United Nations E/CONF.93/BP.11

Economic and Social Council

Distr.: Limited
15 December 2000

English only

Seventh United Nations Regional Cartographic Conference for the Americas
New York, 22-26 January 2001
Item 7 (a) of the provisional agenda*
Reports on achievements in surveying, mapping and charting in addressing national, subregional, regional and global issues, including policy and institutional issues

Global mapping and national mapping organizations at the turn of the millennium: the challenge of a changing world

Submitted by the Secretariat**

* E/CONF.93/1.
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00-81157 (E) 100101

Abstract

As we enter the New Millennium we are confronted with a world where the actions of humans rival natural processes as agents of environmental change. With respect to the land surface of the globe there is currently no comprehensive, coordinated, operational, science quality, global measurement, mapping, monitoring, and modeling program in existence. The facts are: Large scale datasets do not exist for most of the earth at the present time, even in highly developed countries; development of such datasets is labor intensive, in terms of both scientific and technical personnel and is, therefore, labor expensive; and, although such datasets could support a wide variety of useful applications specific to a given locale, no single use can generally justify the cost of their development. Since the late 1800s there have been attempts to create global scale maps through international cooperation. While these efforts were well meaning the challenges inherent in the production of such maps could not be overcome; challenges such as national security and national sovereignty, lack of appropriate technologies and institutional support and the lack of resources, both human and financial. Today as we move forward together toward a better appreciation of the nature and limits of our planetary resource base an important question arises: Can you imagine our world today without maps? Let us ask another question: can you imagine a world without National Mapping Organizations? Do not dismiss these rhetorical questions too quickly. Think seriously about their implications and the potential alternatives, fueled by rapidly evolving technologies, which are beginning to come into existence in some Nations. Then turn it around. If you could design the charter of your National Mapping Organization today, what would you include? The whole field of mapping is undergoing a revolution. National Mapping Organizations must change in response to advancing technology on the one hand and end user expectations on the other. What would you do to your organization to make the policy makers of your governments today so pleased with the products that its stature and funding would benefit measurably? One thing I am certain of, we must all become proactive within our own National systems. The facts are that we need to put more resources toward the science, technology, research and development, and operational aspects of large scale global mapping. Such an investment can have significant economic and security returns. From an improved understanding and management of agricultural and forest resources to identification of public health problems and the protection of diversity. From improved demographic data which can pinpoint markets or be used to mitigate suffering in times of national disasters, to a better understanding of the factors affecting freshwater quantities and quality, up-to-date

programs of mapping, and long term monitoring will help all of us.

Resources are, however, required to improve our global mapping capability, to generate the products required to support the science, planning, and resources management community. To insure that these resources are made available, each reader must become an activist. Role-up your sleeves and help.

Introduction

With respect to the land surface of the globe there is currently no comprehensive, coordinated, operational, science quality, global measurement, mapping, monitoring, and modeling program in existence (Estes and Mooneyhan, 1994). A key feature making this statement true is the inclusion of the word *mapping*. Today, no civil organization in the Federal government of the United States has a global mapping charter; no civil agency globally has the resources, or the backing of its respective government, to aggressively develop a major, high resolution, science based global scale mapping effort. The facts are:
1. Large scale, science-based datasets do not exist for most of the earth at the present time, even in highly developed countries;
2. Development of such datasets is labor intensive, in terms of both scientific and technical personnel and is, therefore, labor expensive;
3. Although such datasets could support a wide variety of useful applications specific to a given locale, no single use can generally justify the cost of their development.

There is a lack of accurate, up-to-date, geospatial data. Yet, there is no lack of issues for which such data are required. Biodiversity, demography, deforestation, desertification, freshwater resources, poverty, and sustainable economic development all are important (Htun, 1993). Important too are ecosystem health, human health, air quality, environmental treaty enforcement, and mitigation of natural disasters. A major factor hindering both scientific research and operational applications associated with these issues today is that adequate maps do not exist for many areas of the world. Depending upon scale, thematic content, and timeliness, this is equally true for both the developed and the developing world.

Many people find this hard to believe. Too often the public and the decision-makers we serve assume that the map they require exists, contains the information they seek, is accurate, and is up-to-date. Although employees of mapping organizations all know the problems associated with maps today, we must constantly remind decision-makers that information is dated when it is collected and maps resulting from such information can have limited utility in certain types of decision-making. Some mapped information is more perishable than others, e.g. continental outlines as opposed to forest clear-cutting, or urban development. We should also be aware that the value of data could many times be related to its currency. From regional planning for national sustainable economic development to understanding the current localized demographics of an urbanized area for locating a specific type of retail establishment, the spatial component of information is key in the decision making process.

We must also remind those we serve that there are a wide variety of reasons why specific types of maps may not exist for given areas. Reasons such as national security and/or national sovereignty, economic competition, pricing policies, lack of infrastructure, unavailability of technology in some nations, lack of adequate support for training and capacity building activities in some nations. The list could go on. But it is important to note here that I believe that a revolution is occurring in mapping today, fueled by rapid advances in those geospatial technologies that support mapping (e.g. Softcopy Photogrammetry, Geographic Information Systems, Global Positioning Systems, and Remote Sensing). The revolution is to some extent being inhibited by institutional inertia and lack of understanding on the part of key policy and decision-makers.

The material that follows traces the background of global map development. The focus here is on an understanding of the historical efforts that have evolved into those programs supporting the realization of improved global mapping today, with a discussion of the importance of global mapping following. Here economic and social imperatives are discussed. The paper ends with conclusions and a call for all in the mapping science to become more proactive as we seek to provide the framework information for a truly sustainable future.

Background

Murakami (1993) subdivides the history of "global geographic dataset production" into two phases. The first phase covers the period from 1891 to 1960. Murakami's second phase was the period from 1960 to approximately 1993, the time his paper is published. I believe however, that a third period of global dataset production has begun. This third phase has its beginnings in the 1993/94 time frame and is continuing today.

