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The World's Topographic and Cadastral Mapping Operation

The 1980 United Nations' Survey on the Status of World Cartography.

Introduction

In pursuance of Economic and Social Council resolutions, the Cartographic Section (Chief: Dr. Maximilian DeHenseler) of the United Nations has undertaken at regular six-year intervals, surveys on the status of world topographic mapping. In 1968, a first such survey was conducted, and the results were published in *World Cartography*, Volume X.[5] A recount survey was undertaken in 1974, which was reported in *World Cartography*, Volume XIV.[6] In 1980, a third survey was conducted which included cadastral mapping for the first time, and the results are published in *World Cartography*, Volume XVII.[7] The original draft for Volume XVII was prepared by the authors of this paper, and it is the purpose of this paper to present and discuss the most important results of the 1980 survey.

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World Topographic Mapping, 1980 Inventory

For the 1980 UN survey of the status of the world topographic mapping, the required information was obtained from completed UN questionnaires sent through diplomatic channels to the national cartographic agencies (responsible for national cartography, geodesy, and, in a number of countries, also cadastral surveying and mapping (S&M) of all Member States of the United Nations. This information was supplemented by data contained in the S&M Data Bank of Laval University's Department of Photogrammetry.

Abstract: *An adequate topographic coverage of the land area of the world at appropriate scales is an essential prerequisite for a comprehensive assessment of the world's resources. According to the United Nations' surveys, this requirement is far from being satisfied. Only about half of the land area of the world has coverage in the economically important scale 1:100,000/1:50,000 and the annual progress rate in the period 1974-80 even decreased when compared with the period 1968-74. Furthermore, there is a critical situation regarding revision of existing topographic maps: in only about 1 percent of the land area of the world are such maps revised each year. As far as cadastral mapping throughout the world is concerned, considerable efforts are made, quite often in an uncoordinated fashion, as there exist few or no regionally or internationally established comprehensive policies or standards. The world's surveying and mapping (S&M) manpower of some 1.2 million persons (including about 150,000 in photogrammetry and remote sensing) and annual expenditures of more than U.S. $7 billion for civilian S&M are obviously unsufficient to produce the required annual progress rates in an appropriate time. A reevaluation of the significance of S&M (and of photogrammetry and remote sensing) in national and world development and strengthening of the professions involved will be necessary in the future.*

As in previous UN surveys the available map coverage information was classified according to four scale ranges as follows:

Range I:	1:1,000-1:31,680 (2 inches to 1 mile): category 1:25,000 and larger.
Range II:	1:40,000-1:75,000 (1 inch to 1 mile): category 1:50,000.

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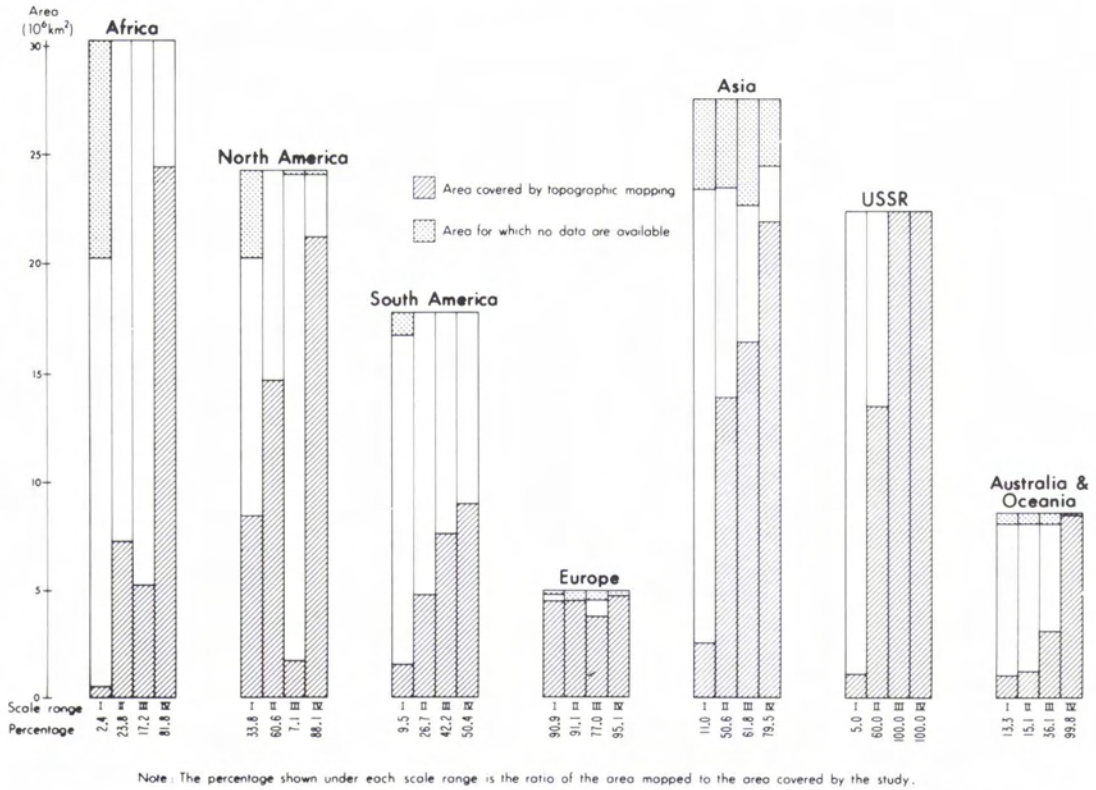

