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A PROTOTYPE SHELL FOR RUNNING FIELD SCALE NATURAL RESOURCE SIMULATION MODELS

Mariano Hernandez, Phil Heilman, Leonard J. Lane, Jeffry J. Stone, James A. Abolt, and John E. Masterson, II*

Abstract

Many different simulation models have been developed over the last decade to study natural resource issues. For these models to be used as management tools, rather than for research, the user should be able to build the necessary input files, run the simulation model, and examine the results quickly and easily. We have developed a prototype interface shell which will facilitate those tasks, thus allowing the user to apply natural resource models routinely. With the addition of a multiobjective decision making component, a comprehensive decision support system will be created. This system has been implemented using the X Window System to allow access to the power of workstations and the graphical capability of X Windows.
KEYWORDS: GLEAMS, Hydrologic Modeling, Interface, Water Quality.

Introduction

The role of the USDA Agricultural Research Service (ARS) includes developing and evaluating water quality protection technologies for implementation on farms and developing computer software to enable decision makers to select the best management practice for a given situation. Natural resource simulation models such as the Chemical, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model (Knisel, 1980), the Erosion Productivity Impact Calculator (EPIC) model (Williams et al., 1989), and the Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) model (Leonard et al., 1987) have been used on a national level to evaluate the effect of management practices on runoff, erosion, chemical, nutrients, productivity, and farmer income. For these models to be used as management tools, the user should be able to build the necessary input files, run the simulation model, and examine the results quickly and easily. Generally, the user has access to an input file builder to create the required input files to run the simulation model. In spite of the availability of input file generators, the task of building the input files for the simulation model may require a considerable amount of effort because input files are complex and the data bases are not consistent among users. Moreover, once the simulation has been run, the output can be voluminous and difficult to interpret. Consequently, decision makers have been reluctant or unable to routinely use simulation models as management tools to study natural resource issues. To overcome this problem, we have developed a generic Interface Shell (IS) to provide a menu driven dialogue tool between the user and the Prototype Decision Support System (PDSS) of the USDA Water Quality Initiative (Fig. 1). The PDSS evaluates environmental and economic consequences of alternative farming practices on water quality. Following is a brief description

*M. Hernandez and P. Heilman, Research Specialists; L. J. Lane, Research Leader; J. J. Stone, Senior Research Specialist; J. A. Abolt and J. E. Masterson II, Computer Specialists, USDA-ARS Southwest Watershed Research Center, 2000 E. Allen Rd., Tucson, AZ 85719.

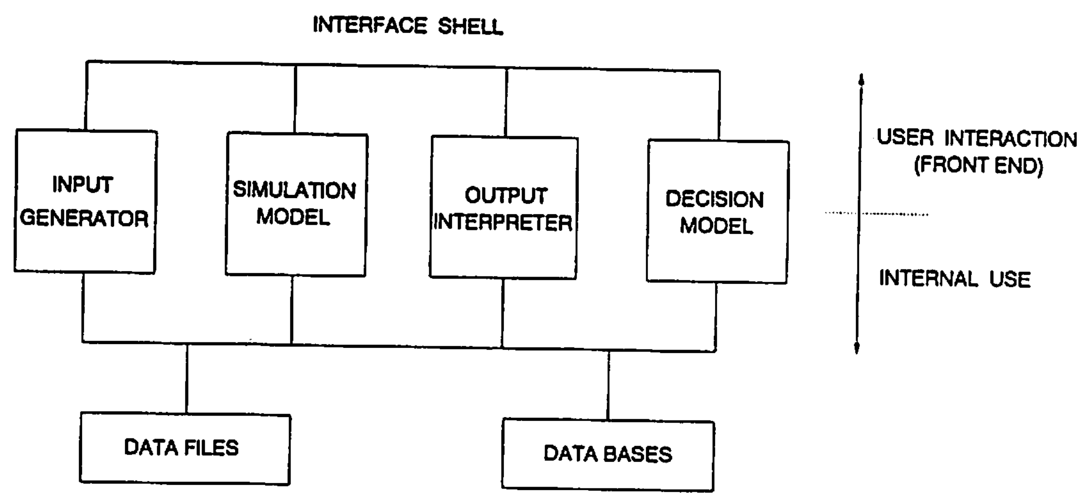

Figure 1. The Interface Shell Diagram

of each component of the IS : a) Input Generator, b) Simulation Model, c) Output Interpreter, and d) Decision Model.