The first international effort directed at global geographic data collection, discussed by Murakami (1993), is traced back to 1891 when Albrecht Penck, a geographer, proposed to the world, at the Fifth International Geographical Congress in Berne, Switzerland, that each country should compile maps of their territory using standard specifications. These data could then be employed in geographic research. Substantial opposition to this idea had to be overcome, but at subsequent congresses the idea began to be accepted. Experimental map sheets were produced in several European countries and in 1909 the First International Map Committee met in London, England to discuss specifications and production methods. Agreement on specifications and production methods was reached at a second meeting in Paris, France in 1913. Both World Wars I and II had an impact on the production of these maps. Perhaps the most significant impact was the increased need for aeronautical charts driven by the evolving significance of air power. To meet this demand for map data a new International Map of the World (IMW), at 1:1,000,000 scale, the World Aeronautical Chart (WAC) was compiled. WAC map sheets were produced according to specifications by the International Civil Aviation Organization. Most of this work was done in the United

States under the direction of the U.S. Aeronautical Chart Service, now the U.S. Defense Mapping Agencies (DMA) Aerospace Center.

During World War II the U.S. Army Map Service (AMS) was also directed to produce maps at a scale of 1:1,000,000. This mapping was accomplished primarily in areas of military significance. This work by the AMS was done in collaboration with mapping organizations in the United Kingdom, Canada, and Australia. In 1953 the functions of the IMW Central Office, at the British Ordinance Survey in Southampton, England were transferred to the Department of Economic and Social Affairs of the United Nations in New York. There was concern expressed about possible duplication of the function of IMC by WAC personnel (Thrower, 1972). This concern was dispelled and it was decided to keep these two world map series separate, because their objectives are different. The IMW products are produced primarily for general and scientific purposes, while the WAC sheets are produced specifically for the aviator. It was agreed, however, that source materials should be available for the compilation of both map series and that consideration should be given to the use of a common projection and uniform sheet limits (Thrower, 1972).

At this time the millionth scale map of the world is still not complete. Some revised sheets in this series, however, have been produced. In contrast, the WAC at a scale of 1:1,000,000 was completed, in that sheets had been made for all areas of the Earth prior to 1968. Today, DMA maintains the WAC series as the Operational Navigational Charts (ONC), while the former Soviet Union and its Eastern European allies compiled international maps at a scale of 1:2,500,000 (Murakami, 1993). This product, the Carta Mira, was published by the former USSR and its allies with each of the cooperating countries having specific areas of responsibility (Thrower, 1972).

It is significant to note that all of the maps compiled during this phase were derived from larger scale existing products. Typically, this process began with the use of 1:25,000 scale maps which were successively generalized to 1:50,000, 1:250,000, and finally 1:1,000,000 (Murakami, 1993). Most of these international maps were produced for a specific purpose. The purpose was the support of military operations. The AMS maps for ground operations and the WAC/ONC products for flight operations. While the IMW products were produced to improve our understanding of global geographic conditions, most of the information depicted on these maps comes from the products developed for military operations. There is little land use information or maps and most of that which was included became quickly dated. Land cover information, particularly with respect to vegetation information, was not shown on these maps. On all of these maps the quality of the base information varies enormously from region to region depending upon the nature and availability of the source materials used in the complication of the individual products (Thrower, 1972).

The final status of these two efforts, IMW and WAC, is a good case in point with respect to the motivation of nations in the mapping area up to this time. The fact that World Aeronautical Charts are complete is because it was in the best interest of the U.S. military and civil aviation community, which has controlled a large percentage of the world aircraft industry, to have these charts complete. On the other hand, there has not been, to date, the military, economic, or environmental imperative to complete the land areas of the world through the International Map of the World Project.

Murakami's second phase begins in 1960 with the advent of digital spatial information production and the rise of geographic information systems, remote sensing, and associated technological advances that continue today. It was not until 1967 that the Central Intelligence Agencies produced World Data Bank I and in 1969 World Data Bank II was produced, although, it was not released to the public until 1975. These early digital map products are perhaps the most well known databases of the early portion of this period.

World Data Bank I and II, however, include only vector information on coastlines and national boundaries. Since this time a number of digital global data products have emerged. From the National Oceanic and Atmospheric Administration's (NOAA) ETOPO-5 product, to the project began in 1984 by the International Geographical Union (IGU) and the International Cartographic Association (ICA) to produce a standard global dataset in modern topologically structured form (Bickmore, 1988), to the Global Land One-kilometer Baseline elevation (Globe) project and the Digital Chart of the World (DCW) small scale digital global datasets have begun to emerge (Murakami, 1993). DCW, in particular, is significant, although it contains errors whose lineage can be traced back to the quality of the source material employed in its compilation.

A variety of organizations are currently in the process of revising and upgrading the quality of this important dataset. Yet, the scale and the thematic content of these datasets still do not meet the needs of environmental planners, resource managers, or public policy decision-makers, particularly below the national scale.

As stated above, the third phase in the production of global scale datasets begins in the early 1990s and can still be characterized as dependent upon continuing advances in geospatial technologies. Yet, this new phase is different because we are now witnessing the beginnings of a nascent international infrastructure to support global dataset development. An infrastructure that, while still diffuse and only partially organized, is setting directions that can take mapping to new levels as we enter the new millennium. Three separate but related efforts deserve mention here as the type of programs that characterize this period and set it apart from Murakami's second phase of global dataset development. These projects are the International Steering Committee for Global Mapping's Global Map Project, the Global Spatial Data Infrastructure effort, and the Digital Earth Project.

Global Map

Global Map is a product of the International Steering Committee for Global Mapping (ISCGM). The concept for the development of Global Map was originally presented by the Geographical Survey Institute of Japan as a result of the call for global data in Agenda 21, the document resulting from the 1992 United Nations Conference on

Environment and Development (UNCED), held in Rio de Janeiro. The plan is for a global database that consists of elevation, vegetation, land use, drainage systems, transportation, and administrative boundaries layers. The sources for these data include the Vector Map Level 0 (drainage, transportation, populated places, and administrative units), GTOPO30 (elevation), and the global land characteristics data produced from the 1 km AVHRR land cover data (vegetation, land cover, and land use). An important characteristic of this project is the involvement of National Mapping Agencies/Organizations (NMA/NMOs) and other interested organizations in the production and contribution of data sets and the validation of their accuracy.

