#457

Technology Transfer NOTE

SOIL CONSERVATION SERVICE 10/1/83

WEST NATIONAL TECHNICAL CENTER

PORTLAND, OREGON

Frank Reckendorf, Editor

VOLUME 2 NUMBER 1

TABLE OF CONTENTS

The following article concerning models was prepared by Kenneth G. Renard, Hydraulic Engineer, ARS, for use at the SCS State Resources Conservationist Meeting in Fort Worth, Texas (January 31, 1983). It is a good overall summary of ARS models and is presented in total.

NATURAL RESOURCE MODELS IN ARS

Rosenblueth and Wiener (1945) state:

> "No substantial part of the universe is so simple that it can be grasped and controlled without abstraction. Abstraction consists in replacing the part of the universe under consideration by a model of similar but simpler structure. Models, formal or intellectual on the one hand or material on the other, are thus a central necessity of scientific procedure."

Such an introduction to an overview of the natural resource modeling efforts in the Agricultural Research Service is especially appropriate, because the material presented is a further abstraction of the salient model features. Thus, this handout is intended primarily to enumerate the models and some references to published information regarding the details involved. Finally, the intention is to encourage you to contact the persons in ARS responsible for the model development.

SPAW

The Soil, Plant, Air, Water (SPAW) model has been developed by K. E. Saxton and cohorts (USDA-ARS, Washington State University, Smith Agricultural Engineering Building, Pullman, WA 99164). The model (Saxton et al., 1974) is a comprehensive model which computes daily actual ET from small watersheds. The model separates the major climatic, crop, and soil effects into a calculation procedure with emphasis on graphical representation of principle relationships. Calculated amounts of interception evaporation, soil evaporation, and plant transpiration are combined to provide daily actual ET estimates.

Daily potential ET is computed by any one of the several methods. Intercepted water at the plant and soil surfaces is then considered to have first use of the potential ET energy, and no limits are imposed. Remaining potential ET is divided between soil water evaporation or plant transpiration according to plant canopy present. Actual soil evaporation is the potential limited by soil water content at the surface, except in the very wet range, thus representing the traditional two-stage drying sequence. For dry soil with a plant canopy, a percent of the unused soil evaporation potential is returned to the plant transpiration potential to account for radiated and convected energy from the heated soil and air. Actual transpiration is computed through sequential consideration of (1) plant phenology to describe the transpirability of the existing canopy, (2) a root distribution to reflect where in the soil profile the plant is attempting to obtain water, and (3) a water stress relationship which is applied to each soil layer and is a function of the plant available water of that soil layer and the atmospheric demand on the plant. The soil water is adjusted by subtracting the daily actual ET from each soil layer with roots, adding daily infiltration computed from daily precipitation minus measured or estimated runoff, and estimating soil water redistribution and percolation by a Darcy-type unsaturated flow computation. Further documentation and testing of model applications are given in Saxton, 1982, Saxton and Bluhm, 1982, and Sudar et al., 1981.

CREAMS

Chemicals, Runoff, Erosion, and Agricultural Management Systems (CREAMS) has received a fair amount of publicity since its original publication (Knisel, 1980). The principal objective of the project which produced the model was to develop a hierarchy of mathematical models for use at a field level to (1) assess non-point-source pollution, (2) quantify responses from alternative management practices, and (3) evaluate best management practices. Although additional testing and development continues on this model (e.g., CREAMS II should be forthcoming within 6 months), much of the effort now includes technology transfer and development of user packages to implement the model.

Dr. Walter G. Knisel (USDA-ARS, Box 946, Tifton, GA 31793) is the leader of this effort. The model considers precipitation, radiation, and temperature to be the driving forces of the watershed system, together with man's management of the system through land use, cultural practices, and the use of chemicals. Output from the system includes surface runoff, which results in erosion and sediment transport and the associated dissolved and adsorbed chemicals. Some infiltrated water may become subsurface flow and/or percolation, both of which may carry dissolved chemicals. Evapotranspiration is also considered as an output, since it affects the uptake of chemicals by the plants.

