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A web-based GIS Decision Support System for managing and planning USDA's Conservation Reserve Program (CRP)

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Abstract

The Conservation Reserve Program (CRP) is one of the largest programs of the U.S. Department of Agriculture (USDA) aimed at encouraging farmers and ranchers to address soil, water, and related natural resource issues on their lands in an environmentally sustainable manner. This paper outlines the design and development of a prototype web-GIS Decision Support System (DSS), CRP-DSS, for use in resource management and assessment of environmental quality. Specifically, the DSS is targeted toward aiding USDA to better manage and plan CRP enrollments. The DSS is based on the emerging industry-standard ArcIMS GIS platform and integrates a mapping component AFIRS (Automated Feature Information Retrieval System) and a modeling component SWAT (Soil and Water Assessment Tool). Our novel integrated web-GIS DSS is implemented using web server and Java Servlet technology over an ArcIMS platform to support data access and processing in a distributed environment. AFIRS functions as a feature extraction protocol that uses multisource geospatial data sets and SWAT serves to simulate long-term trends of soil and water quality. The prototype DSS was applied to simulate the sediment and nutrient dynamics of a small watershed in the Oklahoma Panhandle. We intend to develop the prototype CRP-DSS into a full-fledged tool geared to enable USDA better manage and plan future CRP enrollments.

Keywords: Decision Support System; Web-GIS; Environmental modeling; USDA CRP evaluation

Software availability

Name of product: CRP-DSS.
Coding language: Java (J2SE).
Software requirements: ArcGIS (9.0), ArcIMS (4.0), MS SQL server.
Hardware requirements: PCs with Windows.
Availability: Prototype.

1. Introduction

Continued human population growth and increasing demand for sustainable agriculture underscore the need for restoration of degraded cultivated soils (Doran and Parkin, 1994). Important soil restoration goals include reducing erosion, enhancing soil structural stability, and increasing soil nutrient conservation (Baer et al., 2000). United States Department of Agriculture (USDA)'s Conservation Reserve Program (CRP) seeks to encourage farmland owners to adopt sustainable management practices. Under the CRP, agricultural producers voluntarily retire environmentally sensitive land for 10 to 15 years. In return, USDA's Commodity Credit Corporation makes annual rental payments to producers and shares the cost of establishing approved conservation practices (USDA-NRCS, 2002). This

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contractual program encourages farmers to plant long-term resource-conserving vegetative covers to improve soil, water and wildlife resources. The recently announced Farm Bill 2002 further enhances the CRP program by increasing the acreage cap of 36.4 million acres to 39.2 million acres (USDA-NRCS, 2002). Furthermore, the USDA is fulfilling its commitment to soil, water, and habitat quality by issuing $1.7 billion in CRP payments to participating producers for the fiscal year 2005, allowing producers to earn an average of $4143 per farm enrolled (USDA News Release, 2005). The State of Oklahoma ranks 12th in the nation regarding acres enrolled with rental payments of more than $33 million. As of November, 2005, the total CRP in Oklahoma from 1987–2003 is 428,583.26 hectares (1,059,066.7 acres) and Texas County ranks the first in Oklahoma in terms of CRP acreage. Total CRP in Texas County from 1987–2003 is 88,045.33 hectares (217,567.7 acres) and accounts for up to 20.54% of all Oklahoma acreage (USDA-FSA, 2005).

Farmers and crop consultants in general, and legislators, economists, and scientists in particular are challenged with important decisions pertaining to the environmental objectives of the CRP (Young et al., 1994; Skaggs et al., 1994). Additionally, with about 16 million acres expiring in 2007 important, important decisions and management policies need to be formulated to continue the benefits of CRP (USDA-CCC, 2004). It is essential that accurate and timely decision-support aids and research tools are developed to help evaluate and justify the environmental benefits that accrue as a result of enrolling in the program. Currently, the USDA-Farm Service Agency uses the Environmental Benefit Index (EBI) as a rudimentary decision support tool to rank land offered for enrollment to in the CRP during the general signup period (Farm Service Agency, 1999). Scores are assigned based on expected environmental improvement in soil and water quality, wildlife habitat, and other resource concerns for the duration the land is to be enrolled in the program. A major drawback of this ranking system is lack of an objective and scientific analysis of the environmental benefit index. More of the factors that govern the assignment of the score for the lands that are bid are derived from the soil databases. USDA will be greatly benefited by a Web-enabled DSS to manage, plan, and prioritize CRP enrollments in a distributed environment.