Global mapping, as defined by Kunio Nonomura, former director of the Geographical Survey Institute of Japan, and one of the primary instigators of the Global Map project, is a group of global geographic data sets of known and verified quality, with consistent specifications which will be open to the public, considered a common asset of mankind and distributed worldwide at marginal cost (Nonomura, 1994; Nonomura, 1996; Kidokoro, 1999).

What makes this product unique is the level of active participation and call for additional national mapping organization participation. Below, figure 1 shows the status of participation as of September 2000. There are three levels of participation in the project. These levels are defined as follows:

- Level A: provide and process data for your own country, and assist one or more Level C countries (red)
- Level B: provide and process data for your own country (green)
- Level C: provide data for their country (blue)

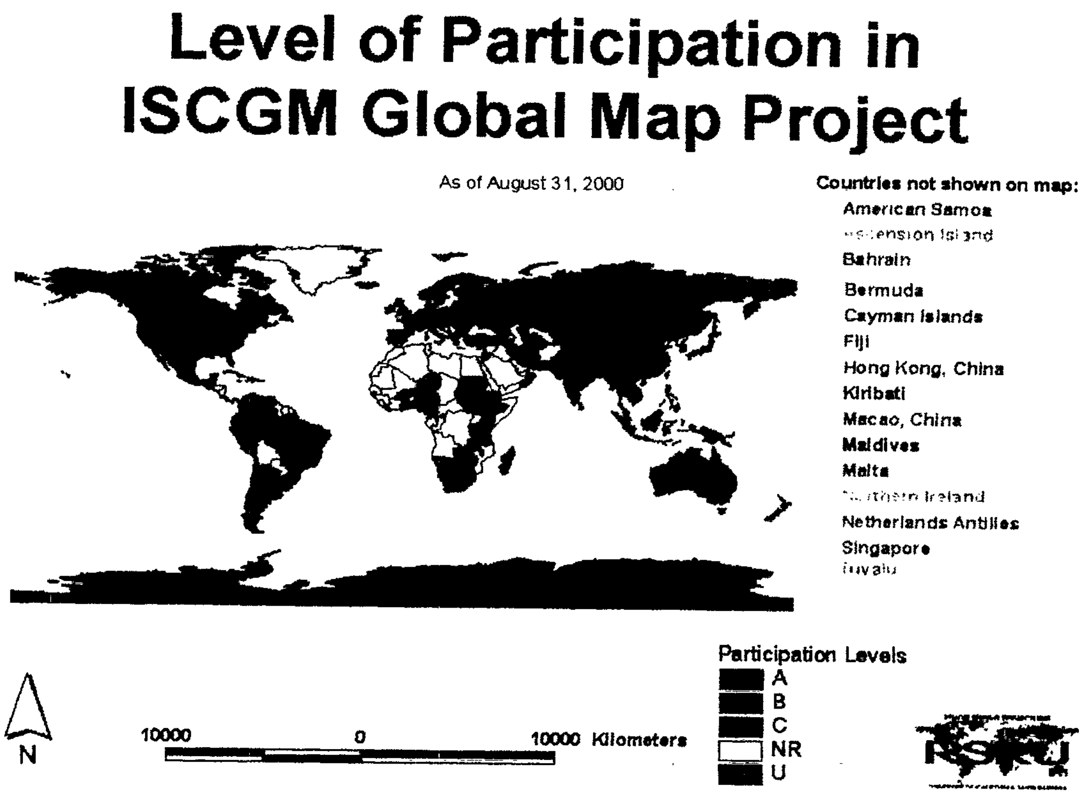

Figure 1 Participation in the Global Map project

In addition to NMOs, several organizations are participating as either full members or observers. SCAR, the Scientific Committee on Antarctic Research is participating as the representative for Antarctica. There was discussion as to whether or not CERCO, the Comité Européen Des Responsables de la Cartographie Officielle, the organization of European national mapping agencies, would represent its approximately 35 members in the Global Map project. The decision reached was that each country would participate on their own, if they so choose. Additional organizations that are represented at ISCGM in an advisory capacity include the United Nations and the United Nations Environment Programme, the United Nations University, the National Geographic Society, and the International Cartographic Association. Liaison status has also been accorded the International Standards Organization (ISO) and CEOS. Other organizations are added to the list as they indicate their interest in participating.

The effort put into this project has been significant. Meetings of the ISCGM have been held since 1994 (Tsukuba, Japan, 1994; Santa Barbara, California, 1996; Gifu, Japan, 1997; Sioux Falls, South Dakota, 1998; Canberra, Australia, 1998; Cambridge, United Kingdom, 1999; Cape Town, South Africa, 2000; Cartagena, Colombia, 2001 (planned)). During this time, several working groups have been formed to focus on specific issues, including standards and specifications. Some of these have subsequently been disbanded, their tasks completed.

Currently, data from the GTOPO30, Digital Chart of the World, and the 1-kilometer global land cover data sets have been distributed to the participating countries. These countries' national mapping agencies will then have the option of validating the data as it currently exists, or contribute more up to date national level data at the 1:1,000,000 scale. The completion date of Global Map version 1.0 is November 2000. Discussion is underway for version 2.0.

Figure 2 is an example of the Global Map product, presented by Motoyuki Kidokoro at the Cambridge Conference, July 1999.

