Learning Center for Advancing Natural Resources and Environmental Sustainability in the Mexican State of Jalisco

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Abstract—*This paper addresses the need and opportunity for creating a learning center for advancing the monitoring and assessment of ecosystems resources and their sustainability in the Mexican state of Jalisco. It is an initiative that responds to the growing needs of a more sophisticated world in which knowledge is the tool for creating social and environmental progress and information is the key that unleashes this power. One of the goals of governments in this "Knowledge Age Era" is to create an environment in which ecosystem resources can be managed and utilized in a fashion that simultaneously allows societies to meet their needs, economies to grow, and the ecosystem resources to be sustained for future generations. It is among the most pressing demands of science and technology in the 21st century. The main actors and players of these evolving processes advocate the empowerment of people to make management and utilization decisions as the most rational approach to achieving profitable and sustainable ecosystems. However, to do this, a drastic change to information- and knowledge-based technologies will be needed as the new paradigm will have to be adopted on a large scale. At the heart of these transformations is the generation of data, information, and synthesis based on geospatially explicit frameworks that are scientifically credible and technically defensible. Key strategic components of this initiative are discussed in this paper.*

Introduction

Throughout the 20th century, a set of scientific and technological developments converged to bring about a new and evolving view of the relationship between the natural environment and human society. For many years, extreme views regarding this relationship, advocating either preservation of the environment at the expense of social and economic progress or social and economic development without regard to environmental health, dominated the discussion with each side demonstrating little tolerance for the other opinion. Today, because we know more about the workings of the human mind, have the technological capabilities to collect tremendous amounts of spatial and temporal data, and have learned the lessons of failed paradigms concerning ecosystem resource management, there is a growing belief that there exists an opportunity to simultaneously improve the human condition (for example, economically, socially, environmentally, etc.) and the sustainability of ecosystems.

Through modern psychology, we have gained a greater understanding of how the human brain works and how information is received, processed, and retained. It is known that people have the ability to absorb billions of bits of information instantly. When the brain receives information that is in an isolated form and disconnected from a larger context, its significance is analogous to that of a single piece of a jigsaw puzzle. Any one piece has very little meaning in and of itself. However, when each of the individual pieces of the puzzle is seen in the context of the adjacent pieces, a picture begins to form which is recognizable and has meaning. Historical means of information transfer have gathered and presented information as individual puzzle. Future methods will have to present the information in a complete contextual and integrated framework.

A new paradigm in information technology is forming that recognizes how people best acquire, retain, and utilize information. Fundamental to this paradigm is the consideration of the value of any bit of information in its spatial and temporal context. Each information bit takes on greater meaning when it can be viewed in relation to its position in space and time relative to neighboring bits. Furthermore, a higher utility is achieved when it is possible to view the change of each bit as a function of time or other variable. Technological advances in geo-spatial sciences provide us with a flexible and adaptable

approach to acquire, analyze, visualize, and disseminate spatially- and temporally-explicit information and knowledge to wider audiences quickly and efficiently.

For this information to have the greatest social utility, it is imperative to have a firm grasp of the natural processes that support environmental sustainability; the social, economic, and other factors that promote social growth; and their interactions. Until fairly recently, there was very little opportunity to consider these issues in the context of time and geographic location. Today, with the use of geo-spatial technologies that involve space and aerial photogrammetry, global positioning, information management, spatial analysis, and statistical procedures, Bayesian statistical decision making methods, communications, and innovations in computer and peripheral equipment, the ability exists to examine a wide range of environmental, social, and economic issues and incorporate their spatial and temporal interactions on a pixel-by-pixel basis. As such, the tools are becoming increasingly available to make more intelligent decisions regarding ecosystem resources sustainability and management. Furthermore, complimentary innovations in information and communication technologies, that when combined with geo-spatial technologies, are making it increasingly possible to get high-quality, spatially-explicit information and knowledge into the hands of a wide range of decision makers (for example, agencies, governments, scientists, industrialists, land managers, farmers, educators, etc.).

People throughout the world are realizing that in order to achieve both a healthy and vital environment for this and future generations and create a thriving and sustainable ecosystem resources-based economy which will provide numerous social benefits, it is imperative that a framework be put in place that will empower people with high-quality, temporally- and spatially-explicit information and knowledge of high social and scientific utility. Furthermore, this information and knowledge must be available to all ecosystem resource stakeholders. To achieve the desired goals, an infrastructure, both human and physical, must exist to integrate the entire spectrum of disparate, but related, sciences and technologies into a cohesive and seamless system of data collection, storage, and management; analysis; visualization; and dissemination.

