BUILDING LOCALLY ADAPTED REMOTE SENSING PROGRAMS IN DEVELOPING NATIONS

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ABSTRACT

One of the most important elements required to preserve peace in the world is to narrow the disparities in the standard of living, know-how, productive capacity and bargaining power between developed and developing nations. Present inequalities may be responsible for the political instability within countries, as well as pose a threat to the stability of and a challenge to the conscience of the highly developed nations.

It is widely recognized that the slow rate of development in over two thirds of the world is a consequence of the failure to make adequate use of human resources, which in turn hampers the rational utilization and conservation of natural resources. Development of the human resources of a country is essential to harnessing the full potential of modern technology. Only well-trained, local professionals will be in a position to insure that the new technologies are <u>properly adapted</u> to the specialized needs of a particular country. However, the potential positive contribution from these professionals may be realized only through institutions that can absorb their expertise and provide a creative environment. Therefore, building institutions is paramount; as stated by Waterson (1965), "development simply cannot be achieved without them."

A strategy for building locally adapted remote sensing programs in developing countries is discussed in depth in this paper. This strategy is based primarily on the development of human resources and on the creation and strengthening of remote sensing institutions through which local specialists may guide the evolution of an integrated natural resources information system. Recent developments in aerospace data-gathering technology and advanced computer systems for remote sensing data processing make it possible to obtain basic information on the quantity, quality and location of earth resources, information that is essential to identifying, planning, and implementing development programs.

This paper identifies four phases in the development of local understanding and adoption of the technology. The first phase is to acquire an understanding of the fundamentals of remote sensing at different technical levels. The second is to develop a capability for visual interpretation of remote sensing imagery. During the third phase, digital approaches to image enhancement and data analysis are introduced; at this point a significantly higher level of natural resources information can be obtained. The fourth phase involves the definition, design, and implementation of digital geographic information systems for efficient access, storage, and retrieval of natural resources information.

This gradual, long-term development process is essential for the successful adaptation of remote sensing technology.

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1. INTRODUCTION

The present worldwide economic and social problems, if unsolved, may lead to future catastrophic events. To avoid such events and to preserve peace in the world requires, among other things, narrowing the economic gap between highly developed and developing countries (Hoover, 1943). The disparities in their standard of living, know-how, productive capacity and bargaining power have been responsible not only for the economic and social instability of developing nations; they have constituted some of the most powerful impediments to an orderly development, management and utilization of their natural resources (Amuzegar, 1976). These inequalities cause political instability within the developing countries, as well as pose a threat to the security of and a challenge to the conscience of the highly developed nations. In a recent report on the problem of relations between developed and developing nations, former West German Chancellor Willy Brandt, together with 17 other world leaders, concluded that "both peace and continued prosperity in the industrialized nations will depend on success in developing the Third World," and that "the search for solution is not an act of benevolence but a condition of mutual survival"(World Bank, 1980).

It is widely recognized that the slow rates of development in over two-thirds of the world is a consequence of the failure of these nations to make adequate use of human resources (Curle, 1963). This in turn hampers the rational utilization and conservation of natural resources. This year's nobel laureate in economics Theodore W. Schultz in a lecture presented at Purdue University has stated emphatically, "For any country to benefit fully from the advances of science, whenever these are made throughout the world, and the new productive technologies that emerge from these advances, it must have a corps of competent scientists and technicians." In other words, development of the human resources of a country is essential to harnessing the full potential of modern technology. Only well-trained local professionals will be in a position to insure that the new technologies are properly adapted to the specialized needs of a particular country. The realization that knowledge is an important factor in the process of development is not new at all. Alfred Marshall writing in 1890 stated, "knowledge is the most powerful engine of production."

However, the traditional economic view has been that expenditures to improve human resources have a low priority. Instead, increases in the stock of conventional, more tangible capital have been rated much higher. The traditional view holds that education is only comsumption and therefore the natural order is, first, to spend in physical structures, equipment and large installations, and then, out of the resulting income, to spend more in education (Schultz, 1968).

In remote sensing we see a similar trend. Developing countries and to a certain extent international development agencies are willing to spend funds for sophisticated instrumentation, computer hardware and complex software systems, but at the same time they are reluctant to invest in education and training.