FIG. 1. Area covered by topographic mapping on the four scale ranges, by geographical region.

Range III: 1:100,000-1:126,720 (1/2 inch to 1 mile): category 1:100,000.

Range IV: 1:140,000-1:253,440 (1/4 inch to 1 mile): category 1:250,000.

In the 1980 survey the coverage data were determined for each country; in addition, they were tabulated for all the geographic regions of the land area of the world and according to the four scale ranges. Figure 1 shows the coverage data for each of the geographic regions.

Analysis of the Status (Progress) of World Topographic Mapping

Based on the data contained in Reference 5, 6 and 7, progress lines were drawn for the four scale categories as shown in Figure 2. According to this figure, in which the annual progress rates (in percents) of map coverage are also indicated for the four scale categories, there has been a considerable progress decrease for the period 1974-80 when compared with the period 1968-74. There even appears to be a slight coverage decrease for the scale category IV. This might be explained by the possibility that, especially in Africa, some areas with only reconnaissance-type maps could have been omitted in data reported later. Nevertheless, it can be concluded that no real progress whatsoever was achieved in the scale category 1:250,000 during the period 1968-80. In 1980 there was still only an 80 percent coverage of the land area of the world in this category. The fact that progress in topographic map coverage has decreased in the period 1974-80 entails rather serious consequences, and this in view of the usefulness of base mapping for resources mapping. This is particularly true for the economically important scale categories 1:100,000 and 1:50,000. Considering the poor progress rates in these categories for the period 1974-80, it appears that the recommendation formulated in Reference 6, i.e., to achieve full coverage for the entire land area of the world on these two scales by the year 2000, can not be fulfilled. There is a similar progress-rate decrease for the scale category 1:25,000 and larger, and this is also serious because of the importance of these large scale maps in the world's cadastral S&M operations, especially in urban areas.

It was therefore recommended in Reference 7 that the authorities responsible for base mapping (topographic mapping) in the respective countries should exert every effort to accelerate base-map production.

Topographic Map Revision

An analysis of the information obtained from the 1980 survey reveals that, for the land area of the world, the percentage of topographic maps revised

