Of Maps and Myths

John E. Estes and D. Wayne Mooneyhan

Abstract

For many areas of both the developed and developing world, the spatially accurate data required to effectively support environmental planning, resources management, and public policy decision making do not exist. There are a variety of reasons for this lack of map data. Mapping is neither easy or cheap. Issues of both national security and national sovereignty are involved. There is a need to reinvigorate and expand our mapping programs to make them national in focus but global in scope. It is also essential that a civil agency be given a lead role in global mapping. There is a need to work to break down the barriers that inhibit the open flow of map information that does exist, garner the resources required to fill in where there are gaps, and support efforts to increase funding for research in mapping and spatial analysis. All this must be done if we are to improve our understanding of our rapidly changing world.

Introduction

There is no lack of issues for which spatially accurate global data are required. Biodiversity, demography, deforestation, desertification, freshwater, and poverty, all are important (Htun, 1993). Important too are ecosystem health, human health, air quality, and all the major issues involved in the U.S. Global Change Research Program (USGCRP, 1993). A major factor hindering research and applications oriented studies of 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 we assume that the map we require exists, contains the information we seek, is accurate, and is up-to-date. We must remind ourselves, however, that information is dated when it is collected, and maps resulting from such information can have limited utility for certain types of studies. Some mapped information is more perishable than others, e.g., continental outlines as opposed to forest clear-cutting. The value of data is, many times, related to its currency. Mapping is an important, complex, expensive, and time-consuming task that, we believe, we are not performing today in an acceptable fashion.

The term "map," as used in this paper, refers to both digital and paper (analog) products. "Map" does not refer solely to a standardized base cartographic product, such as a U. S. Geological Survey (USGS), National Mapping Division (NMD), 1:24,000-scale, 7.5-minute topographic map that has been compiled to exact specifications, but applies as well to what might typically be termed as "maps," e.g., charts, sketches, and/or plans. The term "science-quality" is used in this paper to refer to maps whose lineage is known and traceable. In this context, "science-quality" means that, in so far as both practical and possible, the errors inherent in the overall production of these "maps" have been documented. In this paper, scale may be referred to as a specific representative fraction, e.g., 1:100,000. Scale also may be referred to by association to a particular area of study. In this regard, the following scales would generally apply:

Site = 1:10,000 or larger
Local = 1:10,000 to 1:50,000
National/regional = 1:50,000 to 1:250,000
Continental = 1:250,000 to 1:1,000,000
Global = 1:1,000,000 or smaller.

The authors realize that scale can be confusing. Yet, one more set of internal definitions is needed to help clarify what follows. The reader should be aware that, when we say high resolution datasets, we are talking about maps whose scales would generally be in the range from 1:10,000 to 1:100,000; while low resolution datasets would generally be in the range from 1:1,000,000 to 1:5,000,000 and smaller.

The myth that the world is "well mapped" is perpetuated in a variety of subtle ways; from the road maps we use, to the atlases we possess. Just because people can use road maps to guide them from one place to another does not mean that those maps will accurately depict how many acres of agriculturally active land one will pass through. Nor will a road map or an atlas typically provide information on timber volumes, or how fast urban areas are gaining or losing population. The myth is further perpetuated by the material we see and read in news media and scientific literature concerning the state of various parts of the Earth System: declining forests, expanding deserts, or the loss of soil productivity and biological diversity. We may know how many acres of old growth forest existed in the Pacific Northwest in, say, 1985 – but we really need to know what the acreage of old growth forest is today. How much reliance can we place on any published figures? What are the current facts? The facts are: we often really do not know.

Do we as individuals need science quality spatial information for the land and coastal zone areas of the world? Most of us might waffle on our own specific need for this kind of data/information, or may only need such data for specific areas of interest to us. Do we as a nation need this kind of information? Most of us might say yes. Do we as a nation have this kind of information? Most of us might say yes. The right answer is, we do not currently have the types of map data we require for either the U.S. or the world at scales and accuracy and timeliness necessary to support op-

Universities Earth Science Program, Universities Space Research Association, 300 D Street SW, Suite 801, Washington, DC 20024.

Photogrammetric Engineering & Remote Sensing,
Vol. 60, No. 5, May 1994, pp. 517–524.

0099-1112/94/6001–517$03.00/0

timun use in environmental planning, resources management or in the public policy decision making process. Yet, decisions still get made. Decisions based often on inadequate, *imperfect* data. Results of such decisions can be seen all around us.

The Problem

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 *et al.*, 1992). 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

- Large scale, science-based 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;
- 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;
- 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; and
- 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).

