manner.

34. A second reason for promoting cartographic work as a regular activity of the statistical organization is the magnitude of the cartographic work that must be undertaken to meet all the requirements for information. For example, the preparatory work for a national census is, in the case of a country with a population of around 13 million, such an extremely large undertaking that it is doubtful if an outside agency can be geared to a highly specialized cartographic operation of this magnitude. Of course, population censuses can be conducted without a very elaborate cartographic support network but the information so obtained can then be put to use for limited application only. Given the size of this task, even the statistical organizations would need several years to establish this element of statistical infrastructure. As staff is trained and properly directed, standardized means of format and symbolization

can be developed to portray census and survey data more effectively. In other words, a mapping style most appropriate to the role to be played by a statistical organization will evolve as the cartographic work matures.

35. A third very important reason for promoting cartographic work in statistical organizations stems from the fact that the cartographic work related to data collection and processing should be undertaken as a continuing activity. Of necessity, maps must be continually up-dated, old samples must be replaced periodically and the results from each census or survey must be displayed appropriately to suit the needs of the users of such information.

36. Given that these considerations point to a relatively large investment in terms of human and material resources dedicated to serving quite specialized cartographic needs, it appears that these needs would best be looked after in most countries by the central statistical organization itself. Nevertheless, close liaison should be maintained between the specialized cartographic unit of the statistical organization and the central government mapping/survey office so that they can supplement each other's work. At a more formalized level, there will also be a need to involve the government department responsible for identifying administrative area boundaries. As a long-term goal, the statistical organization should aim to convince the other two co-operating organizations of the advantages of recognizing the basic enumeration area used in the population census as an elementary land unit which should, as far as possible, be retained intact in any changes in boundaries of administrative areas.

37. In the case of many developing countries which are poorly endowed with material and trained manpower resources, the task of establishing a continuing cartographic capability may well be beyond the ability of their statistical organization. In such a situation, various forms of technical assistance may be of value. If countries can group themselves regionally or subregionally, it may be possible to provide such assistance more usefully on a regional or subregional basis rather than on a country-by-country basis. Moreover, as indicated in paragraph 36 of document E/CN.3/473, also before the Commission, it may be advisable for several national statistical offices to consider collaborating in the establishment of a joint cartographic unit to serve their common needs. Such intercountry institutions could maintain a current cartographic base for all co-operating countries and provide cartographic support for census undertaking establishment of national area samples and other related work.

38. Such an undertaking would involve a high degree of co-operation at national and international levels as well as appropriate assistance from international and bilateral sources. However, such co-operation can be effective only if the countries concerned themselves recognize the need for improved statistics for which an effective cartographic capacity is an essential input and appreciate that one of the best ways to obtain this coverage in the forseeable future is through regional and international co-operation.