This initiative, a learning center for advancing the monitoring and assessment of ecosystems resources and their sustainability, describes the vision of a strategy designed to support the creation of this center in a new and innovative fashion which involves the principles associated with the integration of an array of scientific and technical disciplines related to spatial estimation and modeling at multiple scales and resolution levels.

Vision

Through this Center, the vision is to develop the human and physical infrastructure necessary to implement 21st century capabilities in the field of integrated geo-spatial sciences and modeling to enable individuals, agencies, organizations, communities, governments, and other entities to effectively inventory, monitor, assess, and manage their ecosystem resources in a scientific credible and technically defensible manner, and at multiple temporal and spatial resolution levels.

Mission

In pursuit of that vision, the mission of the Center is to be an instrument which fosters a climate of intellectual discovery and growth in the subject areas and applications related to monitoring and assessment of ecosystem resources and their sustainability, and more importantly, instills the spirit of an integrated approach to problem solving that recognizes the value of each scientific and technical discipline and their interrelations.

Through this mission, the Center will contribute to:

- Developing new knowledge and applications through the interaction of professionals involved with environmental, social, and economic issues through technology transfer and development projects.
- Instructing the experts who will train a variety of technicians in the applied components of monitoring and assessment in Jalisco or institution of the individuals involved in this process.
- Facilitating the creation of the technical capabilities for acquiring and geo-referencing field and remotely sensed data; transforming this data into useful, precise, and accurate geo-spatial information and knowledge; and disseminating that product through visualization to desired locations.
- Forming an "Inventory and Monitoring Network" that will close the gap between the demand for and supply of geo-spatial information and knowledge and between the prevailing problems and potential solutions.

Goal

The goal of the Center is to fulfill the mission through a strategy that incorporates education, research, training, and infrastructure development to enable a variety of ecosystem resource-related institutions, individuals, organizations, communities, governments, and other entities to make wise managerial and utilization decisions regarding monitoring and assessment, using the tools and critical

thinking associated with spatial modeling and representation of the information resulting from these processes. As a growing assortment of highly-sophisticated, user-friendly technologies become available to a diverse cadre of ecosystem resource stakeholders, a physical infrastructure will grow which will allow information and knowledge with high social utility to be delivered in an efficient, visual form to the intended audience.

Objectives

To achieve the desired goals and guide the investments in this Center, the following specific objectives will be achieved:

Create the next generation of human infrastructure (through education, training, and other outreach) that will have the scientific and technical expertise to use knowledge and technologies in an integrated fashion to acquire, geo-reference, and analyze geo-spatial data; synthesize the data into scientifically-credible, geo-spatial information and knowledge that is technically defensible and of high social and economic utility; and visualize and disseminate the results to the user groups.

Develop a set of integrated monitoring and assessment technologies through a comprehensive program of applied research that for the most part will be associated with experts from universities and result in the development of a broad spectrum of application tools.

Support the development and organization of a geo-spatially-based infrastructure for monitoring and assessment (both physical and human) through which scientific and technological expertise can flow on a variety of projects to be conducted under the auspices of sponsoring and partner institutions.

Facilitate the formulation and implementation of an Internet-based expert system to structure, manage, and communicate monitoring and assessment syntheses and their application for use in decision-making and planning for sustainable ecosystem resource management and utilization.

Program Design

The program activities of the Center must be designed to enhance the technical capabilities of the participating institutions and organizations. It is expected that some of the clients involved in the program will (in time) become self-sufficient with respect to sustaining their own human and physical infrastructure. Others may never have in-house training and research capabilities, and therefore, may choose to participate in the Center on a more frequent basis. Great effort will be made to ensure that the program maintains the flexibility needed to accommodate all participants and create deliverables suited to individualized sets of needs, while at the same time, retain its focus on the advancement of monitoring and assessment technology and their application.