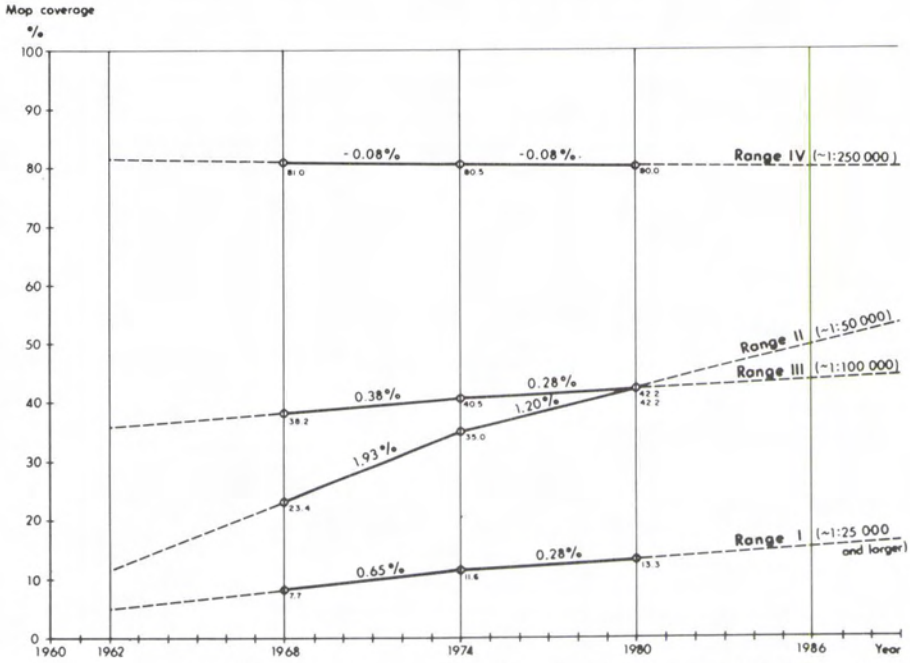

FIG. 2. Percentages of total world area covered in each scale category, 1968-1974-1980.

in the period 1974-80 is about 14 percent of the available map sheets, or less than 3 percent of the available sheets per year. Here, one has to take into account that up to 1980 less than half of the land area of the world has been topographically mapped in the scale categories II and III, which are of particular need. For these scales the annual revision progress rate is only about 2 percent of the mapped area. This means that, in the period 1974-80, such topographical maps were indeed revised per year for only about 1 percent of the world's land area, on the average. This must be considered inadequate, because it results in far too large a number of obsolete maps and consequently in a substantial loss of value of existing maps.

AERIAL PHOTOGRAPHIC COVERAGE

Aerial photography is an essential operation of today's map making. For this reason, in previous surveys as well as in the 1980 UN survey on the status of topographic mapping, some information was collected on aerial photography operations and coverages. Unfortunately, this information is rather fragmentary and insufficient to give accurate figures on all existing aerial photography coverages for the land area of the world. For this reason, in 1981, a special questionnaire was sent to responsible authorities jointly by the United Nations and the Remote Sensing Centre (RSC) of the Food and Agriculture Organization of the United Nations (FAO). This questionnaire has provided some additional information on existing aerial photography coverage, and all the available data are being used by FAO/RSC to establish a World Aerial Photographic Index (WAPI). For more information on this WAPI project, reference is made to publications 2, 3 and 4.

GEODETIC BASES AND GROUND CONTROL FOR BASE MAPPING

The available geodetic bases affect the world's topographic mapping operation. For this reason, the 1980 UN survey included and provided detailed information on the available geodetic bases.[7]

The reference ellipsoids used, the available official geodetic control, and the projection systems utilized for the various geographical regions of the land area of the world are listed in Tables 1, 2, and 3 (year 1980).

From Table 1 it can be seen that presently 16 different reference ellipsoids (or spheroids) are used, a relatively large number. For practical purposes it would be desirable if this number would be reduced to a very few standard ellipsoids. The most used reference ellipsoids, area-wise, are the International (Hayford) (28.3 percent); Krassovsky (25.0 percent); the Bessel (19.86 percent); and the Clarke 1880 (19.44 percent). Note: Sometimes for the same areas more than one reference ellipsoid is used. For this reason, the percentages in Table 1 do not round up to 100.