In many developing countries, even the most basic information related to resources and the environment do not exist. In Thailand, detailed soils data exist only for the lands that were deemed arable (rice producing) some 50 years ago. Therefore, much of the then-forested lands and all of the hilly and mountainous regions have never been the subject of a detailed soils survey. While these mountainous regions may not be economically important for commercial agriculture, they are the home of millions of "Hill Tribe" peoples who practice subsistence agriculture to feed an exploding population. This "slash and burn" agriculture is now on a cycle of 10 to 12 years (sometimes less), and the resulting deforestation and associated soil erosion have become major environmental problems. Soil types and erodability information, which are necessary to quantify the present condition and predict future impacts on local and regional ecosystems and/or the already marginal food supply of these "Hill Tribe" peoples, are not known. Yet each year donor agencies spend millions of dollars in Thailand and numerous other countries to support hundreds of development projects that employ modern technologies to improve economic productivity, communications, education, and environmental monitoring and assessment (often using satellite remote sensing and GIS technology). None of these donors, however, seems interested in funding such a rather mundane project as a soil survey. The result is that, as of 1993, Thailand, a rather advanced developing country, still has no detailed soils information for approximately one-third of its territory.

Thailand also can serve as an example of a second type of problem that complicates the acquisition of high resolution science quality datasets — the classification of certain data for "internal use" only. Today, in Thailand, there are topographic maps at 1:50,000-scale that have been developed using modern techniques during the last two decades. However, these data and, in fact, all high resolution topographic information are restricted by military classification to "internal use" only and are not generally available for use by Thai resource planning and management agencies, or the international science community.

Thailand is just one example but is, compared to some, one of the more cooperative countries with respect to scientific data availability. Some of the worst case examples are in countries where entire data archives have been lost or destroyed by actions during revolution, wars, and/or civil disturbances. Examples include Cambodia, Laos, Afghanistan, Liberia, Angola, Chad, Uganda, and Somalia. Other examples are countries in which high resolution spatial (large scale map) information and almost all information relative to the physical and human environment has been under internal embargo for decades. These include large areas of the world that have been under communist rule for many years, such as what was the former USSR, Bulgaria, Romania, North Korea, the People's Republic of China, and Cuba. While the situation with respect to some of these nations seems to be improving with recent changes, it could be decades before information with verified reliability is available to the world community for global research and applications oriented studies.

There are still other countries that have high resolution spatial information and the freedom to release it, but simply choose not to share it with the international science community. Both India and Brazil have been in this category for a long time. Both now, however, seem to be relaxing their environmental data/information policies somewhat following the United Nations Conference on Environmental and Development (UNCED) meeting in Rio de Janeiro in 1992.

There also exist situations where a country is not constrained by either lack of resources or by data classification policies, but simply does not place a high enough political priority on long term environmental investments to cause large scale, science quality, baseline datasets to be generated for general utility. Therefore, the information is not available to either indigenous environmental planners, scientists, and/or resource managers who are concerned with managing change on a site, at a local or national scale, or the international science community, which is concerned with change on a regional, continental, or global scale. Most of the so called "developed countries" fall in this category. Here in the United States, as in most industrialized nations, large scale, site specific datasets are often generated for one-time studies or for the solution of a specific local problem. At present, very few of these datasets ever make their way into databases that can be accessed by the interested community at large. As a result, although much of an area may be covered, the coverage consists of data that is thematically incompatible both within a given theme or between themes, was compiled at different scales, or was collectied in different time series. The result is that the datasets that cover the area cannot be combined for larger area studies or applications. In addition, because these data often reside in non-networked local databases (a map drawer in a planning agency or on the agency's tape rack), the data for all practical purposes are lost to the community. This is, in essence, the map equivalent of the scientific gray literature or worse.

Another recent trend affecting access to map data today is the move by a number of nations to operate their mapping agencies on a full cost recovery basis. The base cartographic coverage of the United States, produced by USGS/NMD, is essentially provided to the public at the marginal cost of filling a user request. The move towards full cost recovery by other nations is beginning to have an effect similar to that associated with the U.S.'s commercialization of the Satellite Land Remote Sensing Program in 1984. Both developed and developing national resource planning, management, and environmental agencies, and the scientific and educational communities are finding it increasingly difficult to accommodate these new pricing policies and justify the costs associated with the systematic acquisition of map coverages at local to national scales, let alone regional, continental, or global. This situation appears of particular concern in areas that once relied on former colonial powers for their mapping needs.