Education and Training

The development of a capable human infrastructure is an evolving process that requires a considerable amount of time. However, when a series of well-organized, high-quality, and focused educational and training experiences (short courses, workshops, seminars, etc.) are delivered, positive impacts will be felt over a fairly short period of time. Training and educational programs will begin almost immediately in a variety of subject areas that relate to monitoring and assessment, geo-spatial sciences, spatial statistical modeling, and specific technology applications. Short courses will be tailored to specific experts, technicians, resource managers, as well as to the highest level of scientists wishing to elevate their understanding of some component(s) of monitoring and assessment, remote sensing, and spatial statistical modeling. The unique feature of this program is that all courses, regardless of the topic, will include the role of the particular subject in the context of an integrated approach to monitoring and assessment, and the use of information for ecosystem sustainability. Leaders in their fields will be asked to present workshops and short courses to groups of participants in the appropriate geographical locations. Course subject areas may include, but are not limited to:

Geodesy	Spatial Statistics
Field Measurements	Geography
Data Mining	Statistical Sampling
Remote Sensing	Telematics
Point Process Modeling	Spatial Data Management
Spatial Mathematics	Ecosystem Management
Global Positioning Systems	Statistical Programming
Monitoring Methodology	GIS Applications
Quality Assurance	Assessment Methodology
Spatial Modeling	Quantitative Ecology

Workshops and short course schedules will be flexible to accommodate the needs of participants. Conferences and seminar series can be offered as the need for such instruments becomes apparent.

In addition to the courses listed above that are fairly specific in scope which will be offered from time-to-time and are designed to elevate the student's knowledge in a particular science or technology area, an exciting and unique course, entitled Spatial Analysis and Statistical Modeling, will be offered three times per year (January,

May, and August). This course, offered in three parts, will serve as the flagship of the entire training program and cover the spectrum of issues in geo-spatial analysis and modeling from statistical sampling, remote sensing, through data management and analysis using geographic information systems to spatial statistics.

Development of Organizational Physical Infrastructure

Any organization that wishes to be self-sufficient in monitoring and assessment methodology and applications will need to develop both the human and physical infrastructure necessary to perform the required tasks. The physical infrastructure needed to support a comprehensive integrated Ecological Monitoring and Assessment Laboratory (EMAL) is highly dependent upon the desired outputs, personnel, resources, and other considerations of an organization. A successful EMAL will not only need to be equipped with the most modern and functional hardware, but also contain a wide variety of computer software and analytical models to perform the myriad of activities that monitoring and assessment processes and information results applications demand.

Hardware

Such technical equipment as computer hardware and software, assorted peripherals, image interpretation devices, communications and high-speed and high-access telephone equipment are among the components of a modern EMAL facility. The development of organizational physical infrastructure will undoubtedly take place over time. Partner institutions can always assist in the processes of providing technical support for decision making and facilitate the acquisition of desired equipment, as they are needed.

Software and computer models

Physical infrastructure requirements can include a variety of software products. An array of data management, geographic information systems, image processing, statistical, and other widely used commercial products will be needed in a comprehensive EMAL facility. These products can be purchased from vendors and consultants who can always be available to provide advice on product suitability and facilitate the purchase. Consultants can work closely with companies who create the products that are at the cutting edge of technological development.

Scenarios and Applications

While focused on the goals described above, the Center can address a variety of critical questions that specify the data and information that is needed for assessments of ecosystem sustainability at multiple scales and resolution levels. For example, what is the spatial and temporal condition of a watershed's critical resources (for example, vegetation, soils, water, animals, landscapes, runoff, erosion, human activity, etc.)? What components/parts of watersheds are changing and why? Where are the identified changes taking place (for example, within and across watersheds)? Why are specific resources changing faster than others and where are those changes are taking place (for example, within and across watersheds)? As ecosystems, what is the quantity, quality, extent of services provided by watersheds, and how do human systems benefit from them across jurisdictional spatial and temporal scales? Within and across watersheds, where is mitigation/restoration of resources and processes most practical and beneficial, and how are human systems sustaining the ecological integrity and societal value of watersheds? Will the current extent and condition of resources/services of watersheds meet future ecological and economic needs? How can stakeholders (for example, landowners, federal and state government, industry, academia, and nongovernmental organizations) work together to confront appropriately the complexity of problems and issues within and across watersheds so that we can ensure the health of these systems and the well being of present and future generations? These and other important questions open a world of opportunity for advancing monitoring and assessment technologies and their application to a portfolio of environmental resources. Other scenarios and applications are limited only by our imagination.