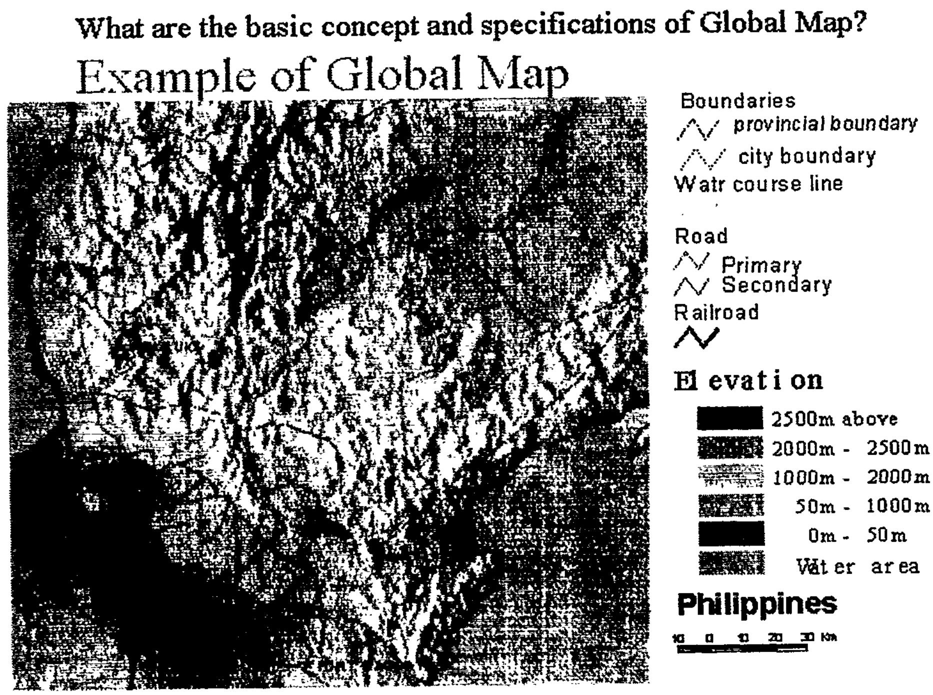

Figure 2 Example of the Global Map product (Kidokoro, 1999)

Global Spatial Data Infrastructure

The Global Spatial Data Infrastructure (GSDI) activity is comprised of a group of individuals representing national mapping agencies, international organizations, and standards organizations. GSDI was defined at the second GSDI Conference (1997) as "the policies, organizational remits, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that those working at the global and regional scale are not impeded in meeting their objectives."

Personnel from organizations and individuals interested in the establishment of a GSDI first met September 1996 in Bonn, Germany, and focused on "The Emerging GSDI." A second meeting was October 1997, Chapel Hill, North Carolina, and the focus was "Towards Sustainable Development Worldwide." At Chapel Hill, GSDI was defined, as noted above. Also, "one of the central findings of the 2nd GSDI Conference is that the GSDI is of vital importance to implementation of Agenda 21 of the Rio Summit and to multi-national environmental conventions and that it should be placed as central support for decision making before the meeting of the UN Commission on Sustainable Development in 2001. Further, the GSDI is critical to the attainment of substantial and sustainable development in both the developed and developing countries of the world" (1998). The third meeting, in Canberra, Australia, November 1998, focused on the "Policy and Organizational Framework for a GSDI." A primary finding from this third meeting is that "National Mapping Organizations/Agencies play a key role in ensuring that accurate, up-to-date geospatial framework data are developed and maintained. Such data are key to, among others, the promotion of sustainable economic development, improvement of environmental quality, resource management, upgrading public health and safety, modernization of governments at local, national or regional levels, and the responses to natural and other disasters. Therefore such organizations play a vital role in facilitating the development of a GSDI" (1998).

Digital Earth

The concept of Digital Earth was first publicly announced in 1998. The idea is summarized as: A Digital Earth could provide a mechanism for users to navigate and search for geospatial information - and for producers to publish it. The Digital Earth would be composed of both the "user interface" - a browsable, 3D version of the planet available at various levels of resolution, a rapidly growing universe of networked geospatial information, and the mechanisms for integrating and displaying information from multiple sources (Gore, 1998).

As a result of this challenge by the Vice President, NASA and cooperating federal agencies and industries have responded by creating a Digital Earth organization, headquartered at NASA. Digital Earth was formally defined at the 2nd Interagency Digital Earth Workshop in September 1999 as "a virtual representation of our planet that enables a person to explore and interact with the vast amounts of natural and cultural information gathered about the Earth" (http://www.digitalearth.gov). The current proposed structure for this effort includes a consortium of relevant and interested agencies and organizations, a steering committee, and a federally sponsored institute to provide administrative support (Foresman, 1999).

Digital Earth will have an effect on a wide variety of areas related to geospatial data and technology, including science and applications, standards and architecture, data access and distribution, visualization and exploration, and education and outreach. In essence, digital earth focuses on the technology, while GSDI focuses on the standards, and Global Map will provide the content.

Currently, major players in this effort include federal government agencies participating in the Interagency Working Group on Digital Earth, these include NASA, the Environmental Protection Agency (EPA), USGS. Private industry, the media, and academia are also playing roles in the U.S. Digital Earth effort. In addition, an international Digital Earth symposium is being held on a biannual basis, the first one hosted by China, with Canada scheduled to host the second one in 2001.

Discussion

In many developing countries, even well-understood environmental changes with local causes and effects, that in the aggregate may represent a global concern, often have very low priority with officials compared to such issues as food, health care, and safety of the people. Global change issues and environmental concerns are often treated as rumors from more fortunate neighbors. In a number of countries, the high-resolution datasets needed by the world community are classified and are not permitted to leave the country in any form. In some instances where such data are exchanged with "friendly" nations, restrictive agreements limit access to these data. Even in highly developed countries, where scientific understanding is widespread, it is often difficult to generate the political and financial support for the correction of widely recognized environmental problems (Mooneyhan, 1993).

There is a growing recognition that the environmental and/or economic health of Nations affects national security. Indeed, in the United States Land Remote Sensing Policy Act of 1992 (Public Law 102-555) in its findings, Section 2. (1) finds: "The continuous collection and utilization of land remote sensing data from space are of major benefit in studying and understanding human impacts on the global environment, in managing the Earth's natural resources, in carrying out national security functions, and in planning and conducting many other activities of scientific, economic, and social importance." While an image from a satellite is not a map, it is important to note that mapping is now being done from satellite systems. The fact that United States Public Law 102-555 puts the understanding of human impacts on our global environment and management of the Earth's natural resources on a par with national security is significant.

In times of military threat maps are rapidly generated. Conditions are assessed. Positions are analyzed. Options are developed, and actions are taken. What we have today are unprecedented global, environmental, and economic threats. When we understand that our ability to create environmental change on a global scale now rivals and is surpassing that of natural factors, we have in a very real way a new type or class of national security threat. These new threats also require that we assess conditions, analyze positions, develop options, and take action. But first, we need to come to some understanding of the nature of the threat. So if we produce maps to better understand the nature of the military might we are up against, why shouldn't we also have maps that help us to better understand the nature of the social, economic and environmental issues (threats) we face?