In the overall process of transferring remote sensing technology to developing countries, the authors believe that an effective strategy is first, to develop the human resources by means of long-term educational and training programs and second, to develop and strengthen locally adapted remote sensing institutions through which local specialists may guide the evolution of an integrated natural resources information system.

2. GEOGRAPHIC INFORMATION SYSTEMS FOR RESOURCE MANAGEMENT

The concept of a geographic information system for natural resources is rapidly developing. This development is made possible by advances in technology associated with both computers and aerospace platforms. These technologies have fostered growth in remote sensing, communications, data base management, computerized mapping, pattern recognition, and many other capabilities which have enhanced the development of a geographic information system for natural resources.

Interest in these capabilities is growing in many countries, and, when they are properly assembled to form a geographic information system for natural resources in a particular country, can yield many benefits for that country. Principally the system will provide basic information on the quantity, quality (status), and distribution of earth resources, information which is essential for identifying, planning, and implementing development programs.

The system is expected to provide information in areas of agricultrue, forestry, hydrology, geology, land use and many other natural resources areas. Time and space do not permit a discussion of the system in each of these application areas; only applications to agriculture will be discussed as an example of the need for the system. Similar examples could be given for the other application areas.

There is a growing belief that the world would be better served in terms of social-economic benefits by having the capacity to appriase and even predict the production of major crops on as accurate and timely basis as possible (Bauer, 1975). Few countries, however, have reliable methods for gathering the data necessary for food planning, much less forecasting and estimating agricultural crop production (Peterson, 1978). Developing countries have instead viewed agriculture as a lowly form of economic activity. As pointed out by Schultz (1966), "Failure to recognize the potential economic contribution of agriculture has resulted in planned economic growth in which industrialization was given priority, often at the expense of agriculture." When information on the areal extent and condition of agricultural crops, obtained through remote sensing techniques, together with agri-meteorological data and other economic variables are stored in digital data bases, improved early season and at-harvest estimates of food production can be made for the major crop producing regions of the world. The development of geographic information systems in developing countries, based on present and future advances in remote sensing, computers and global communication technologies should enable countries to skip decades in their ability to manage resources.

Significant hardware and software components of such an information system are currently available from vendors; however, these components are changing rapidly and, in fact, the total concept of the information system is still evolving. It is currently impossible to point to a specific information system which will solve present and near-future needs of a particular country. Therefore, one must focus on the important characteristics of a geographic information system for natural resources; the system's geographic attributes, its information accessibility, and its ability to accept data. These characteristics, as the authors currently conceive them, are described here to provide context for the remainder of the paper.

2.1 GEOGRAPHIC ATTRIBUTES

The current computer literature contains much information about data management systems. A geographic information system for natural resources is distinguished from these data management systems by the quality and quantity of its geographic attributes. The system's ability to store and retrieve data through geographic references and provide powerful geographic interfaces to its users makes the system more complex than most existing data management systems. The geographic capabilities are the characteristics that add to the complexity of storing, retrieving and manipulating this data, (Cicone, 1977). These geographic attributes are probably the most important characteristics to evaluate when investigating potential hardware/software systems. Informed system purchasers will find a wide variety of geographic capabilities in available systems.

The data based management systems described in current computer literature refer to systems which are useful for parts inventories, accounting, employee records, sales data, etc. but do not provide geographic capabilities. Early geographic systems made heavy use of available data management capabilities. An example is the use of a polygon map and a common data base management system for the storage of attributes of the areas on the earth represented by the polygons. These systems provide greater geographic capabilities than ordinary data management systems, but are not as powerful as systems which have all of their data stored by geographic references.

The cost of storing data in computers has impeded the development of geographic information systems. Since the storage costs are rapidly decreasing, new concepts in data management systems which are more easily interfaced with users are developing. Thus we are entering an era of rapid increase in the capability of the user to geographically interface with his data and rapid decrease of the cost of storing and retrieving this data.

2.2 INFORMATIVE ACCESSIBILITY

Another important characteristic of a geographic information system is its ability to provide information to a wide variety of users. The obvious reason for this characteristic is that the system exists to provide information to users. However, it is also important to note that the quality of data in the system will depend on feedback and input from the users.