Conceptual Design

The structure of the IS was designed so the user would not need to build input files with a specific format for a given simulation model. As a result, the IS will be easily adaptable to other natural resource simulation models. The IS is the system's controller or driver and contains the input generator and output interpreter for the resource model. This output interpreter provides the input for the decision model. The IS input generator creates the input files for the simulation model. Once the input files are created, the IS runs the simulation model and shows the user the simulation output, either graphically or tabularly. The format of the input files are model dependent. Currently, the format of the input files is the one required by a modified version of GLEAMS. The Input Generator creates the files to run the simulation model using information stored according to input data classification. For example, for a specific field, the user may enter the data based on soil texture, field geometry, management practice, economics, or climatic characteristics of the area. The Input Generator provides the values of the input parameters from a data base. The process of building the input files ends when the Input Generator checks that all the input files required to run the simulation model are completed and error free.

The Input Generator can be operated at three different levels (Fig. 2) which provide a trade off between ease of use and precision of input parameters. The first level allows the user to easily characterize a watershed by using default values. For instance, given the soil texture, the Input Generator would select from the data base values for saturated hydraulic conductivity, porosity, wilting point, etc. At this level the user may only be required to input topographic data, hydrologic data such as SCS curve number, and the geometry of the hydrologic elements representing the agricultural field or watershed. At this level the user is not allowed to edit the default values. This first level may be used to characterize watersheds where limited data are available. The second level allows the user to edit the most sensitive of the default parameters. For the modified GLEAMS model the following sensitive parameters were identified: curve number, saturated hydraulic conductivity, soil loss ratio, field capacity, wilting point, porosity, and Manning's roughness coefficient for both overland and channel elements. The third level allows the user to edit all parameters. This level is useful for users interested in calibration and validation of the model using historical data for research applications.

The IS is being developed under the UNIX (UNIX is a trademark of AT&T Bell Laboratories)** operating system using the X Window System (X Window System is a trademark of the Massachusetts Institute of Technology)** with the OSF/Motif (Motif is a trademark of the Open Software Foundation)** libraries to allow access to the power of workstations and graphical capability of X Window System. UNIX is a multitasking operating system, by taking advantages of this, the IS allows the user to continue using the IS while the simulation models are being run.

** Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may also be suitable.

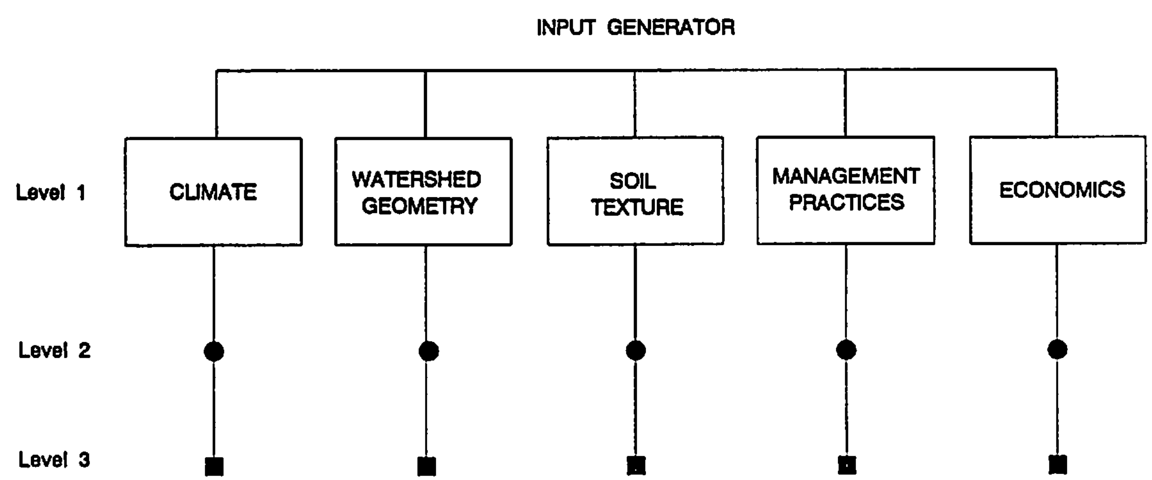

Figure 2. Input Generator Diagram

Components of the IS

Input Generator

The Input Generator is subdivided into five dialogue windows: a) climate, b) watershed geometry, c) soil texture, d) management practices, and e) economics. The user selects any window and is prompted to enter the appropriate information. Depending upon the level of interaction between the Input Generator and the user, the user may select the suggested default value shown in the dialogue window or change it. Each default value shown in the dialogue window contains a brief description of the source of the value. In addition, if the user elects to change the default value, the Input Generator checks whether the input value is within the range of the selected parameter. If the user inputs a value outside the range of the selected parameter, an error message appears on the screen along with a help window. The default input parameter values for the modified GLEAMS are stored in a data base which contain information regarding soils, climate, crops, pesticides, nutrients, management, and economics. Once the input files are created, the user may save input files or retrieve existing files.

A brief description of each dialogue window in the Input Generator follows.

Climate
Climate input values can be generated by a stochastic weather generator or obtained from historical weather records. The weather generation methods used in the Input Generator component are based on the climate generator CLIGEN (Nicks and Lane, 1989), which generates rainfall amounts, maximum and minimum temperature, and solar radiation for over 1000 locations in the U.S.

Watershed Geometry
The watershed geometry dialogue window gathers the information pertinent to drainage area, topographic data such as slope length and slope steepness and whether the hydrologic element is a hillslope, channel, or impoundment. The dialogue window will query the user to input the geometric characteristics of each hydrologic element. For example, if the agricultural field is to be represented by a sequence of overland flow and two channel elements, the dialogue window will query the user to input the overland flow profile geometry, the channel length, the slope of the channel segment, and the channel cross section for both channel elements.

Management Practice
This dialogue window parameterizes different management scenarios for agricultural fields or watersheds. All information with regard to the type of crops, updatable parameters for crop rotation, different types of conservation practices, and application rates of nutrients and pesticides are integrated in this window. Many of the parameters used in the simulation model are management practice dependent. For instance, the soil loss ratio value depends on the type of tillage system. Given a tillage system, the crop stage period and canopy cover for a crop, the management practice dialogue window queries the data base to select the appropriate value for the soil loss ratio. Over 20 crops can be simulated including all major cereals and legumes. In addition, the user may select default input parameter values for pesticides using either trade or common names. Given the name of the pesticide, the data base provides values for water solubility, foliar residue half-life and partition coefficient. Similarly, default input parameter values can be provided for nitrogen and phosphorous. The user defined parameters are the planting and harvesting dates.

Soil
The soil dialogue window provides parameter values related to physical and hydrological properties of soils. The user may provide a soil texture for each soil layer and the dialogue

window will query the data base to select appropriate parameter values for hydrologic, physical, and chemical parameter values. At the present time, the user may select from the data base 21 generic soil textures (i.e. sandy loam, silty clay, etc.). Given a soil texture, the data base provides default values for parameters such as average primary soil particle (clay, silt, and sand), specific surface area for clay particles and organic matter, field capacity, wilting point, porosity, bulk density, and saturated hydraulic conductivity.