As a result of all of this, more money continues to be spent on the generation of site and local scale datasets than might be needed to develop science quality baseline datasets for an entire country. The loss to the community, however, is far more than just the money. Many local projects (scientific studies, environmental planning and resource management decisions models), with funding levels too low to produce their own datasets, are either abandoned or poorly done. The result is usually detrimental to the local environment and collectively to the global environment. In addition, large area studies (either regional or global) continue to suffer for the lack of high resolution information for (1) baseline model development, (2) calibration of remote measurements, and (3) verification of indices of change.

The authors are not the only individuals who recognize the lack of data as a major problem for "global" science. Eric Rodenburg, in *Eyeless in GAIA* (1992), writes: "Those who seek data on the condition of the world's environment are often shocked by the depth of ignorance they find." The authors of the International Geosphere Biosphere Program's report, relating global land-use and land-cover change (Turner *et al.*, 1993), state that: "At present we are unable to answer even the most basic questions, for example: Are the world's deserts really spreading and if so why? Are population pressures extending land uses, such as agriculture or settlement, to areas that cannot sustain the uses? How are deforested areas of land used, and what are the implications of these different uses for the net emissions of greenhouse gasses?"

U.S. Global Change Program related documents seldom mention the word mapping. In ranking observations and measurements of variables important to the study of global change or various time-scales, of the 68 variables mentioned, the word map is used only once. Soil maps are important in studying global change on decadal time frames (NASA, 1988; CEES, 1992). NASA (1988) also ranks the adequacy of information with respect to these 68 variables. From these rankings, it is readily apparent that those compiling the NASA (1988) report also did not feel that good land baseline data exist for the study of global change. In addition, the preparers of the CEES (1992) report realized that information with respect to these variables was (1) already dated, (2) that new variables needed to be added, and (3) that the information was held by a wide variety of institutions and organizations. The CEES (1992) report states that, while at first glance the holding of information by U.S. Federal agencies on the variables important to the study of global change may appear extensive, total holdings are "... far from adequate." For example, non-satellite data sources in the table are usually "only local, not global" and satellite sources, while "usually more global, span only limited periods of time" (CEES, 1992).

Today, then, we find that specific information on the status of mapping the globe is scarce and found in widely scattered sources (e.g., NASA, 1988; United Nations, 1990; CEES, 1992; Wolf and Wingham, 1992; Townshend, 1992). From these sources we learn that as of 1987 only 33.3 percent of the world's land surface area was covered by topographic maps at a scale larger than 1:25,000 (see Figure 1). Only 56.1 percent of the world's land surface is covered at scales larger than 1:50,000 and 58.9 percent at scales larger than 1:100,000, while some 90.2 percent is covered at a scale of 1:250,000 (United Nations, 1990). Neither the currency nor the accuracy of this coverage is directly addressed. We are told, however, that as of 1968 only 7.7 percent of the world's land surface was covered at 1:25,000 scale or greater; 23.4 percent at 1:50,000 scale; 38.2 percent at 1:100,000 scale; and 81 percent at 1:250,000 scale. So it would appear that slow, steady progress is being made.

A survey of global digital evaluation data done by Wolf and Wingham (1992) resulted in the first "...global inventory of digital elevation data stocks of known reliability." These authors conducted a survey that they report as "...accurate over 11 percent of the Earth's surface, and shows data held for 10 percent of the Earth's surface area." The authors go on to state that, "For 11 percent of the surface area of the Earth the status of data is known, for the remaining 89 percent the status is unknown" (Wolf and Wingham, 1992). If we take the potential for significant changes to occur over time, this already small number is reduced even further.

While a number of global scale thematic datasets have been developed for land cover, there is little agreement among primary sources and a distinct lack of information upon which to judge the accuracy of the data. While existing sources have proven to be "useful first-order delineations of land cover" (Townshend, 1992), they are basically unrelia-

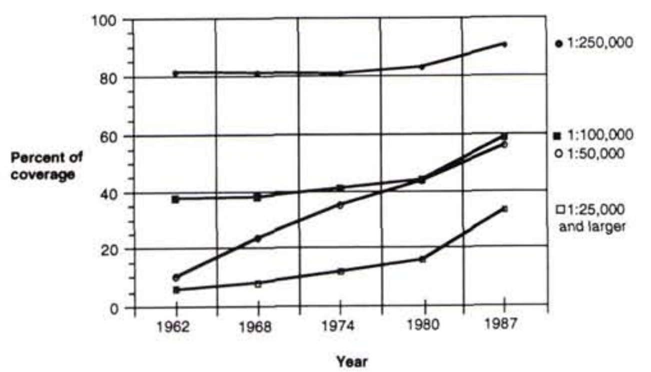

Figure 1. Percent total world land area mapped in each scale category, 1968-1974-1980-1987 (U.N.).