It should be recognized that the driving force for most systems usually comes from users at national levels. These users require more detailed information than are generally available to them because of the large area scope of their work. People at the local level usually have the knowledge of data at the local level and therefore more capable of judging the accuracy of the data stored in the system and inputing new data when it is required. What local users do not have is the ability to relate their local information to national information.

A system designed to meet user's needs at both the national and local levels will enhance the information available to both. Such a system can provide a spirit of cooperation between the various users that will provide the maximum amount of information to all. Fortunately modern computers and communication systems provide a capability for this type of interface. Therefore, it is recommended that the Geographic Information System for Natural Resources be a distributed system such as shown in Figure 1 and provide maximum interface between users of all levels.

2.3 DATA INPUT

The third important characteristic which we will discuss is associated with data entry. For most countries, the cost of data entry will be one of the major determining factors in the acquisition of a Geographic Information System for Natural Resources. Applications of data collection systems such as Landsat and data analysis capabilities used in remote sensing play a significant role in this characteristic. These newly developed capabilities provide relatively inexpensive mechanisms for developing initial data bases. Once initial data bases are developed and information begins to become available to a wide variety of users, then the procedures for inputing data from the field and upgrading existing data must be in place.

3. STRATEGY FOR BUILDING LOCALLY ADAPTED GEOGRAPHIC INFORMATION SYSTEMS BASED ON REMOTE SENSING PROGRAMS

The authors believe that the most effective strategy for building locally adapted geographic information systems for resource management based on remote sensing programs involves two major activities: (1) Education and training, and (2) Institution building.

3.1 EDUCATION AND TRAINING

Successful transfer of a new technology, such as remote sensing, to developing nations requires the adoption of concepts, methods, and practices used elsewhere but molded to meet local needs. This local modification can be accomplished only by a multidisciplinary cadre of local professionals who understand the basic concepts underlying all phases of the technology.

Four major phases in the development of local understanding and adaptation of the technology should be considered:

a. Gaining an understanding of the fundamentals of remote sensing.

b. Training and development of a capability for visual interpretation of remote sensing imagery.

c. Training in digital approaches to image enhancement and numerical analysis of digital remote sensing data.

d. Definition, design, and implementation of digital geographic information systems for efficient access, storage, and retrieval of natural resources information.

3.1.a Understanding the Fundamentals. For a remote sensing analyst to be able to extract accurate and reliable information from remotely sensed data, it is imperative that he understand thoroughly the fundamental physical principles that determine the characteristics of the data. For example, what transformations have the photons undergone during their long path from their source to the target, through the sensor, and eventually as numbers and/or images in the hands of the analyst. The analyst should be familiar with the basic concepts about electromagnetic radiation, its sources, it modes of interaction with matter, and its detection. It is also important that the analyst understand well the spectral characteristics of earth surface materials.

3.1.b Training and Development of a Capability for Visual Interpretation of Remote Sensing Imagery. Developing countries, especially the large ones, can obtain both economically and in a short period of time large amounts of useful information about the areal extent and location of their natural resources through visual interpretation of remote sensing imagery gathered by space borne sensors such as Landsat satellites. One such example is Bolivia. The entire Bolivian territory, which covers over one million square kilometers, was for the first time mapped into major earth cover types through visual interpretation of 65 Landsat images at a scale of 1:250,000. The analysis took approximately two years (Brockmann, 1978). Based on this information at the national level, it was possible to select priority areas to be analyzed at a higher level of detail using more sophisticated digital data processing techniques.

Visual interpretation of the imagery at relatively small mapping scales enables the countries' decision makers to view their entire territories synoptically, a capability brought about by the recent development of space data gathering technology. Dr. Robert A. Frosch (1977), administrator of the National Aeronautics and Space Administration, has pointed out that we are the first generation of people to have seen the entire earth; "what we saw before were only little bits and pieces of the earth, and we would take the little bits and pieces and hang them together in maps which in a sense were an attempt to construct a picture of the earth as it would be seen from space." Today it is the other way around; "instead of starting with the details and trying to construct the big picture, we now have the big picture and then figure out how to extract the details that explain it."