The hydrologic portion of the CREAMS model has two basic options, one using the curve number approach of SCS where only daily rainfall is available, and a second which uses breakpoint rainfall data and an infiltration equation.

The erosion-sedimentation part of the model is based on modifications of the Universal Soil Loss Equation (USLE). The modifications involve allowing parameter values to change along complex overland flow profiles and along waterways to represent both spatial variability and variations that occur from storm to storm. Thus, the model facilitates description of detachment and transport and deposition of sediment from complex slope shapes, as well as from numerous overland flow-channel-pond sequences (Foster et al., 1981).

Another strong feature of the model is that it considers soil loss by particle-size class, so that the adsorbed chemicals associated with finer-sized particles are considered (Foster et al., 1981; Del Vecchio and Knisel, 1981; Foster, Lane, and Knisel, 1980). CREAMS has also been used with great success to measure concentrated flow erosion. DR. G. R. Foster, the prime author of this portion of the model (G. R. Foster, USDA-ARS Soil Erosion Laboratory, Purdue University, W. Lafayette IN 47907), states that studies show that soil conditions play a major role in erosion by concentrated flow. For example, tillage increases rill erosion by a factor of 3. Deposited soil in furrows becomes strongly resistant to erosion over a 2-month period, but soil deposited during a given storm is highly erodible. Additional documentation on the concentrated flow erosion is given in Foster and Ferreira, 1981; Foster et al., 1982a, b, and c.

The chemical part of the CREAMS model considers both plant nutrients and pesticides. It calculates nitrogen and phosphorus loads runoff and sediment at the field edge, and it estimates nitrate leached through the root zone. The chemistry component also considers internal soil nitrogen processes of mineralization, denitrification, and plant uptake. It calculates water and sediment fractions of pesticide load for the field. Foliar applied, soil-surface applied, and soil incorporated pesticides are considered, including multiple applications such as are used for insect control. Examples of some hydrologic sedimentation and chemical balances for different management systems are presented in Del Vecchio and Knisel (1982).

SWAM

The Small Watershed Model (SWAM) is also a nonpoint pollution model. However, its prime difference is that it is intended for use on watersheds composed of a number of CREAMS-sized areas. Thus, the objective is to facilitate the spatial variability encountered in going from a field to watershed of some size, which will allow spatial rainfall variability as well as topography, soils, crops, etc. A major feature of the model is to route the outputs from CREAMS-sized elements to points downstream. The model, which is still undergoing development, will use the fully dynamic version of CREAMS II mentioned earlier. Major elements, in addition to the channel routing, is the need to consider groundwater flow and reservoir processes for runoff, sediment, and chemicals. Dr. Donn G. DeCoursey, USDA-ARS, P. O. Box E, Ft. Collins, CO 80522, is the coordinator for the SWAM effort.

EPIC

The Erosion Productivity Input Calculator (EPIC) model was developed recently to determine the relationship between soil erosion and soil productivity throughout the United States (Williams et al., 1983; Williams and Renard, 1983). The model was developed specifically to assist USDA with responses to the 1977 Soil and Water Conservation Act (PL95-192), commonly referred to as RCA. The leader of the EPIC model is Dr. Jimmy R. Williams, USDAARS, Box 748, Temple, TX 76503.

The components of EPIC can be catagorized into eight major divisions: weather, hydrology, erosion, nutrients, plant growth, soil temperature, tillage, and economics. Four options are provided for inputting weather information into EPIC. The first three deal with precipitation, air temperature, and solar radiation (all three variations can be read into the program; precipitation can be read in and temperature and radiation simulated; or all three variables can be simulated). Precipitation, such as snow, is estimated as a function of precipitation and air temperature. The fourth option, wind (velocity and direction), is simulated if wind erosion is to be considered by the model. Wind erosion is predicted using the Wind Erosion Equation (Woodruff and Siddoway, 1965) modified to operate on a daily time step. Water erosion is simulated with the USLE (Wischmeier anbd Smith, 1978, the Onstad-Foster (1975) modification of the USLE, or the MUSLE (Williams, 1975).