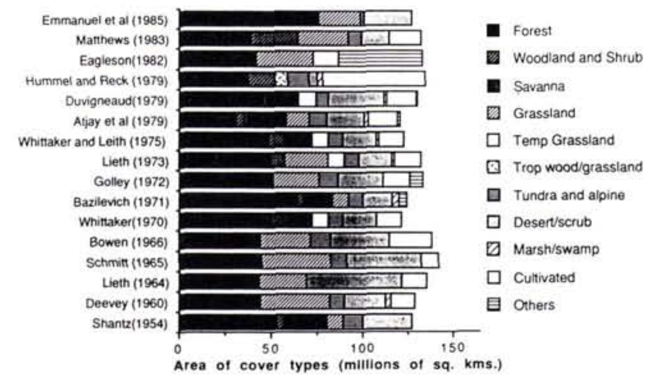

Figure 2. Variations in estimates of global land-cover classes based on calculations from cartographic sources. Differences in the total cover relate to the inclusion or exclusion of categories such as ice fields and deserts (Townshend, 1992).

ble. As seen in Figure 2 from Townshend (1992), comparisons of these global land-cover classifications for the period 1954 to 1985 show variations of as much as 100 percent in major cover types (e.g., forests) among different sources. Townshend (1992) goes on to state that the "... shortcomings of these cartographic approaches suggest the strong need to develop land-cover datasets derived from remotely sensed data."

Discussion

Science quality, global land surface cover maps are important for a number of reasons. If we are asked to maintain current global environmental conditions to look for subtle changes, it would seem logical that we would need a map of the areal extent of key components of the Earth System as a baseline. If the global change science community continues to take point measurements of key environmental parameters, e.g., biomass, carbon loading, and albedo (CEES,1992), then there is a need to areally extrapolate these measurements to gain global predictions for specific cover type classes. The error terms associated with areal extent of global land-cover types today far exceed the errors in precision with which many land-related global change measurements are made. In addition, if point measurements of such parameters are to adequately represent the universe being sampled, then for some of these measured parameters areal extent and spatial distribution information is critical to derive meaningful sample designs. Yet, today, we appear primarily focused on the making of measurements, not the refining of maps.

Let us illustrate by a recently published example how global land-use estimates have been developed. Information shown in Table 1 is extracted from a publication by J.F. Richards in a 1990 book, *The Transformation of the Earth by Human Actions,* edited by Billie Lee Turner. Table 1 illustrates both the changes in percent and changes in area of several classes of vegetation cover at a global scale for the period 1700-1980. The table in Richards (1990), from which this information is derived, provides data on changes for ten regions for three aggregate vegetation types: Forests and woodlands, grasslands and pasture, and croplands, which combine to give the global figures.

It is instructive to read how these figures were derived. Richards (1990) states that: These are estimated figures arrived at by "assigning" areas of natural vegetation to all world regions, then reducing that vegetation by the "assumed" area of agriculture in 1700. The area of agriculture was calculated by "estimating" the areal extent of agriculture in each region "on the basis of population estimates" in C. Mc Evdy and R. Jones, *1978 Atlas of World Population History,* Penguin Books, Middlesex, England. The remaining values in Richards (1990) are said to be taken from World Resources Institute, *1987 World Resources,* Table 18.3, "Land Use, 1850-1980," Basic Books, New York. R.A. Houghton and David Skole provided the "modeled" values for this table for the report. The source material for the table was derived from four sets of information. These sets included maps of natural vegetation, population size, and growth data for the period 1700-1980; literature on historical land use and land cover; and recent (post 1950) land-use data collected by the Food and Agricultural Organization of the United Nations. Richards (1990) goes on to state that the forcing function in land conversion was "presumed" to be expansion of sedentary agriculture. The expansion of agriculture took land from natural ecosystems in "direct proportion" to its area. The model also presumes change to be generally linear" (Richards, 1990).

The last paragraph of the note at the bottom of the table (Table 10-1) in Richards (1990), from which the information in Table 1 is extracted, is worth quoting here: "Despite its obvious limitations, this model estimate is the most plausible scenario of the land use change that we possess at a global scale. Until much more detailed work is done aimed at quantifying changes in land over time, world region by world region, we can do little more than this." This quotation sums our feelings up very well.