Economics

The data required for the economic component of the Input Generator consists of the costs for all inputs, per unit price for all crops produced, and parameters which allow the calculation of the fixed and variable costs of machinery. The economic data are intended to be used in an accounting program which associates a cost with each operation performed on a crop and sums the costs to calculate total expenses. Total sales calculated are the product of the simulated crop yield and sale price of that crop. The difference between sales and expenses will be the return which can be shown as income statements in varying levels of detail. The economic program Cost and Return Estimator (CARE) (Midwest Agricultural Research Associates, 1988) used, has been developed for use by the Soil Conservation Service, so the required economic data should be available, at least at the state level, for a number of areas in the country. CARE has been modified to provide multiple year simulations

The Simulation Model

The current simulation model is a modification of GLEAMS. The model has three major submodels: hydrology, erosion/sediment yield, and pesticides. The hydrology component uses daily climate data to compute the water balance in the root zone. The erosion component calculates estimates of rill and interrill erosion on overland flow areas for each storm event. Sediment enrichment ratios are computed for use in the estimation of adsorbed pesticide transport. The pesticide component simulates the movement of pesticides over the surface and through the root zone. Surface losses of pesticides are those contained in surface runoff and sediment. The vertical movement is through percolation, evaporation, and plant uptake. The movement of pesticide metabolites is also simulated. Because the original GLEAMS model did not have a nutrient component, the nutrient component of CREAMS was added to GLEAMS. This submodel estimates the amount of nutrients lost in the runoff and sediment, and losses by leaching and plant uptake. To simulate crop yields the crop growth component from EPIC was integrated into GLEAMS. The major processes simulated include water and nutrient uptake, conversion to biomass, and conversion of biomass to yield. The economic component uses the crop yield estimate from the modified GLEAMS to calculate net returns to the farmer.

Output Interpreter

The Output Interpreter prepares graphs and statistics from the output of the simulation model using graphics from a statistics package. In the future, the Output Interpreter will contain its own graphics capability. The GLEAMS output consists of: runoff, sediment yield, nitrate and phosphorous concentrations in runoff and sediment, amount of nitrogen lost by leaching and plant uptake, crop yield, and net return to the farmer. The user may select either detailed output or an annual summary for the variables mentioned above. The user selects the type of output desired at the front end of the IS. In selecting the detailed option for the GLEAMS model, the user obtains storm by storm output. This output consists of daily amounts of rainfall and runoff produced by the storms generated by CLIGEN. The detailed output for nutrients and pesticides includes concentrations in each computational soil layer before and after each storm. The annual summary yields total amount of rainfall, runoff, percolation into the root zone, sediment leaving the watershed, plant nutrient losses, pesticide losses, and crop yield production.

Decision Model

The decision model combines the use of scoring functions as described in Yakowitz et al. (1992a) and the decision tools described in Yakowitz et al. (1992b). To compare the noncommensurable decision criteria such as runoff volume, nitrogen in sediment, crop yield, and sediment yield, a scoring function which converts the predicted data from the simulation model to values on a 0 to 1 unitless scale is specified by the decision maker for each decision criterion. These functions are modified for each criterion by setting threshold values. The conventional or baseline practice scores 0.5 for each decision variable by definition. Based on the slopes of the scoring functions an importance order of the decision criteria is established. Once all the alternatives have been scored, a score matrix is available to complete the analysis which involves ranking the alternatives based on best and worst composite scores as described in Yakowitz et al. (1992a).

Summary

The trend in national natural resource management is toward using decision support technology. The Prototype Decision Support System for the USDA Water Quality Initiative incorporates a user Interface Shell which is the system's controller or driver. The Interface Shell is being developed to assist users of natural resource models to easily build input files, run the simulation and decision models, and interpret the output by means of menu driven graphics. Currently, the only simulation model integrated into the Interface Shell is a modified version of GLEAMS. The Interface Shell will facilitate the routine application of data, through simulations, to natural resource problems. The user will be buffered from the complexity of building files for particular simulation models. This Interface Shell is a powerful tool to help simulate and ultimately to evaluate alternative agricultural management systems.

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