The hydrology component of EPIC simulates surface runoff volume and peak discharge rate for a given daily rainfall depth (these values are needed in the erosion model). Other hydrology components include evapotranspiration, percolation, lateral subsurface flow, drainage, irrigation, and snow melt. The two plant nutrients considered in EPIC are nitrogen and phosphorus. Nitrogen processes simulated include runoff of NO_3, organic N transport by sediment, leaching, upward NO_3 movement by soil evaporation, denitrification, immobilization, mineralization, crop intake, rainfall contribution, fertilizer addition, and fixation. Phosphorus processes simulated include loss of soluble P with runoff, mineral and organic P losses with sediment, immobilization, mineralization, sorption-desorption, crop uptake, and fertilizer addition.

A general plant growth model is used to simulate above-ground biomass, yield, and roots for corn, grain, sorghum, wheat, barley, oats, peanuts, sunflowers, soybeans, alfalfa, cotton, and grasses. The plant growth model simulates energy interception (energy conversion to roots, above-ground biomass, and grain and fiber production) and air temperature stresses. Soil temperature is simulated to serve the nutrient cycling and root growth components of EPIC. Soil temperature is predicted at the center of each soil layer as a function of the previous day's soil temperature, the present day's air temperature and solar radiation. The EPIC tillage model simulates row height, surface roughness, change in bulk density, transition from standing flat residue, and mixing of soil layers, nutrients, and plant residue for any tillage operation. The economics component of EPIC uses a crop budget to calculate crop production costs. Income is determined from simulated annual crop yields. Net profit (income minus cost) is subject to change as the soil erodes away.

Although EPIC is a fairly comprehensive model, it was developed specifically to assess the erosion-productivity problem. Thus, user convenience was an important consideration in designing the model. The computer program contains 53 subroutines, although there are only 2700 FORTRAN statements. Since EPIC operates on a daily time step, computer costs for low priority computing are only about $0.15 per year of simulation on an AMDAHL 470 Computer[1]. The model can be run on a

[1] See standard footnotes on page 18.

variety of computers, since storage requirements are only 210 K.

SPUR

The Simulation of Production and Utilization of Rangelands (SPUR) model is one of the newest models to be developed in ARS. The model coordinator is Dr. J. Ross Wight, USDA-ARS, 1175 South Orchard, Suite 116, Boise, ID 83705.

SPUR is a physically based rangeland simulation model developed to aid both resource managers and researchers. It can be applied to a wide range of conditions with a minimum of "tuning" or "fitting." As a management tool, it provides a basis for management decisions by predicting herbage yields, livestock production, runoff, and erosion. As a research tool, it helps identify research needs, enhances organization and transfer of information, and provides a focus for ARS range research programs. SPUR is composed of five basic components: (1) climate, (2) hydrology, (3) plant, (4) animal (both domestic and wildlife), and (5) economic. A subroutine is available to simulate the impacts of either grasshopper destruction or control, but at present, this is an option, and is not triggered by any model component. A soil frost subroutine is also included in SPUR. It predicts depth of frost penetration and thaw of the soil profile, frost type, and permeability. Simulation is generally on a daily basis.

The climatic routine of SPUR is very similar to that of EPIC. The hydrology routine is capable of considering the effects of management changes and spatial soil and topographic features, as well as temporal variation in precipitation on individual storm events. Furthermore, the model considers runoff losses (transmission losses) in ephemeral streams or gains due to groundwater sites, including the effects of flow into and out of reservoirs. The current erosion (Wight, ed., 1983) model does not include any provision for chemical routing, although it undoubtedly will in the future.

WHERE DO WE GO FROM HERE?

The CREAMS, EPIC, and SPUR models all use the curve number concept to convert daily rainfall estimates to runoff volumes, with the residual then being the infiltration. This concept has stood the test of time well, but hydrologists have known for some time that it is a weakness when hydrologic analysis is to be used for things besides flood peak estimates. The continuous similation models can only be improved with the use of infiltration models, which have been available for decades, but are difficult to use because of limited precipitation data (except daily totals). Work by Woolhiser (ARS colleague of mine in Tucson) and others is offering great promise by using stochastic models to estimate short-term intensities from daily rainfall models. With such an approach, time-distributed infiltration models can in turn be used to compute rainfall excess.