Based on the available data (Table 2) it can be estimated that in 1980 there were about 3.67 million official horizontal geodetic control points and about 3.15 million official vertical control points on the land area of the world (excluding Antarctica). The density of this control varies enormously from one

TABLE 1. REFERENCE ELLIPSOIDS, AREA COVERED, 1980 (km²)

Ellipsoid	Africa	N. America	S. America	Europe	Asia	USSR	Oceania	World	Area with available data	Percent
Clarke 1880	21 518 717	6 489		547 027	3 255 755		18 272	25 346 260	130 166 517 or appr. 96 per cent of the world's land area (excl. Antartica)	19.44
Clarke 1880 modified	4 394 605	3 560						4 398 165		3.38
International	2 428 116	2 184 570	17 259 559	2 150 308	12 079 576		797 520	36 899 649		28.3
Clarke 1866	531 442	21 934 380			300 000		746	22 766 568		17.46
NAD 83		2 175 600						2 175 600		1.67
Bessel			163 265	1 304 919	2 002 829	22 402 200		25 873 213		19.86
Delambre 1810				30 513				30 513		0.0234
Krassovsky				566 577	9 596 961	22 402 200		32 565 738		25.0
UGGI-1967				93 030				93 030		0.0713
Danish Special				70 283				70 283		0.0538
Airy				244 046				244 046		0.187
Australian National							7 686 898	8 334 395		6.4
Spheroid					647 497					
Everest					5 341 943			5 341 943		4.1
GRS 67					1 904 345			1 904 345		1.46
Bessel 1841					372 313			372 313		0.286
Everest modified					329 749			329 749		0.253

TABLE 2. GEODETIC CONTROL, 1980

	Horizontal geodetic control points				Vertical geodetic control points			
Continent or region	Area with available data (sq km)	Number of points	Area per point (sq km)	Number of points extrapolated to entire continent	Area with available data (sq km)	Number of points	Area per point (sq km)	Number of points extrapolated to entire continent
Africa	22 612 063	58 440	388.8	78 300	11 375 299	48 980	232.0	130 600
North America	21 535 902	435 500	50	490 000	21 623 751	549 200	39	616 000
South America	5 917 631	24 795	266	74 800	5 917 631	60 809	97	183 000
Europe	2 777 231	1 229 000	2.66	2 185 000	2 189 083	605 600	3.61	1 364 000
Asia	17 601 806	380 934	42.7	596 000	16 670 022	328 990	50.7	543 000
USSR	22 402 200	200 000	112	200 000	22 402 200	200 000	112	200 000
Australia and Oceania	7 715 294	40 130	192	44 300	7 974 582	105 300	75.7	112 400
World	100 562 127, or 74 per cent of the world's land area (excluding Antartica)	2 368 799	42.5	3 668 400	88 152 568, or 65 per cent of the world's land area (excluding Antartica)	1 898 879	46.4	3 149 000

horizontal geodetic control point per 2.66 km^2 and one vertical geodetic control point per 3.61 km^2 in Europe to one horizontal geodetic control point per 388.8 km^2 and one vertical geodetic control point per 232 km^2 in Africa. It is evident that an inadequate geodetic control density, particulary in Africa, hampers many development projects in general and satisfactory base-mapping progress in particular.

In 1980, there were altogether 27 different projection systems used (see Table 3) for the land area of the world, which number appears to be rather excessive. It would be desirable to reduce considerably this number to arrive at a few standard projection systems. Presently, the most used projection systems (area-wise) are UTM (56.9 percent), TM (37.75 percent), Polyconic (12.9 percent), and Gauss-Krüger (12.0 percent). Here it should be noted that in various geographical regions several projection systems are sometimes used for the same areas. For this reason the percentages in Table 3 do not round up to 100.

Surveying, Photogrammetric, and Cartographic Equipment Used in the World's Cartographic Agencies

Topographic mapping progress depends on the available equipment. At the present time no global inventory of such equipment exists for the world's entire S&M operation except for the equipment owned by the national cartographic agencies responsible for official national cartography, geodesy, and sometimes also for cadastral S&M. Such information (for the national cartographic agencies) was provided by the 1980 and previous UN surveys. In 1980 these agencies altogether had among others the following ground-surveying instruments available:

- 12,120 instruments of the theodolite class (theodolites, tachometers, alidades), or one instrument per 11,179 km^2 of land;
- 5,790 leveling instruments, or one leveling instrument per 23,426 km^2, and
- 1,914 electronic distance-measuring instruments, or one instrument per 70,773 km^2 of land.

This indicates a ratio between these three categories of instruments of 61 to 29 to 10 percent, or a somewhat significant increase of the number of electronic distance measuring instruments when compared with the year 1974.