Today's economy is most certainly a global economy -- economic downturns in one part of the world can and do have effects on other parts of the world. The financial stability, human health, environmental health, and political stability are all susceptible to events occurring around the world. Transboundary issues, such as air and water quality, shared watersheds, can have great impacts on a region's economic well-being. A number of these issues are in the process of being covered by international conventions or protocols. Global geospatial framework data can assist in speeding the recovery from major natural disasters, such as hurricanes and earthquakes. Two specific examples are included here. The first deals with the use of geospatial data/information in times of natural disasters and the other with the use of such data in the enforcement of multi-national environment agreements (e.g. the Kyoto Protocol).

Local To Global: Example Of The Application Of Global Map Data

To demonstrate the usefulness of global map data, Researchers in the Remote Sensing Research Unit, University of California, Santa Barbara, overlaid a variety of global data sets upon imagery of the flooding in Mozambique, which occurred in March and April 2000. Their goal was to demonstrate the use of global scale data for the assessment of local to regional scale natural disasters; in this instance, to assess the extent and the effects of the flooding in the southern African country of Mozambique.

Questions asked were could data sets such as those that are available, those included in version 1.0 of Global Map, and those that may potentially be included in version 2.0, be employed within the context of a GIS that combines raster and vector data to determine:

- How many people were affected by catastrophic flooding?
- What was the total area of different land cover classes that could have been or were affected?
- How much of the transportation routes were damaged or potentially could have been damaged in the area surrounding the Limpopo River Basin, Mozambique?

Several global datasets were found to be useful for this course scale analysis. Using global to regional scale data, a disaster's affects can be mapped and assessed. Using data published by several international aid organizations, as well as maps of the flood extent that they had made using different datasets and methodologies, it was determined that their differences were considerable.

The flooding related to the Mozambique disaster events occurred during the February - April period of 2000 as a result of five large tropical storms and hurricanes, the floods that resulted covered a 50 mile wide area, displaced hundreds of thousands of people and devastated the recovering economy of Mozambique (Kriner, 2000; Murphy, 2000). Floodwater rose quickly, in one instance as much as three meters in half an hour! Winds in excess of 100 miles per hour were recorded, heavy precipitation and cloud cover hampered rescue efforts for weeks (CNN, 2000a). By April approximately 700 people were confirmed dead and nearly 1,000,000 were either homeless or in need of aid. Nearly 70 percent of Mozambique's 19 million people live in poverty, this heightens the necessity for international involvement when disaster strikes (CNN, 2000b; Datt et al., 2000). International aid organizations, along with the aid organizations of governments from the surrounding countries, began to react to the situation and assess the damage but the international community was said to have been slow to react, this could possibly have been due to the unavailability and/or inaccessibility of accurate spatial information. For the purpose of this effort, at this time, it is unclear what information was available to those aid organizations at the time the events occurred, and on what data they based their assessment and planning. What is quite clear, however, is that the quality and value of the map data that is currently publicly available can be improved considerably by a globally consistent base dataset. Although there are many aspects to this disaster assistance effort, those who direct aid to people need access to reliable, accurate and timely spatial data upon which to base decisions.

Satellite imagery of the affected area was provided to the public by several agencies. Processed image map products derived from imagery acquired by weather satellites (Meteosat-7 and NOAA-14 AVHRR) of the hurricanes were provided on several NASA/NOAA sponsored websites. Remote sensing imagery can be used to track the progression of hurricanes, to forecast rainfall intensities and to assess damage caused by flooding. USGS, NASA and the European Joint Research Centre made Landsat 7 ETM+ as well as classified SPOT-4 image maps of the extent of the flooding available on the web as well. These images were useful for determining the extent of flooding involved, especially the SPOT-4 imagery, which was classified by the European Joint Research Centre's Space Applications Institute to show the extent of the flood for two critical periods between hurricane events, 21-29 February 2000 and 1-10 March 2000. The NASA Landsat imagery was acquired during two periods, before the flooding (August 22, 1999) and after the floods reached their maximum extent (March 1, 2000), clouds and shadows obscured some inundated areas but provided a very real perspective on the magnitude of the flooding.

Radar imagery is quite possibly the best sensor system available for mapping the flood extent of such a vast area because it is not impeded by clouds or atmospheric moisture and, due to the extreme difference in the reflective capacity of standing water and the volume scattering capacity of the closed canopies, has the capability of accurately mapping flooded vs. non flooded areas. Radarsat provided a series of images of the flooded area that demonstrated this capability. Visible wavelength imagery (i.e. Landsat 7 ETM+ and Spot 4) also showed the extent of flooding well, and by using a time series composite the flooded areas can be reasonably well classified.

Four datasets were found to be useful for deriving the aforementioned statistics: the 1-km resolution IGBP DISCover land cover dataset, the Gridded Population 4-km resolution dataset, a Land use polygon coverage at stated scale of 1:200,000 and Digital Chart of the World coverage of transportation routes, political boundaries and coastline at 1:1,000,000 scale.

Figure 3 USGS/USAID Cropland Use Intensity (1:200,000)

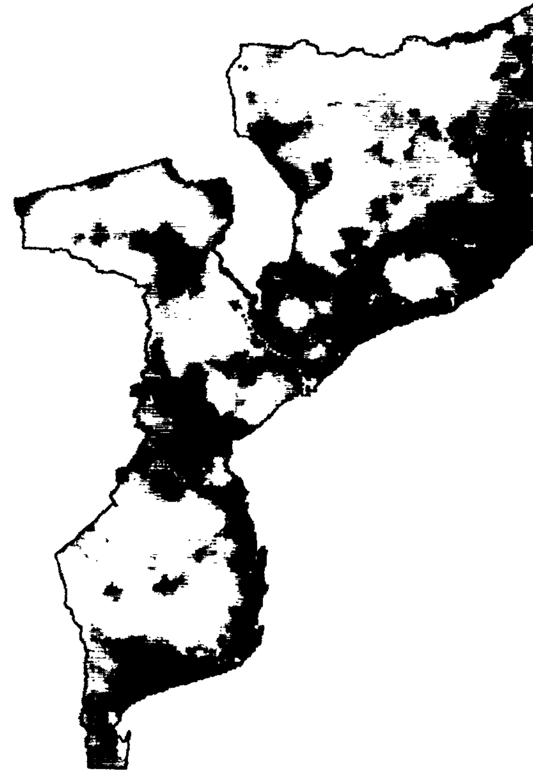

Figure 4 UNEP/GRID Population Density (4 km grid cells)