The most important element required to develop successful local capabilities for visual interpretation of remote sensing imagery is not the acquisition of complex and expensive photographic laboratory equipment, but the development of local expertise through educational and training programs. The decision as to the kind of equipment that is required should be made by these local specialists based on their technical expertise and knowledge of their country's realities, and not based on vendor pressures or foreign assistance experts.

3.1.c Training in Digital Approaches to Image Enhancement and Numerical Analysis of Digital Remote Sensing Data. Once a country's remote sensing specialists are well acquainted with visual image interpretaion and after they have exhausted the capabilities of extracting useful information from the imagery in photographic format for regional, small-scale mapping, the next step should involve training in numerical processing of the remote sensing digital data (CCT format). The aim of this is to increase their capability of extracting natural resources information at larger scales and higher levels of detail.

Because of the inherently quantitative nature of multispectral scanner data, such as the Landsat MSS data, they lend themselves to being treated numerically using digital computers. In remote sensing applications, two major types of numerical processing of MSS data are common: (1) image enhancement and (2) multispectral classification. When numerical processing is applied to an image in order to improve, emphasize, or suppress certain features in the image, this type of processing is known as image enhancement. The result of an image enhancement process is often a transformed image with improved visual qualities which can be more effectively analyzed through visual interpretation techniques. The other type of numerical processing of digital remote sensing data is multispectral calssification, by which the computer assigns each and every element (pixel) of a data set into a specific class on the basis of a given classification rule.

The degree of success and to a certain extent the cost of developing a local capability for numerical processing of digital remote sensing data depends upon the degree of understanding that local specialists have acquired through appropriate training in the various aspects that make up such a capability. Basically, a digital remote sensing system is composed of three elements: (1) hardware, (2) software, (3) the most important component, the human element. As previously stated, many developing countries believe that by purchasing sophisticated and expensive computers and software packages they can have a digital remote sensing system. A system as such is worthless, unless they have acquired sufficient expertise to run, maintain, and properly use their equipment and programs. The specialists' training should be done long before decisions are made as to what kind of hardware and software to buy. Because of the needs and particular realities of different countries, only local experts can intelligently adapt or, if necessary, modify already existing digital processing capabilities.

3.1.d Definition, Design, and Implementation of Geographic Information Systems. Most developing countries do not have effective conventional procedures of gathering the necessarily large amount of information they need about their natural resources. However, once remote sensing programs are well established and enormous amounts of resource information become available, digital geographic information systems will have to be designed and implemented to efficiently access, store, and retrieve the information. The characteristics of such a system have been described in section 2 of this paper.

3.2 INSTITUTION BUILDING

The potential positive contribution of well-trained local remote sensing experts may be realized only through institutions that can absorb their expertise and provide them with a creative environment that promotes innovation. In many cases, however, the knowledge and skills of newly trained experts returning to their countries cannot be fully utilized and applied to solve local problems of development because of the lack of appropriate local institutions, that is, the lack of "processes by which, through the instrument of organization, new ideas (technologies) are integrated and fitted into developing societies, are accepted and acquire the capacity to sustain themselves, and in turn influence the larger environment in which they function" (Thomas, et al., 1972). In this context the concept of institution "is not simply a specific organization of program" (McDermott, 1971), it means much more. It involves a complex set of interactions between the institution and the environment in which two-way communication and transfer of information is essential to the existence of the institution.

The authors envision a resource management institution not simply as an organization or program where only analysis of data is performed, but instead as an environment where training and eventually research for further advancement of science and technology are also carried out. Such institutions should provide the links among the different segments of society that deal with natural resources, from the highest administrative levels to the individual citizen. They should, in addition, provide technical advancements which can contribute to global scientific understanding and thus actively participate in the furthering of future systems.

The creation of digital geographic information systems, because of their information handling and transferring nature, should facilitate the institution building process.

4. CONCLUSIONS

There is little doubt of the need for building national institutions that concern themselves with natural resources and little doubt of the benefits a country can gain from having these institutions. Some of the benefits are immediately apparent, for example, the proper development and use of the nation's agricultural resources. But others, though more subtle, such as the development of the country's human resources, may be even more crucial to long-term national development. There are many ways of establishing a natural resources institution, and the approach described in this paper is only one. However, because of the broad approach that is an intrinsic characteristic of the geographic information system, this is a particularly appropriate one to use. It involves people at many levels of decision making and it provides not only a facility but also an environment for developing expertise. Properly directed technology transfer is a means for developing national institutions which are a benefit to the nation and world not only for this decade and next but, because they are people-based, for the century ahead.