Because many national cartographic agencies contract out aerial photography work, the number of survey airplanes and aerial cameras owned by these agencies is relatively small, namely:

- 162 survey airplanes, or one survey airplane per 804,000 km^2 of land; and
- 267 aerial cameras, or one aerial camera per 508,000 km^2 of land.

More significant is the number of photogrammetric compilation instruments (first-, second-, and third-order stereoplotting instruments, rectifiers, rectifier-enlargers, orthophoto instruments, analytical plotters, comparators) owned by the national cartographic agencies. For 1980, the number was 3,120 photogrammetric compilation instruments, or one instrument per 43,400 km^2 of land. This figure indicates an essentially higher instrument density per area when compared with the year 1974, for which year there were approximately 2,260 compilation instruments, or one instrument per 60,000 km^2 of land.

As to cartographic and reproduction equipment, the world's national cartographic agencies owned, besides other less important items, the following:

- 284 coordinatographs (excluding plotting tables of photogrammetric compilation instruments), or one coordinatograph per 478,000 km^2 of land;
- 245 reproduction cameras, or one reproduction camera per 554,000 km^2 of land; and
- 783 printing presses, or one printing press per 173,000 km^2 of land.

Manpower in National Cartographic Agencies

Based on information received through the 1980 UN survey, it can be estimated that all the world's national cartographic agencies in 1980 had the following manpower per category:

Geodesy (surveying):	25,920	or	16.6 per cent
Photogrammetry:	16,020	or	9.9 per cent
Remote Sensing	1,820	or	1.1 per cent
Cartography	22,800	or	14.0 per cent
Reproduction	14,420	or	8.9 per cent
Administration	11,300	or	7.0 per cent
Others	69,720	or	43.1 per cent
	162,000		100.0

In this listing the manpower under the heading "Others" is exceptionally large. This can be explained by the fact that in a number of countries the responsibilities of the national cartographic agencies include cadastral S&M, with a large number of technical and non-technical personnel listed under the heading "Others".

It is interesting to compare the figures of 162,000 for 1980 with the comparable figure for 1976 published in Ref. 1. According to this source, all the world's national cartographic agencies had, around 1976, a total manpower of 149,385. This would indicate an annual increase of the manpower of all the world's national cartographic agencies in the period from 1976 to 1980 of 2.1 percent. This annual increase is practically the same as that for the period 1970 to 1974 (2.0 percent) (Reference 6). If the manpower figures for the headings "Geodesy," "Photogrammetry," "Cartography," and "Reproduction" are compared with the status in 1974 (Reference 6), it can be noticed that in 1980 there were slight percentage increases for "Photogrammetry" and "Reproduction." The ratio for 1980 was 1.00:0.62:0.875:0.56, while the 1974 ratio was 1.00:0.58:1.00:0.46.

TABLE 3. PROJECTION SYSTEMS, AREA COVERED, 1980 (km²)

Projection System	Africa	N. America	S. America	Europe	Asia	USSR	Australia & Oceania	World	Area with available data	Percentage
UTM	25 583 530	15 950 882	12 055 706	1 163 990	18 800 556		516 636	74 071 300	130 168 058	56.9
Lambert Conical Conformal	602 237	2 247 340	756 945	1 029 300	3 459 806			8 095 628	or appr. 96 per cent of	6.2
TM	5 852 466	1 907 421	3 564 355	1 595 479	13 480 285	22 402 200	291 225	49 093 431	the world's	37.75
Polyconic	1 784 479	9 372 364	2 788 850		2 896 085		218	16 841 996	land area	12.9
Polar Stereographic	7 557							7 557	(Excl. Ant-	0.006
Oblique Mercator	587 041							587 041	artica)	0.45
Gauss-Laborde	2 510							2 510		0.002
Bonne	163 610			192 878	569 459			925 947		0.71
British West Indies Grid		564						564		0.0004
Lambert Conical Orthomorphic		10 962	11 961					22 923		0.018
Cassini		5 128		70 283			18 272	93 683		0.072
Gauss-Krüger			4 672 748	1 002 551	9 969 274			15 644 573		12.0
Cartesian			1 138 914					1 138 914		0.875
Polyhedric			1 285 216	339 653	372 313			1 997 182		1.53
Stereographie			163 265	133 874	10 400			307 539		0.236
Flamsteed modified				1 399				1 399		0.0011
Cylindrical				108 178				108 178		0.083
Hatt				131 944				131 944		0.101
Recessed Cylindrical				93 030				93 030		0.0715
Gauss-Boaga				301 286				301 286		0.2315
Oblique Cylindrical Conformal				41 445				41 445		0.0318
Rectified Oblique Conformal					5 765			5 765		0.0044
Cassini-Soldner					371 030		2 842	373 872		0.287
Pseudo-Lambert					10 400			10 400		0.008
Rectified Skew Orthomorphic					330 030			330 030		0.254
ACT Grid							7 686 848	7 686 848		5.9
Special							549	549		0.004