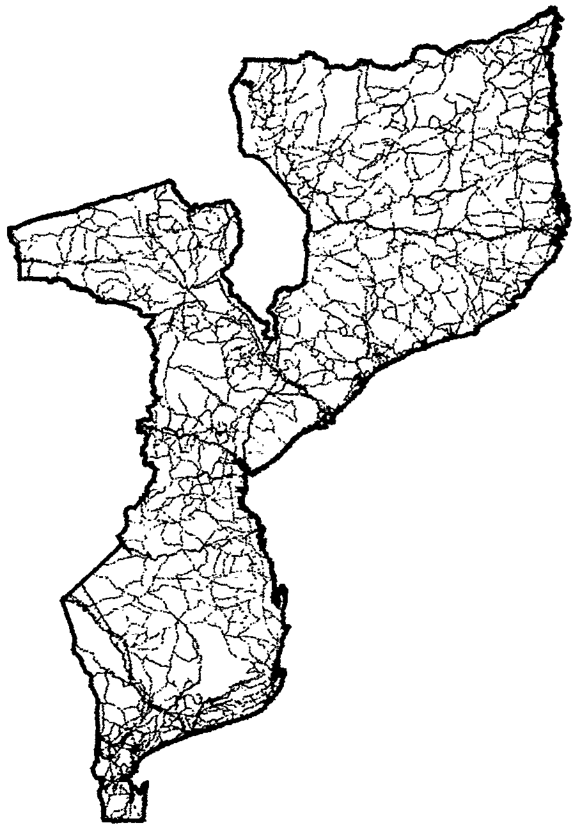

Figure 5 Roads, Railroads, Rivers, and Political Boundaries (1:1,000,000)

Figure 6 USGS/EDC IGBP DISCover (1 km grid cells)

Mapping the transportation, land cover and population density of the affected area provided a general picture of the flooded area but expectedly there were differences in the statistics derived from the base data using the flood extent maps provided by the various agencies. The nonspatial data, i.e. current mortality statistics and other site specific information, were ubiquitous due to media attention but actual map data were not. For the most part, the maps of Mozambique and the area of interest, found through numerous intensive searches, often did not have a date or source associated with them. Some of the web images were not intended for use in mapping but were never the less all there was available. It was interesting to note that a vast majority of the transportation routes, rivers and other important feature locations such as airports and towns on these maps were derived from one or two sources. These sources are Digital Chart of the World compiled by the Department of Defense and from Operational Navigational Charts, also compiled by the Department of Defense. These data are out dated, especially in poorer third world countries, but, as of this writing there is still no base map from which individual mapping programs can begin to compile globally referenced locally usable spatial information that are both relatively current and verified.

Table 1 Comparison of results from data from different agencies

	World Food Program	State Department	Joint Research Centre
	No Date	March 3	February 21-29
Affected Area (km^2)	8,253	11,514	4,239
DCW Roads (km)	907	1,296	457
DCW Railroads (km)	121	200	63
Developed, Irrigated Cropland (km^2)	377	389	324
IGBP Class 12 (km^2)	695	1,152	310
IGBP Class 13 (km^2)	285	397	166
IGBP Class 14 (km^2)	743	542	234
Affected Population (people)	526,704	544,864	376,560

The 1-km resolution IGBP DISCover land cover dataset (a Global Map data layer) downloaded from the USGS EROS Data Center was the first global scale dataset used in this investigation because it contained land use classes that encompassed human use. One of the original questions was how, and more importantly where, the flooding had affected people; how many square kilometers of cropland were flooded? Where were the urban centers within the flooded areas? How much area of mixed use (i.e. seasonal agriculture or small crop farming) was flooded? The IGBP dataset uses 17 classes to describe the earth's land surface. There were three land use/land cover classes (IGBP classes 12 (Croplands), 13 (Urban and Built-up) and 14 (Cropland/Natural Vegetation Mosaic)) that were of use in this course scale investigation into the uses of global to regional scale datasets for disaster assessment. These three classes were used to determine the number of square kilometers of land being actively used by people, or being utilized for various types of farming, that were affected by the flooding using the different flood extent boundaries. It is important to note here that in the DISCover data set the urban class was derived directly from the Digital Chart of the World and was not derived from the processing of satellite data as all other classes were. The urban class was also not subject to the validation that all other DISCover classes underwent.

The Gridded Population 4-km resolution dataset, downloaded from UNEP/GRID, was used to assess both the distribution of population density and to see how many total people, according to a sum of the clipped grid cell values, the floods potentially affected. Population density is calculated based on an interpolation of point data values and difficult to collect and update in isolated areas of sub-Saharan Africa. At 4-km, this was the coarsest global scale dataset used for this general investigation. The maps produced by clipping this dataset with the different flood extent boundaries shows the population density and allowed for tabulating the population totals, but these figures are at best rough approximations due to the nature of the data. Civil wars, drought and natural disasters over the past decade have caused large population fluctuations between the six provinces within Mozambique, these factors add to the uncertainty of this dataset. All data issues aside, this dataset did provide a general depiction of the population distribution within the extent of the flooded area but the population totals calculated from each of the flood extent maps may be in error due to many reasons, including the course resolution.

A land use polygon coverage at a stated scale of 1:200,000, downloaded from USGS Eros Data Center was the finest scale data used for this project. Being a well documented vector polygon coverage made it easily to incorporate into a GIS with the other layers. This dataset, like the IGBP dataset, contained numerous classes for use by researchers and regional resource assessment applications that were not applicable for our purposes. Two classes were extracted from this dataset, the "Developed, Irrigated" and the "Flood Recessional Agriculture" classes. Using the flood extent coverages, these extracted polygons were clipped and the areas of each were totaled. These statistics are believed to be the most accurate because they were derived from 1:200,000 scale data. Unlike the IGBP DISCover data and the Gridded Population data, which were global in scale, this data set is only reasonably applicable for regional to local scale applications. This scale restriction for global datasets however is changing with the creation of new software technologies that offer the potential for high speed virtual roaming access, via the internet, to fine scale multi-layer spatial information that is a part of a seamless globally consistent database. With the aid of high speed computing and large capacity storage hardware, scientists have the tools to access and work with global datasets.