In still another modeling effort, Drs. D. L. Brakensiek (USDA-ARS, 1175 S. Orchard, Suite 116, Boise, ID) and W. J. Rawls (USDA-ARS, Bldg. 007, BARC-West, Beltsville, MD 20705) have been quite successful in estimating the parameters in the Green-Ampt infiltration model from the physical properties of soils (Brakensiek et al., 1981; Rawls et al., 1982; Rawls et al., 1983). This research, although continuing, appears to be very promising.

Another major problem with the natural resource models involves data assembly. Certainly, remote sensing offers great potential in this problem. The remote sensing probably involves observations other than from satellites. In ARS, Dr. E. T. Engman (USDA-ARS, Hydrology Laboratory, BARC-West, Beltsville, MD 20705) and others have shown that airplanes equipped used for mapping of vegetation, soil moisture, and curve numbers (Engman, 1982).

As a final comment, as additional experience with these models is obtained, we will undoubtedly need to modify them to consider things not anticipated, or new research will show how they can be improved. It is imperative that SCS personnel, when using this technology, feed comments (both pro and con) back to the authors, so that the models do what you need them to do.

Thank you for the chance to convey this material to you.

REFERENCES

Brakensiek, D. L., R. L. Engleman, and W. J. Rawls. 1981. Variation Within Texture Classes of Soil-Water Parameters. Trans. ASAE 24(2):335-339.

Del Vecchio, J. R. and W. G. Knisel. 1982. Application of Field-Scale Nonpoint Pollution Model. In: Proc. ASCE Specialty Conference, Environmentally Sound Water and Soil Management., Orlando, FL. pp. 227-236.

Engman, E. T. 1982. Remote Sensing Application in Watershed Modeling. In Applied Modeling of Catchment Hydrology, V. P. Singh (ed.), Water Res. Publications. pp. 473-494.

Foster. G. R., L. J. Lane, and W. G. Knisel. 1980. Estimating Sediment Yield from Cultivated Fields. Proc. ASCE Symposium on Watershed Management, Boise, ID. pp. 151-163.

Foster, G. R. and V. A. Ferreira. 1981. Deposition in Uniform Grade Terrace Channels. Proc. Conf. on Crop Production with Conservation in the 80's. Amer. Soc. Agric. Engrs., St. Joseph, MI. pp. 185-197.

Foster, G. R., L. J. Lane, J. D. Nowlin, J. M. Laften, and R. A. Young. 1981. Estimating Erosion and Sediment Yield on Field-Sized Areas. ASAE 25(5):1253-1262.

Knisel, W. G. (ed.). 1980. CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U.S.D.A., Science and Education Administration, Conservation Research Report No. 26. 643 pp.

Knisel, W. G. and G. R. Foster. 1980. CREAMS: A System for Evaluating Management Practices. In Economics, Ethics, Ecology: Roots of Productive Conservation, W. E. Jeske (ed.), Soil Conservation Society of America. pp. 177-194.

Onstad, C. A. and G. R. Foster. 1975. Erosion Modeling on a Watershed. Trans. ASAE 18 (2):288-292.

Rawls, W. J., D. L. Brakensierk, and K. E. Saxton. 1982. Estimation of Soil Water Properties. Trans. ASAE 25(5):1316-1320, 1328.

Rawls, W. J., D. L. Brakensiek, and N. Miller. 1983. Green-Ampt Infiltration Parameters from Soils Data. J. Hydr. Engr., ASCE 109(1):62-70.

Rosenblueth, A. and N. Weiner. 1945. The Role of Models in Science. Philosophy of Science XII, No. 4, pp. 316-321.

Saxton, K. E., H. P. Johnson, and R. H. Shaw. 1974. Modeling Evapotranspiration and Soil Moisture. Trans. ASAE 17(4): 673-677.

Saxton, K. E. and G. C. Bluhm. 1982. Regional Prediction of Crop Water Stress by Soil Water Budgets and Climatic Demand. Trans. ASAE 25(1):105-110, 115.

Wight, J. R. (ed.) 1983. SPUR-Simulation of Production and Utilization of Rangelands: A Rangeland Model for Management and Research. USDA-ARS Miscellaneous Publication No. 1431. 126 pp.