The question we have is how long into the future will we still be saying this type of thing? Why aren't we doing more to establish baselines now? There is some work going on here – notably, the International Geosphere Biosphere Programme, Data and Information Systems (IGBP-DIS) global land data project, and the U.S. Geological Survey (USGS) EROS Data Center's (EDC) global land-cover characterization activities. These are important, but they are in an early stage, not sufficiently funded nor staffed, and the work is at a resolution too coarse for many site, local, and national level needs. What is required is agency and international support and coordination to produce and keep current high resolution science quality datasets. We have the tools. We have the technology. Yet, we continue to lack the ability to influence

TABLE 1. GLOBAL LAND-USE 1700-1980 CHANGE

Vegetation Types (mkm^2)	Area (104 km^2)					Percentage Area
	1700	1850	1920	1950	1980	1700-1980
Forests and Woodlands 11.62 mkm^2	6215	5965	5678	5389	5053	−18.7%
Grasslands and Pasture 0.72 mkm^2	6860	6837	6748	6780	6788	−1.0%
Croplands 12.36 mkm^2	265	537	913	1170	1501	+466.4%

Source: Richards, 1990.

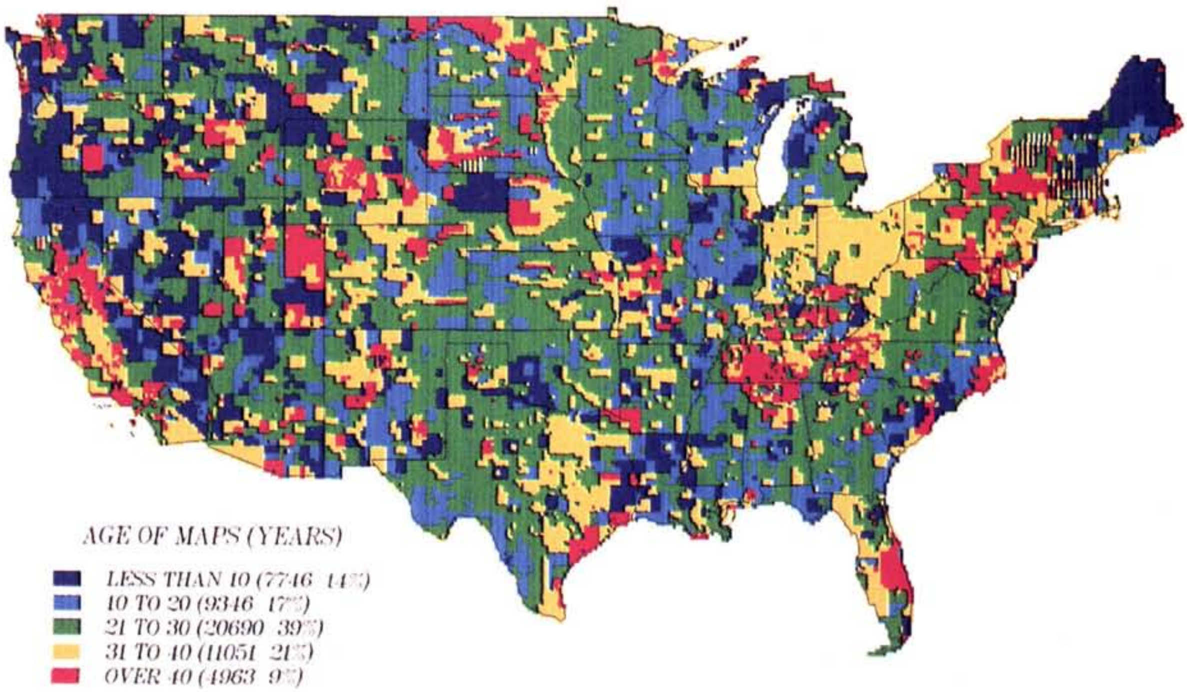

Plate 1. 1:24,000-scale topographic maps. Status by age of 53,796 maps as of 20 April 1993.

key policy makers to provide the resources and develop the infrastructure to accomplish the task.

We, as a nation, should not take comfort in the current state of our own mapping. By 1990, the National Mapping Division (NMD) of the U.S. Geological Survey had completed the 1:24,000-scale topographic quadrangle map coverage of the United States, excluding Alaska. Yet as of April 1993 only 14 percent of the area of the United States is covered with 1:24,000-scale maps that are less than 10 years old, while 9 percent of the United States is covered by 1:24,000-scale maps more than 40 years old (see Plate 1). As of June 1993 only 11 percent of the United States is covered by digital base cartographic products (see Table 2), while there are variations in the coverage by specific data layers. At a scale of 1:100,000, 65 percent of the country is covered by digital cartographic products from the U.S. Geological Survey, while 100 percent of the U.S. is covered at scales of 1:250,000 (Table 2).