Digital Chart of the World Level 1 coverages of transportation routes, political boundaries and coastlines were used, and served as the geographic reference for all of the other data sources collected. DCW is the digital representation of Operational Navigation Charts with an original scale of 1:1,000,000. This base cartographic map series was designed to support medium altitude route navigation, operational planning and intelligence briefings (Langaas, S and Tveite, H. 1995). Because DCW is a globally consistent vector database, it often serves as a geographic reference for many other global datasets and, most importantly, it is free and publicly available. The Roads, Railroads, and Political Boundaries of Mozambique were downloaded, imported and extracted. These layers were clipped with the different flood extent boundaries and the lengths of each set were tabulated. Because the political boundaries, rivers and roads of DCW were used as a geographic reference for registering the image maps of flood extent collected, it was feasible to co-register and compare them. Both the flood extent map produced by the World Food Program (using GTOPO30) and the map produced by the World Food Program (using "imagery, reports, elevation analysis and flood history") used these same features as a reference in their compilation. By sharing a common base layer these maps can be accessed in terms of their relative accuracy, as well as to compute statistics that can be used for disaster assessment.

UNFCC/Kyoto Protocol

Article 3 of the Kyoto Protocol to the United Nations Framework Convention on Climate Change, signed in December 1997, requires of the "Annex I" countries (developed nations plus the FSU states) returning individually or jointly to their 1990 levels these anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol. Five greenhouse gases or classes are specifically mentioned in the Protocol: carbon dioxide, methane, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. In July 1997, the U.S. Government issued a

Climate Action Report that attempted to reconcile the congeries of assumptions for the US as to sinks (e.g., forest coverage) and sources (e.g. rate of adoption of energy-efficiencies), and "emission-trading mechanisms"—factors that will determine reductions required of Annex I countries from the 1990 baseline, once the treaty is ratified.

The question arises now for all of us, just how will the baselines for Kyoto be established. A suggestion that has been made is to link emission levels to various land cover types. An important question in establishing the Kyoto baseline is the development of the linkage between source level terms for the greenhouse gases covered in the protocol and global land cover types. The next question is do we as a global community have a relevant land cover product from which the area term for each class of cover for specific geographic areas can be derived? The answer to this question at this time must be no. There are a wide range of global scale land cover maps and global land characteristics databases derived from a wide variety of sources. Which should we use for establishing the baseline land cover from which Kyoto can be measured?

Considerable discussion is beginning to occur within policy industry and scientific circles concerning the implications of the Kyoto Protocol for future economic development at scales from local to global. This discussion is already global in nature and has important implications for how the U.S. is perceived by the global community. The European Commission is in the process of focusing a research agenda entitled: "Global Monitoring for Environment and Security". This agenda is laid out in a document entitled: Global Monitoring for Environmental Security: A Manifesto for a New European Initiative. This Manifesto proposes the idea that a global environment information service would represent a significant European contribution to the implementation of the Kyoto Protocol. The document already has the formal backing of Europe's space agencies and researchers in Europe are already gearing up to address the challenge of examining how agreements such as Kyoto can be monitored and verified using a combination of remote sensing and in situ data.

An important question here is what is the role of National mapping organizations in this discussion? Space Agencies appear to be leading the way. Is this right? Is this acceptable? What can be done concerning this situation? In all of the discussions that I have been involved in concerning this issue with my European Colleagues is that Europe could care less that the U.S. has not ratified the Kyoto Protocol. They have and they will develop their own tool to verify compliance with this and other important international environmental agreements. That is they will use the data they acquire to derive the information they use in any negotiations involving questions of compliance. Is this really going to be the response of all regions of the world? Can anything be done to come up with an acceptable standard geospatial product here. If so, should not National Mapping Organizations play more of a role here?

The economic and environmental health of nations are key factors affecting national security. Better maps are a fundamental requirement if we are to improve our management of our planetary resource base and improve our economic well-being and environmental quality. Yet, when the reasons for lack of maps are examined carefully, other than nonexistence and perhaps restrictive data policies, national security is the major factor inhibiting access to map products.

Thus we have a paradox. We need accurate, up-to-date, large scale maps to improve our understanding of the Earth as an integrated system; plan the wise use of the resources base of nations; and, to assess and monitor environmental quality at scales from local to global. Improvements in the environmental quality and economic well being of nations around the world can enhance the quality of life of peoples and improve global economic conditions. These factors can have the effect of improving our national security. On the other hand, the widespread availability of large scale maps can represent a tactical military threat. It cannot be denied that maps have and will continue to play a key role in military operations. So we have the mapping paradox. Maps used one way can improve national security, but used another way are a threat to national security.

One answer to this paradox might be that we should have such maps, but access to them should be restricted. This is the intelligence community model. The intelligence community wants to control access to data/information. There are good and valid reasons for the position. These reasons include the reduction in potential threats to the security of a nation by not allowing other nations, or in some cases even their own nationals, access to maps of sufficient quality to support military operations. If we agree that information and the control of its flow to decision-makers represents power, we have another reason for controlling access. We should also be aware that, from a decision-maker's standpoint the concept of plausible deniability applies in a very real way here. If someone does not know, or cannot prove, that I have access to knowledge when a decision is made, the decision maker has a better chance of not being held directly responsible for unintended consequences that might flow from that decision. This concept has served politicians well throughout history. The world is changing, however.

We believe that the problems associated with the management of the Earth as a global community are much more complex than those associated with specific military actions. Control of the flow of information has value in tactical military situations. This control, however, inhibits scientists, planners, and resource managers as they attempt to provide a more basic understanding of the global system; and as they search for the environmental indices that facilitate early detection of global change and the factors that can lead to a more sustainable future.