Economic Aspects: Annual Expenditures and Revenues of the World's National Cartographic Agencies

According to the 1980 UN survey, it can be estimated that the annual expenditures for 1980 of all the world's national cartographic agencies amounted to about 1/9 of all the world's expenditures for civilian S&M, or to U.S. $794 million, or to U.S. $4,900 per employee. These expenditures broken down for 1980 and for 1974 (in comparison) are shown together with the agencies' revenues (from sales of maps, photographs, etc.) in the following listing:

	1974	1980
Expenditures (Percentages)		
Salaries (personnel)	64	64.6
Operational	20	24.2
Equipment	7	6.3
Others	9	4.9
Revenues (Percentage of the annual expenditures)	10	17.65

The 1980 U.S. $794 million may also be expressed in the form of the following figures:

U.S. $5.85 per km^2 of land; or
U.S. $0.18 per capita; or
0.008 percent of World's Gross Product (sum of all GNP)

Such expenditures are indeed very modest, and it appears mandatory to increase the appropriations considerably in order to ensure acceleration of the world's base-map production, which at the present must be considered as being too slow for resource development, planning, etc. Such increased appropriations could also be realized by increasing the revenues of the national cartographic agencies, and a comparison of the revenue figure for 1980 with that for 1974 indeed indicates such a trend. There was an increase in the revenues (as percentage of expenditures) from 10 percent in 1974 to approximately 18 percent in 1980.

When the 1980 annual expenditures of the national cartographic agencies as a percentage of the GNP (Gross National Product) for the various geographical regions of the world are compared, one finds that there are considerable variations as indicated in the following listing:

Geographical Region	*Annual Expenditures of the National Cartographic Agencies; Percentage of GNP*
Africa	0.0177
North America	0.0047
South America	0.0125
Europe	0.0091
Asia	0.0082
USSR	0.0080
Australia & Oceania	0.0330
World	0.0081

From this listing one arrives at the interesting conclusion that North America (including the United States and Canada) spends the least amount per GNP per year for base mapping and related operations (annual expenditures of the national cartographic agencies).

World Cadastral Surveying and Mapping, 1980

The 1980 UN survey revealed that in most countries the cadastral S&M is based on a legal cadastre (for 80 percent of the responding countries). Only in 20 percent of the responding countries is the cadastre solely a tax or fiscal cadastre. Furthermore, in nearly all reporting countries, boundary marks exist and are monumented, or at least are protected.

The survey also revealed that the scales used for cadastral mapping mainly belong to the scale category 1:25,000 and larger, and that altogether a total of 24 different scales are used. It would be highly desirable to use throughout the world only a few standard scales, for example 1;20,000; 1:10,000; 1:5,000; 1:2,000; 1:1,000; and eventually 1:500.

Cadastral S&M plays an important role in the world's S&M operation. A preliminary estimate of total manpower indicates that in 1980 approximately 400,000 persons were engaged in cadastral S&M and that world total annual expenditures of about U.S. $2.5 billion were involved. It also must be realized that there is an impact of cadastral S&M on the national and world economy in terms of cost/benefit. However, at this time it would be difficult to quantify this impact due to a lack of pertinent data and analyses. It is considered that this aspect of cadastral S&M should be the subject of a special and comprehensive study.

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