This should not be read as an indictment of the NMD or other agencies such as the Environmental Protection Agency (EPA), or the U.S. Department of Agriculture's (USDA) Soil Conservation Service (SCS). Those of us who have worked with NMD and personnel from other agencies involved in map production know that these persons are trying to do their best within the constraints of a system where policy makers often do not truly appreciate the difficulties inherent in the cartographic process. It is also true that upper agency management appears, by and large, to either misunderstand or fails to comprehend the range of scientific, technical, managerial, and policy issues involved in mapping a country the size of the United States. A number of personnel in these agencies and organizations are doing what they can to dispel the mapping myths that are commonly held by their management, the Administration, and Congress but they are constrained by the system in which they operate. They need all of our help. We may disagree with some of the specific things Federal agencies and others are trying to do, but at least they are trying. And some are trying very hard.

The United States has endorsed the concept of a national spatial data infrastructure (NSDI) (National Research Council, 1993). We have a Federal Geographic Data Committee (FGDC) looking at ways to improve this infrastructure. The FGDC discusses the concept of a national spatial data framework (FGDC, in preparation), a concept where within given standards various scales of maps can be nested to form a mosaic of multi-scalar digital, thematic coverages for the United States. Why aren't we, as a nation, pursuing the same tack on a global scale? It is equally important. The national security of our nation and the environmental well-being of all people argue that a global spatial data infrastructure and a world geographic data committee should be established and that global baseline mapping at high resolution should be pursued.

Why do we currently find ourselves in this position? Why, with all the technological advancements that we have made, do we still lack global baselines of large scale land surface information? The answers to these questions are not complex, and yet they are not simple either.

The production of maps is a complex and expensive task. Today, the average cost to produce a 1:24,000-scale USGS quadrangle map is some $40,000. There are some 55,000 of these maps in the conterminous U.S. and Hawaii. Some 1,000 man hours of labor are required in the production process. It costs the USGS some $20,000 to completely revise a 1:250,000-scale map. So, mapping is not easy and it is not cheap. On the research side, we could easily expend

TABLE 2. STATUS OF THE NATIONAL DIGITAL CARTOGRAPHIC DATABASE. NDCDB STATUS CHART MOCKUP 22 JULY 1993.

1:24,000-Scale Digital Line Graph Data			
Categories	# Quadrangles for Full Coverage	Quadrangles Available	Percent Complete
U.S. Public Land Survey	41,650	13,990	34%
Boundaries	54,145	16,946	31%
Transportation	54,145	6,634	12%
Hydrography	54,145	6,450	12%
Hypsography	54,145	2,247	4%
Manmade Features	54,145	1,456	3%
Veg. Surface Cover	54,145	1,471	3%
Survey Control	54,145	1,473	3%
Non-Veg Features	54,145	1,462	3%
Totals	474,810	52,129	11%
Digital Elevation Model Data			
Categories	# Quadrangles for Full Coverage	Quadrangles Available	Percent Complete
7 Meter Accuracy		23,836	
15 Meter Accuracy		3,336	
Totals	54,145	27,172	50%
1:100,000-Scale Digital Line Graph Data			
Categories	# Quadrangles for Full Coverage	Quadrangles Available	Percent Complete
U.S. Public Land Survey	1,430	683	48%
Boundaries	1,842	998	54%
Transportation	1,842	1,842	100%
Hydrography	1,842	1,842	100%
Hypsography	1,842	391	21%
Totals	8,799	5,756	65%

the budget of a national lab on a global mapping activity. We are not suggesting that a national lab do the job, we are only indicating what we believe is the relative magnitude of the resource required.

That there is considerable research 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 a few (Estes *et al.*, 1993). 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) technology. GISs are dependent on the accuracy and currency of the base cartographic products that form the foundation of each system's database. As use of these systems expands, more of us are coming to realize that the basic data we require are either not there, not current, or not in a form which we can readily utilize. GIS will increasingly drive the demand for larger scale resolution map products.

As previously stated, there is currently no civil U.S. Government agency with an international land related mapping charter. In the United States, the Defense Mapping Agency has the charter to map foreign nations for U.S. Government use. We are, therefore, largely dependent upon the military and/or intelligence communities of our own and other countries for access to large scale, science quality mapping products of foreign nations. Again, as stated earlier, other nations are even more restrictive with respect to access to their maps than we are. We must remember that maps have multiple uses. Because one major use of maps relates to military operations, nations around the world treat maps as critical national security assets.

The Mapping Paradox

Yet, there is a growing recognition that the environmental and/or economic health of nations are also factors affecting our national security. Indeed, the recently passed Land Remote Sensing Policy Act of 1992 (Public Law 102-555), 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 can and is being done from satellite systems. It is significant that P.L. 102-555 puts understanding of human impacts on our global environment and management of the Earth's natural resources on a par with national security. This, along with other items such as the Vice President's book, *Earth in the Balance* (Gore, 1993), signals a growing awareness of the importance of understanding of the Earth as a system on the part of the Administration and the Congress.

