CURRENT USE AND PROSPECTS OF INFORMATICS IN MODELING, ANALYSIS AND MANAGEMENT OF NATURAL RESOURCES

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Summary

In the coming century, the central and recurring theme in the food production and general agricultural industries will be sustainable development. Such development depends on a highly efficient and integrated system for natural resource management, which relies on the optimization of an agroecoproduction system while taking into account economic, environmental, and social factors. Informatics and computer simulation models have become indispensable tools in combining this diverse multitude of objectives into a comprehensive decision making process. This chapter presents a review of current use of information technology and models in management, as well as their future prospects, from a technical perspective. The review is organized into four sections: 1. Data depot, knowledge base, and encyclopedia assembly, some of which are web-based; 2. System ecological modeling and Web-GIS; 3. Integrated Web-based decision support system; 4. Improving the capacity of modeling systems on usability, performance, management, and technology transfer. In the second half of the chapter, the author's own efforts in building a Web-based environmental modeling system are introduced, and some implementation related issues are discussed. We hope that this chapter will provide researchers, extension specialists, and decision makers at various

levels with an overview of the relevant technical topics in the use of modern computing resources in order to form better management decisions.

1. Introduction

Accompanying the increasing globalization of world affairs, the prospect of food security and the environment has been and will be at the center stage in the coming several decades. A quick survey of the current and projected situations regarding agriculture, population, and water resources by the United Nations Food and Agriculture Organization (UN-FAO, http://www.fao.org/) produces an ominous combination of future high population, dwindling arable land, and increasing environmental pollution in most of the developing world. The prospect is more hopeful for developed countries where long term, systematic research and extensive efforts to improve productivity and to mitigate negative environmental impacts have taken root.

From across the Globe, sustainable development is seen as a growing trend that conserves land, water, and biodiversity. According to the UN-FAO website, a sustainable agricultural system is "environmentally non-degrading and technically appropriate, as well as being economically viable and socially acceptable". Achieving such a multiplicity of objectives in managing our natural resources in the agroecosystems requires timely access to scientifically-based technical and management advice, in addition to material resources. In this chapter, we will explore the use of computer simulation models and the related information technologies that aid in the assessment, analysis, and management of agroecoproduction systems for improved productivity and fewer environmental hazards.

We begin with a survey of the current research and application activities related to the subject matter of this chapter, namely, the informatics and models usage in natural resource management. It is impossible in such a survey to consider all published works on this diverse, far-reaching, and rapidly progressing topic. Rather, we provide an overview of the common trends in order to illustrate the key aspects of the topic, in terms of their development and future trends. Following this review, we present a Web-based hydrologic and hydraulic modeling package that is designed to bring up to date the current generation of hydrologic models, which are utilized in most of the existing decision support systems. The features, potential usage, and future development of this Web-based modeling system, in the larger context of the use of models in facilitating management, will be presented. Categorically, we found the relevant literature to focus on the following aspects of the informatics and model use in various management contexts: 1. data depot, knowledge base, and encyclopedia assembly, some of which are web-based; 2. system ecological modeling and Web-GIS; 3. integrated Web-based decision support system; 4. improvement of capacity of modeling systems on usability, performance, management, and technology transfer. These topics will be introduced separately below.

1.1. Data Depot, Knowledge Base, and Encyclopedia Assembly

Informatics is defined by the Merriam-Webster dictionary as "the collection, classification, storage, retrieval, and dissemination of recorded knowledge treated both

as a pure and as an applied science". The main components of informatics for natural resource management can be organized into three main categories: acquisition and storage of data/metadata; data conversion, analysis, and synthesis; and finally, management and dissemination.

Considering the highly variable nature of biological and environmental events and the need for using spatially explicit computer models in the decision making process, data must be collected from multiple locations, following carefully designed spatial patterns, and for extended periods of time. Such large volumes of data are typically stored in a relational database managed by one of the popular relational database management systems (RDBMS) such as Oracle, MySQL, Microsoft-SQL Server, and ACCESS. The use of the internet has been revolutionizing all of the main components of informatics in natural resource management. In a survey of the use of digital media in managing and delivering information in the current electronic age, Wagner (2003) showed that the use of traditional desktop databases and CD-ROMs has been in decline during the past decades, while the use of World Wide Web (WWW) internet interfaced data collection and retrieval has seen exponential growth during the same time period, and continues growing to date.