There is no dearth of literature pertaining to the use of geospatial technologies such as remote sensing and Geographic Information Systems (GIS) in land use land cover (LULC) mapping (Fitzpatrick-Lins et al., 1987; Baldridge et al., 1975), including CRP tracts (Egbert et al., 1998). Most LULC studies make use of single source data, which although is cost-effective from a data acquisition standpoint, necessitates making compromises in the thematic detail and classification accuracy (Whistler et al., 1995) Applications that use multisource GIS data; e.g., elevation, slope, soil, and other ancillary data, have reported substantial improvements in the classification accuracy over techniques that use a single source data by providing stronger correlation between geospatial data and features of interest (Fuller and Parsell, 1990; Price et al., 1997). In the recent past, newer approaches to image classification have evolved including Decision Tree Classifiers (DTC), which involves a multistage approach to breaking up a complex feature class decision into a union of several simpler decisions (Safavian and Landgrebe, 1991; Dattatreya and Kanal, 1985; Quinlan, 1990; DeFries et al., 1998; Friedl and Brodley, 1997; Hansen et al., 2000). Our research effort is directed towards an automated system that implements a DTC approach to multisource image classification for CRP mapping.

Simulation models, which evaluate impacts of human activities on the natural environment, can efficiently and effectively exploit the immense potential of GIS and remote sensing technologies. Since all the basic units (water, soil, and air) in environmental modeling do have a spatial distribution, which does affect the processes and dynamics of interaction considerably, GIS has a lot to offer to environmental modeling (Fedra, 1993). GIS becomes a useful tool to not only manage large database that include remotely sensed data, but also facilitate extraction of spatially varying parameters as input to simulation models. GIS has successfully integrated with environmental models such as AGNPS (Young et al., 1987; He, 2003), ANSWERS (Beasley and Huggins, 1982), QUAL2E (Yang et al., 1999; Srinivasan and Arnold, 1994) and EPIC (Rao et al., 2000), BASINS (Lahlou et al., 1998) and SWAT (Di-Luzio et al., 2002). We will apply a hydrologic model, SWAT (Soil and Water Assessment Tool) to evaluate some of the environmental benefits of the CRP.

Numerous studies in the past have documented the need and benefits of integrated decision support systems for various environmental applications (Miller et al., 2007; Santhi et al., 2005; Koormann et al., 2005; De and Bezuglov, 2006). Although, these systems incorporate efficient data management systems and provide user-friendly interfaces, there is a need to implement GIS-based modeling systems that are interoperable across the Internet (Denzer et al., 2005). Developments in Internet technologies make it possible for geographically dispersed groups to access and process spatial information that is distributed across the Internet on different platforms. Decision makers can now have real-time (or near real-time) access to critical, accurate, complete and up-to-date spatial data held in multiple data stores that may not be managed or maintained by them (Miller et al., 2002; Marcdavid et al., 2001; Tan, 2002; Prato, 2003). Web-based GIS technologies, although in their infancy are mostly geared toward data dissemination with little or no online analytical capabilities. Our project aims to create a prototype Web-based GIS DSS equipped with a full range of analytical capabilities involving GIS and image data to aid in the CRP decision-making process. More importantly, our system will be able to access distributed data including access to multi-resolution remote sensing data, i.e., Landsat and MODIS, and multi-source GIS data. This will allow for differential CRP mapping at different levels, leading to efficient and effective CRP management, plan, and optimization at both county-level and state-level. We aim to develop a prototype CRP-DSS that will be integrated with Internet, GIS technologies, and distributed datasets.