The economic and environmental health of all the world's nations are key factors affecting the national security of the United States. Better maps depicting a wide variety of themes are a fundamental requirement if we are to improve our economic well being, environmental quality, and management of our nation and the Earth as a whole. Yet, when the reasons for our lack of maps are examined carefully, other than non-existence, we find that national security is the major factor inhibiting access to map products. Thus, we have a paradox. We need large scale, science-based maps to improve our understanding of the Earth as an integrated system, plan the wise use of the resources base of nations, and assess and monitor environmental quality at scales from local to global. Improvements in environmental quality and the economic well-being of nations around the world can enhance the quality of life 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, science-based maps can represent a tactical military threat. It cannot be denied that maps have played, and will continue to play, a key role in military operations. Yet, 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 specific tactical military situations. Yet, this control to be effective must apply to maps in general as it is difficult to predict where advantages in specific knowledge will be significant. Such controls, however, represent restrictions that inhibit scientists, planners, and resource managers as they attempt to improve our general level of understanding of the global system, search for the environmental indices that facilitate early detection of global change, and try to model those environmental factors that can lead to a more sustainable future. So we have the mapping paradox — the classic double edged sword. Maps used one way can improve national security, but used another way are a threat to national security.

One approach 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 this 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 terrorist or 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 to information. We should be aware here that, from a decision maker's standpoint, the concept of plausible deniability applies in a very real way. If someone does not know, or cannot prove, that a decision-maker has access to a critical piece of knowledge when a decision is made, the decision maker has a better chance of not being held directly responsible for unintended or intended consequences that might flow from that decision. This concept has served rulers and politicians well throughout history.

Another major problem is how we deal with the reality that data/information concerning resources and our environment is a basis for power. 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 understanding the Earth as a system are so critical that we must break down the barriers to the development and flow of science quality information? Barriers to open the flow of data we face today inhibit our understanding of our global resource base and the factors that affect the quality of our environment. We need open access to map products on a global scale.

Recommendations

Governments typically engage in programs of systematic mapping in response to a wide variety of national, regional, and local needs – military, administrative, socio-economic, and environmental. The Federal agencies we most often deal with are trying, within the limitations of their charters and their resources, to support the spatial analysis user community. Yet, when we compare the need with current activity, we conclude that changes must occur. We must have better map products in support of a wide variety of spatial data users. Agencies must be given expanded charters and significantly increased resources if we are to improve the quantity, quality, and spatial coverage of our mapping and help to reduce our current ignorance regarding important local, regional, national, and global conditions.

Most of all, we must reinvigorate our national mapping community. A U.S. civil agency must be given the lead in global environmental mapping and the resources to do the job. We recommend that this agency be the National Mapping Division of the USGS. NMD should be chartered with the task of leading coordinated Federal research, development, and operational global mapping activities. This lead should be accomplished with advice from the National Academy of Science and professional societies, and should enlist the talents of personnel in other Federal agencies, academia, and private industry. This effort should also interface with and support, to the extent practical, international mapping efforts.

In addition, we believe we must

- Begin to develop a set of specifications for baseline, country level,spatial information;
- Encourage international donor and national scientific, mapping, and environmental agencies and non-governmental organizations to work toward the production of internally consistent datasets on a country level basis; and
- Study the feasibility of the establishment of a global spatial data framework where, given certain standards, various scales of thematic maps can be nested to form a complete mosaic of multi-scalar, digital coverages for the globe.

To carry this work forward, leading international intergovernmental and national aid agencies (e.g., UNEP, UNDP, World Bank, etc.) should be encouraged to establish a committee to

- Examine the concept of and make recommendations leading towards the establishment of a global spatial data frameworks, a framework in which all mapped data are widely and completely disclosed to the public; and
- Develop a set of specifications for the development of globally consistent country-level baseline datasets needed for environmental assessments and sustainable development.

Finally, every effort should be made to communicate to the public, politicians and policy makers, key agency personnel, the science community, and private industry that (1) spatial information/maps currently needed to fully support environmental planning and resource management efforts are lacking in most parts of the world; (2) there is a great deal of science still to do in mapping spatially specific, environmental development and resource management information that deserves support; and (3) improved mapping of baseline environmental information, even with today's advanced technologies, remains a difficult task. In today's rapidly changing world, an improved understanding of the delicate balance between economic development and environmental security on both the local and global levels is essential. Can we achieve this balance? Can each of us

- Rise above our work in our "own personal perfect pixel packages" and actively support the broader interests of the community by pushing for more global scale coordination in mapping and the establishment of global standards for the production of specific types of map data;
- Look beyond pursuit of the latest technological "flavor of the day" (read: where the bucks are) and work to help create more emphasis on expanded operations and charters for mapping agencies as well as science and technology and research and development in spatial analysis, mapping, and related sciences; and
- Help 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?