The problem is how do we fight the fact that data and information concerning resources and our environment are perceived by some to be a basis for power? The intelligence community is not the only community at fault here. The intelligence community knows data are power but, so also do international organizations, civil agencies, academics, industries, and non-governmental organizations. How do we convince the affected parties, all of us, that the problems associated with sustainable development and global environmental change are so critical that we must, in so far as practical, break down the barriers to the flow of high quality geospatial information? These barriers inhibit our improved understanding of the current status of our global resources base, and the factors that affect the quality of our environment. Even if we break down these barriers, even if we would allow maps to be generated, we must understand that the production of maps is a complex and expensive task. Here we are talking about base cartographic products and/or specific thematic coverages, e.g. topographic, land cover, land use, hydrology, land ownership, not road maps. We are also talking about standard products on a global scale, not just maps for countries such as the United States or the developed world.

If mapping were easy and inexpensive we would already have better maps. If mapping were simple we could have more up-to-date maps. The simple truth is, mapping is complex and expensive both in terms of personnel and financial resources. There is also a lot we do not understand about the type of mapping necessary to improve our understanding of the Earth system. Those of us who are involved in the process of developing the knowledge base in this area are also aware of the abysmal job we have done in trying to garner the resources required to correct this situation.

That there is considerable science left to do in mapping cannot be denied. We have not even come close to answering the basic questions in cartography associated with error/accuracy, scale or time to name an obvious few. As Estes and Star (1993) state "each of these are fundamental attributes of spatial data that require long range thorough research." Morrison, (1993) states: "the ability to visualize intangibles can create a new era for cartographers to explore and research." Such research is made all the more urgent by the rapidly expanding use of geographic information system (GIS). GIS's are dependent on the accuracy and currency of the base cartographic products that form the foundation of the systems database. As use of these systems expand, more and more of us will come to realize that the basic data we require is either not there, not current or not in a form which we can readily utilize. What can and must we do to improve this situation? This question leads to a series of concluding questions and comments.

Conclusions

Questions that arise here include:

1. Can we, all working together, break through the mapping paradox and balance the scientific need to understand the Earth as a system, with the need to protect national security and maintain national sovereignty?
2. Can those of us involved in land processes research rise above our work in our "own personal perfect pixel packages" and support something that can benefit us all?
3. Can we rise above the pursuit of the latest technological "flavor of the day" (where the bucks are) and work to help create a key set of national and global base cartographic products?
4. Can we educate the public, politicians and policy makers, key agency personnel, the Administration, and importantly our science community colleagues to dispel the myths:
    - That the maps needed to support our science do exist;
    - That mapping is easy; and,
    - That there is no science left to do in mapping? And,
5. Can we all work together to generate the resources required to support a significant expansion in the activities in this important area?

We must stop perpetuating the mapping myth. We need to be heard loud and clear. Adequate maps for land processes and many other science investigations do not exist! Mapping is not easy nor is it inexpensive! There is a lot of fundamental work to do in the mapping sciences! If we do not say these things, no one will.

As we enter the New Millennium we are confronted with a world where the actions of humans rival natural processes as agents of environmental change. As we move forward together toward a better appreciation of the nature and limits of our planetary resource base an important question arises. Can you imagine our world today without maps? Think about that for a moment before you decide. Step back, take your time, and contemplate what would be the implications of such a situation for political governance, commerce, environmental management, social institutions, cultural practices, let alone the sovereignty and security of Nations? How would our civilization function? Indeed, could our civilization function?

Now let's ask another question: can you imagine a world without National Mapping Organizations? Again, do not dismiss this rhetorical question too quickly. Think seriously about its implications and the potential alternatives, fueled by rapidly evolving technologies, that are beginning to come into existence in some Nations. Then turn it around. If you could design the charter of your National Mapping Organization today, what would you include? The whole field of mapping is undergoing a revolution. I believe National Mapping Organizations must change in response to advancing technology on the one hand and end user expectations on the other. What would you do to your organization to make the policy makers of your governments today so pleased with the products that its stature and funding would benefit measurably? Answering this is an exercise that is certainly deserving of a future conference.

One thing I am certain of, we must all become proactive within our own National systems. The Federal agencies I most often deal with, i.e. the United States Geological Survey, the National Aeronautics and Space Administration, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, are all trying their best within the limitations of their charters and their resources to support our community. Yet, when we examine the need versus current activity, we conclude that changes must occur. National Mapping Agencies in all countries must be given expanded charters and increased resources if we are to reduce our current ignorance of National and global conditions.

The facts are that we need to put more resources toward the science, technology, research and development, and operational aspects of large scale global mapping. Such an investment can have significant economic and security returns. From an improved understanding and management of agricultural and forest resources to identification of public health problems and the protection of diversity. From improved demographic data which can pinpoint markets or be used to mitigate suffering in times of national disasters, to a better understanding of the factors affecting freshwater quantities and quality, up-to-date programs of mapping, and long term monitoring will help all of us.

Resources are, however, required to improve our global mapping capability, to generate the products required to support the science, planning, and resources management community. To insure that these resources are made available, each reader must become an activist. Role-up your sleeves and help.

Our world is changing. It always has and will continue to do so in the future. Some changes are local in nature with global impacts (e.g. deforestation). Other changes are global in character with local and regional impacts (e.g. greenhouse gasses). The common thread here is to understand the spatial and temporal dynamics of change, and to do so, we must have baselines. Some set of initial conditions away from which rates of change by areas of the globe can be measured. Maps are a key resource required for baselines against which land processes can be judged. Better map information in digital or analog form can improve our understanding of those factors that influence sustainable development and impact environmental quality. The whole mapping process needs to be reinvigorated. We need better, more accurate, more timely, more relevant map products. We need spatial information on subjects for which maps do not exist. More accurate maps can help us to better manage this planet, the only known closed life support system that has sustained life, as we know it, for longer than decadal time scales. Maps are too important to let the myth of their existence be perpetuated. Act now!

Acknowledgements

The author gratefully acknowledges the help and assistance of Ms. Karen Kline, a highly valued Senior Researcher in the Remote Sensing Research Unit at the University of California, Santa Barbara, in the production of this paper. Without her assistance, review and editing this work would not have been completed on time. Thanks also to Mr. Jeffrey Hemphill for his help in the production of the material concerning Mozambique that is included here.

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