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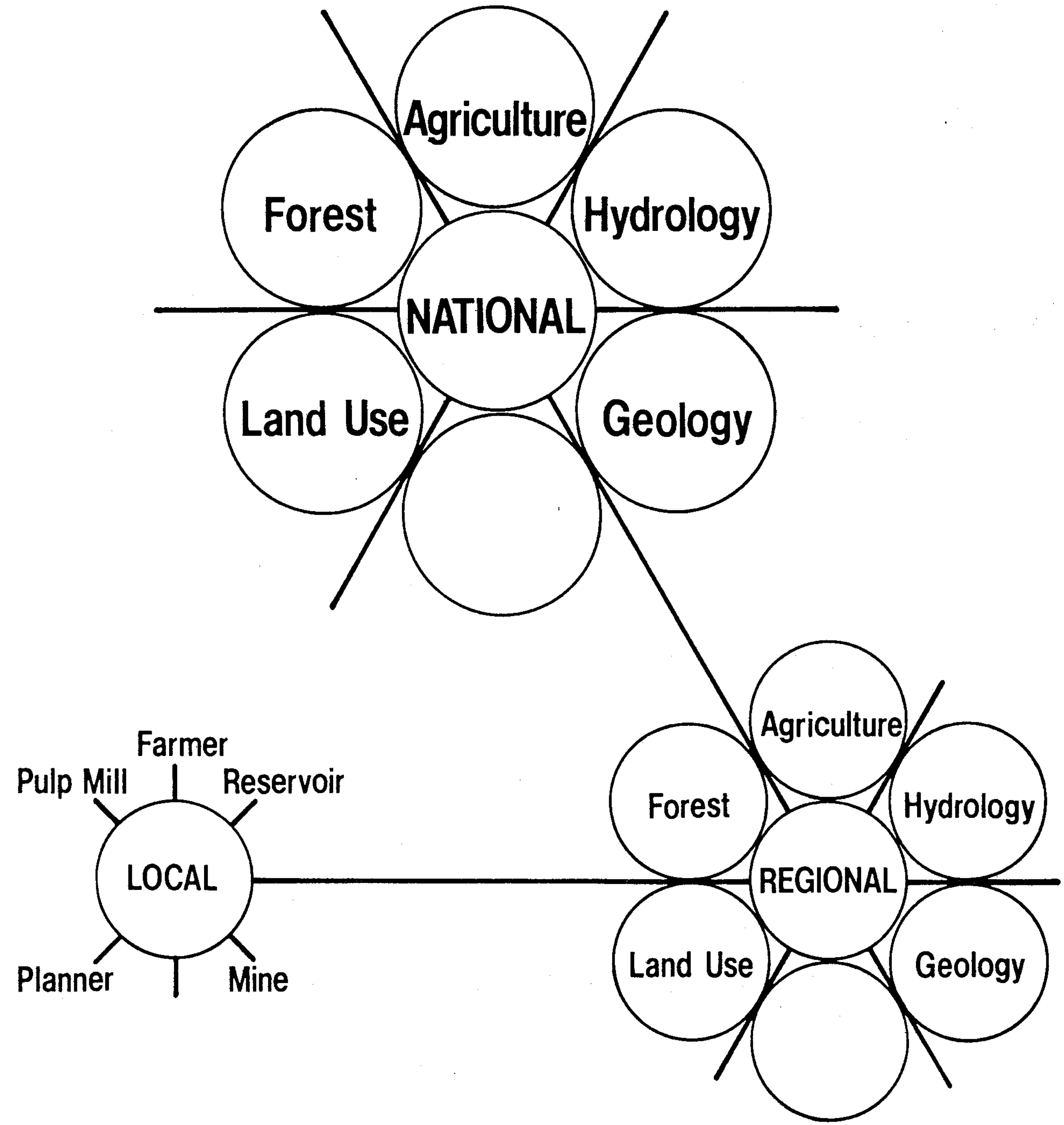

FIGURE 1. **INSTITUTIONAL COMMUNICATION MODEL**