The most common form of organizing and delivering spatial data using WWW is the linkage of a Web-based Geographical Information System (Web-GIS) and a backend relational database. Spatial data layers such as soil, stream, land use, productivity, digital elevation models (DEM), and pollutant concentration are first constructed into an ESRI (Environmental Systems Research Institute) shapefile or grid data. Web-GIS software such as MapServer and ArcIMS then present these data layers through a Web server (Apache or Microsoft Internet Information Server, IIS). Users, with a Web browser, can view, query, and manipulate the presented dataset to create a new dataset, or to access more information through a geo-referenced query delivered through the Web-GIS interface to the backend database. The Web-GIS mediated data retrieval and data organization greatly improved the usability of scientific data and research findings by decision-makers. The advantage of Web-GIS data portal is that it gives structure to the otherwise disaggregated collection of data and facts. This structure can be geared toward a particular application or service, or can be designed to support a more general knowledge base that organizes related information and data to facilitate analysis of issues leading to management conclusions. The commonality among existing Web-GIS-database applications include: 1. layered organization of related data using Web-GIS; and 2. management inference is performed exclusively by the user, based on the knowledge derived from the user's own mental processing of the organized information. This implies that the results obtained could vary significantly from user to user, based on their varying aptitudes on the subject. Therefore, the predictive power of these applications, specifically in quantitative terms, is limited. Such quantitative predictive power is needed to decrease users' uncertainty in their decision making process.

Current efforts in the development of on-line data portals for management purposes are still at an early stage, especially where it involves applications using the Web-GIS technology. While embracing Web-GIS solutions to sustainable natural resource management with its ubiquitous effectiveness in maintaining heterogeneous datasets and its dynamic and interactive data presentation, researchers also noted the need to

address such issues as societal concerns of privacy, differential Internet access, and other technical difficulties related to implementation. Nonetheless, Web-GIS is seen as a way for promoting grassroots monitoring, data collection, and public involvement in environmental management. Existing applications demonstrate that the potential of using Web-GIS to enable community level data collection, either manual or automated, can provide means for real-time bio-monitoring of environmental quality, which is crucial in identifying sources and patterns of pollution and developing management plans accordingly.

In looking at other aspects of Web-GIS based data depot development, many researchers have realized the importance of metadata (i.e. information about data items in a database) in the overall management of spatial data and allowance of research collaboration. With the increasing volume of geospatial data, managing metadata could lead to faster information retrieval and application development. Conformity to a standard Web-GIS format such as the "Web Mapping Specification" defined by the Open GIS Consortium can improve the interoperability among different applications or information systems. Finally, new and advanced data acquisition techniques are needed to obtain real-time spatial data from disparate geographic locations.

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Biographical Sketches

Dr. Tong Zhai is a research associate in the Agricultural and Biological Engineering Department at Purdue University. He has a diverse academic background include agricultural system and environmental engineering. His research focuses on integrated study of agro-eco-production system through field experiment and hydrologic modeling. His recent efforts involve development of spatial decision support system for natural resource conservation and land management strategy assessment in search of most cost effective production and best management practice implementation to reduce pollution. His future efforts will focus on sustainable eco-friendly production system through optimization of natural resources and management.

Dr. Rabi Mohtar is a professor of environmental and natural resources engineering in the Agricultural and Biological Engineering Department at Purdue University. His research interests focus on sustainability involving more efficient use of natural resources while maintaining or improving productivity, economic opportunity, environmental quality, and the health for all people. Dr. Mohtar's research focuses on the conservation of natural resources including land, water, air, and biodiversity in order to meet the increasing food demand and environmental degradation. His research priorities are to continue research in environmental and natural resources conservation engineering, including: water, soil, plant, and animal; evaluation of environmental impacts of land use and water management; innovative soil and groundwater remediation technologies; application of numerical methods to food, natural and biological engineering systems; characterization of the soil water medium at the pedon, field, and watershed scales; and design and evaluation of international sustainable water management programs to deal with water shortage conditions.