We hope we can, for all of our sakes.

Acknowledgments

The authors wish to acknowledge the support for this effort from both the University of California, Santa Barbara, NASA grant NAGW 1743, and the Universities Space Research Association's NAGW 3173. The authors also wish to acknowledge that material herein came in part from the talks presented at the Aspen Global Change Institutes session on Early Detection of Global Change, August 1993. The authors also wish to thank the many individuals who provided comments on various versions of this manuscript, including Dr. Timothy Foresman, Dr. John Jensen, Dr. Joel Morrison, Mr. Jim Jancaitis, Mr. Larry Carver, Ms. Mary Lársgáárd, Dr. Frank Davis, and Dr. Ken Macguire. A special thanks also to Ray Byrnes for his comments. Clerical support was provided through many revisions by Gayle Vasquez, and research, reference, and bibliographic support was provided by Claire, Thomas, and John Estes II.

References

Committee on Earth and Environmental Sciences (CEES), 1992. *The U.S. Global Change Data and Information Management Program Plan,* National Science Foundation, Washington, D.C., 94 p.

Estes, John E., 1992. "Global Change: Remote Sensings' Challenge," paper presented at the 6th Australia-Asian Remote Sensing Conference, Wellington, New Zealand.

Estes, John E., Jeffrey L. Star, and Frank W. Davis, 1993. "Remote Sensing and GIS Integration: Towards a Prioritized Research Agenda," paper presented at the 24 International Remote Sensing Symposium, Graz, Austria.

FGDC, in preparation.

Fox, Robert, and Ira Mehlman, 1992. *Crowding Out the Future World Population Growth, U.S. Immigration, and Pressures on National Resources,* Federation for American Immigration Reform.

Gore, Albert, 1992. *Earth in the Balance,* Houghton Mifflin Company, Boston, Massachusetts, 407 p.

Htun, Nay, 1993. "The Driving Forces of Global Change," paper presented at Aspen Global Change Institute's Fourth Annual Walter Orr Roberts Memorial Public Lecture Series, Aspen, Colorado.

Mooneyhan, D.W., 1993. "International Science Data Set Acquisition for Early Detection," talk presented at Aspen Global Change Institute.

Morrison, Joel L., 1993. *Cartography and the Spatially Literate Populace of the 21st Century,* CAGIS, No. 4, in press.

Murakami, Hiroshi, 1993. Global Mapping: Global Geographic Datasets for Environmental Studies, *Proceedings International Workshop on Global GIS,* Toyko, Japan, International Society for Photogrammetry an Remote Sensing, pp. 8–14.

National Aeronautics and Space Administration Advisory Council (Earth System Science Committee), 1988. *Earth System Science: A Closer View,* NASA, Washington, D.C., 208 p.

National Research Council, 1993. *Towards a Coordinated Spatial Data Infrastructure for the Nation,* National Academy Press, Washington, D.C., 171 p.

Platt, R.R., 1945. Official Topographic Maps, A World Index, *Geographical Review,* 35(2).

Richards, J.F., 1990. Land Transformation, *The Earth as Transformed by Human Action* (B.L. Turner, editor), Cambridge University Press, London.

Rodenburg, Eric, 1992. *Eyeless in GAIA, The State of Global Environmental Monitoring,* World Resources Institute, 19 p.

Townshend, John R.G. (editor), 1992. *Improved Global Data for Land Applications: A Proposal for a New High Resolution Data Set,* Global Change IGBP Report No. 20, The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP) of the International Council of Science Unions (ICSU), Stockholm.

Turner II, B.L., R.H. Moss, and D.L. Skole, 1993. *Relating Land-Use and Global Land-Cover Change: A Proposal for an IGBP-HDP Core Project,* Global Change IGBP Report No. 24, HDP Report No. 5, Stockholm, by International Geosphere-Bioshpere Programme: A Study of Global Change and Human Dimensions of Global Environmental Change Programme.

United Nations, 1990. *World Cartography,* Vol. 20, New York.

U.S. Global Change Research Program, 1993. *Our Changing Planet: The FY 1993 U.S. Global Change Research Program, Washington, D.C.,* Committee on Earth and Environmental Sciences, c/o National Science Foundation, Washington, D.C., 79 p.

Wolf, Michael, and Duncan Wingham, 1992. *WP 4010: A Survey of the World's Digital Elevation Data,* Dorking, Surrey, England, Department of Electronic and Electrical Engineering, University College, London, 87 p.