Williams, J. R. 1982. Testing the Modified Universal Soil Loss Equation. In Agricultural Research Service, Proc. Workshop on Estimating Erosion and Sediment Yield on Rangelands, Tucson, AZ, March, 1981. ARM-W-26. pp. 157-165.

Williams, J. R., P. T. Dyke, and C. A. Jones. 1983. EPIC--A Model for Assessing the Effects of Erosion on Soil Productivity. Proc. Third Intn'l Conf. on State-of-The-Art in Ecological Modelling, Colorado State Univ., May 24-28, 1982.

Williams, J. R. and K. G. Renard. 1983. Assessments of Soil Erosion and Crop Productivity with Process Models (EPIC). In Proc. Symp. on Soil Erosion and Crop Productivity, Soil Sci. Soc. Am., March 1-3, 1983, Denver, CO.

Wischmeier, W. H. and D. D. Smith. 1978. Predicting Rainfall Erosion Losses, A Guide to Conservation Planning. USDA Agriculture Handbook No. 537. 58 pp.

Woodruff, N. P. and F. H. Siddoway. 1965. A Wind Erosion Equation. Soil Sci. Soc. Am. Proc. 29(5):602-608.

(Prepared and submitted by Kenneth G. Renard, USDA-ARS, Southwest Rangeland Watershed Research Center, Tucson, AZ.)

DOW CHEMICAL WITHDRAWS FROM 2,4,5-T BUSINESS IN THE U.S.: EXITS EPA POLICY PROCEEDING ON THE HERBICIDE [1]

The following update was provided by the Agricultural Products Department, Public Affairs Group, Dow Chemical U.S.A.

The Dow Chemical Company has announced its withdrawal from the domestic 2,4,5-T herbicide business. This action includes the voluntary cancellation of all of Dow's remaining U.S. registrations for products containing 2,4,5-T and silvex.

In a related decision, Dow formally withdrew from the EPA administrative cancellation hearings which were convened to evaluate the risks and benefits of 2,4,5-T application.

"The great weight of scientific evidence confirms that 2,4,5-T can be used safely without undue risk to people or the environment," said Keith R. McKennon, Dow group vice president for Agricultural Products. "Our commitment to this position is firm, unwavering, unequivocal."

Reinforcing this position is the judicial decision last month in Canada in which Nova Scotia Supreme Court Justice D. Merlin Nunn stated, "I am satisfied that the overwhelming currently accepted view of responsible scientists is that there is little evidence that, for humans, 2,4,5-T is mutagenic or carcinogenic, and that TCDD is not an effective carcinogen, and further, that there are no-effect levels and safe levels for humans and wildlife for each of these substances."

"We have worked hard to demonstrate that scientific reality," said McKennon, "but we believe further expenditures of Dow and EPA resources on the issue are not likely to be productive. Since we have no significant commercial interest, we have chosen the action announced today.

"Much has changed since 1979 when EPA suspended certain uses of 2,4,5-T and silvex. We are encouraged by Administrator Ruckeshaus' recognition that a risk-free environment is not possible and that EPA must manage risk reductions based on full consideration of the available scientific evidence along with the cost and benefits of regulatory action," McKennon said.

Dow has expended over $10 million to defend the continued use of 2,4,5-T based on the preponderance of scientific data demonstrating the herbicide's safety and utility. These expenses far exceeded the minimal profit return from 2,4,5-T sales.

Despite exhaustive efforts for nearly three years by Dow and the EPA to reach an agreement regarding the future of 2,4,5-T herbicides, the parties were unable to achieve a satisfactory compromise.

Progress made by Dow and others in herbicide product development since 1979 has resulted in substitute products being available to satisfy the needs of foresters, ranchers, and farmers.

Dow has not manufactured 2,4,5-T in the U.S. since 1979 when the EPA restricted some uses of the herbicide. Since then, Dow has been supplying reduced market demand from residual inventories. Dow's U.S.-based 2,4,5-T manufacturing plant has been dismantled for some time and no Dow jobs will be affected by today's action.