Products and Benefits

The Center study creates a window of opportunity for a coordinated national and multinational effort to design and implement appropriate approaches to inventory and monitoring of ecosystem resources in the Mexican state of Jalisco. Central to this initiative is the opportunity to further improve information compatibility and procedures for use in integrating and evaluating information on the status, extent, trends, and projected changes of ecosystem resources within and across jurisdictional scales, and at multiple scales and resolution levels. It will promote the sharing of scientific and technical information and approaches to gain common understanding on

a variety of issues and problems of current and future concern within and across jurisdictional boundaries and geographical scales. Integrated environmental synthesis focused on addressing critical issues and problems will be important outputs produced by the Center and its institutional partners. For Latin American countries, and particularly for Mexico, the Center will serve as a learning facility within which scientists and resource managers would be able to:

- Discuss issues and problems of technical and scientific nature related to integrated- interoperable approaches to inventory and monitoring of ecosystem resources.
- Design, plan, and execute specific inventory and monitoring projects for ecological assessment and management of ecosystem resources.
- Have access to data, information, technical expertise, and technologies related to integrated/interoperable approaches to inventory and monitoring of ecosystem resources.
- Work with technical experts from cooperating organizations to standardize protocols, eliminate redundancy and inconsistency, and promote Quality Assurance/Quality Control procedures on data collection, management, statistical analysis and modeling, and reporting.
- Obtain technical assistance on developing procedures to assess and certify the scientific credibility of data and information from inventory and monitoring projects, as well as technical support on identifying where weaknesses exist and how they should be corrected.

Through this synergy, the Center would function as a network system to deliver geo-spatial environmental syntheses, results, technology, and interoperable data and information to scientists, managers, landowners, policy makers, and the public of the state of Jalisco, as well as other Mexican states and institutions abroad. Moreover, it would provide resource managers and stakeholders in other regions and states in Mexico with a model for developing similar approaches. In addition, the project is innovative and will enhance institutional capacity in that:

- It is the first Western Hemisphere effort to focus on using an integrated-interoperable approach to inventory and monitoring of ecosystem resources across jurisdictional levels and at multiple scales and resolution levels.
- It will link a diversity of stakeholders concerned with the inventory and monitoring of ecosystem resources in Mexico and abroad.
- Experts from cooperating institutions of the Western Hemisphere will work together as a team to address technical and scientific issues and problems concerning the design and implementation of integrated-interoperable inventory and monitoring systems of ecosystem resources.
- Participating experts of cooperating institutions and organizations will become more aware of what has been accomplished in their respective countries, and will have the opportunity to develop stronger linkages through technical and scientific cooperation and collaboration on a variety of disciplines related to monitoring and assessment for ecosystem sustainability.

While the state of Jalisco will clearly receive the most tangible and direct benefits from the Center, it is also clear that this project will benefit many other institutions and people, both nationally and abroad. Additional benefits to cooperating institutions and organizations include: (1) the development of cost-effective, state of the art approaches to integration of data bases developed for diverse purposes into a useful inventory and monitoring system, thus assuring comparability and interoperability across institutions; (2) the integration of multiple scales into one study which has wide application for ecosystem resource management and planning; and (3) the Center addresses many of the technical and organizational problems that face current inventory and monitoring systems, and solutions to these problems would greatly benefit them. Designed as a multi-institutional response capability, the Center will bring about the formation of highly diverse partnerships capable of integrating human and capital resources to understand and confront common problems and issues, define and establish priorities, and seek out ways for alternative options for conflictive solutions.

Organizational Considerations

To achieve successful results, it is necessary that this initiative be organized, administered, and managed by the most effective means possible. It is highly recommended that the state government of Jalisco, through FIPRODEFO, take the responsibility to organize and fund its implementation, as well as its programmatic direction. The organizational structure of FIPRODEFO is well suited for housing and carrying out this initiative and its programs. Other sources of support can be provided through institutional partners of FIPRODEFO and the Jalisco state government. Other possibilities for organizing and funding this center must be analyzed within FIPRODEFO's internal decision making structure in coordination with its clients and institutional partners. Scientific and technical support can always be provided by CAMESA's international partners.

Conclusion

The proposed Center provides a flexible and adaptable strategy for advancing the development and application of pixel level estimation and modeling approaches to monitoring and assessment for ecosystem sustainability, at multiple spatial and temporal scales and resolution levels. Specifically, the Center will focus not only on the use of modern technology tools as a collection of separate entities whose value lies in their independent application, but extends the concept to the integration of scientific and technical disciplines into a seamless fabric of cost-effective and scientifically credible approaches to sample, collect, store, summarize, and manage data; analyze data to synthesize information and knowledge into geo-spatially explicit pixel-based applications; and finally, visualize and communicate the resulting outputs and syntheses in ways that are comprehensible to people of all cultural backgrounds. Most importantly, it is expected that its products and outputs will account for specific stakeholder needs and wants so that they can be readily used to support local planning and decision-making processes for sustainability in a timely and meaningful manner.