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WEPS 1.0 - What It Is and What It Isn't[1]

L.E. Wagner and J. Tatarko[2]

Abstract

The Wind Erosion Prediction System (WEPS) is a process-based, daily time-step, computer model that predicts soil erosion via simulation of the physical processes controlling wind erosion. WEPS is intended primarily for soil conservation and environmental planning. WEPS 1.0 is the first implementation of WEPS intended for use by the United States Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS). It includes a graphical user interface to allow the user to easily select climate stations, specify field site dimensions, pick a predominant soil type, and describe any field wind barriers and management practices applied to an agricultural field. This interface allows the user to quickly assess a site's susceptibility to wind erosion and evaluate the impacts that alternate practices and conditions might have on reducing that susceptibility. Features and capabilities of WEPS 1.0 user interface include 1) the ability to define wind barrier characteristics and their location on the boundaries of the simulation region, 2) selection of soils obtained from the NRCS National Soil Information System (NASIS) soil database, and 3) detailed specification of actual management practices employed by land managers. Display of output information regarding soil loss by transport mode, direction, and size (saltation/creep, suspension, PM10) is also available.

Keywords. Soil erosion, Wind erosion, Air quality, Erosion models, WEPS, Graphical interface, GUI.

Introduction

Development of the Wind Erosion Prediction System (WEPS) was initiated by scientists in the USDA-Agricultural Research Service (ARS) in response to customer requests for improved wind erosion technology. WEPS is intended to replace the predominately empirical Wind Erosion Equation (Woodruff and Siddoway, 1965) as a prediction tool for those who plan soil conservation systems, conduct environmental planning, or assess off-site impacts caused by wind erosion. WEPS incorporates improved technology for computing soil loss by wind from agricultural fields. It also provides new capabilities such as separate calculation and reporting of creep/saltation size particles, suspension loss, and PM-10 emission estimates from the field (Wagner, 1996).

WEPS 1.0 is the first implementation of WEPS to be released and includes a graphical user interface to simplify the use of the model. WEPS 1.0 implements a subset of all the features and capabilities envisioned for WEPS. However, it does include the full process-based, daily time-step, organizational structure; input databases; process-based erosion prediction technology; and most other key elements advertised for WEPS in the past. The mix of features in WEPS 1.0 was determined based upon USDA-NRCS's current primary needs for a wind erosion prediction tool and their desire to have a version of WEPS available for agency-wide use prior to implementation of an anticipated 2002 Farm Bill. Future releases of WEPS are projected to include additional functionality and other capabilities as customer demand dictates. Users trained in the use of WEPS 1.0 should find their knowledge, databases, and management/crop rotation files for WEPS 1.0 to be directly transferable to future versions of WEPS. This paper describes the implemented capabilities of WEPS 1.0, identifies typical problems it can address, and presents an overview of what can be expected in future versions of WEPS.

Background

Soil erosion by wind is a surface phenomenon. It is initiated when the wind speed exceeds the threshold speed for a given soil and its surface condition. After initiation, the duration and severity of an erosion event depend on the wind speed and the evolution of that surface condition. Therefore, WEPS requires wind speed

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[2] Larry E. Wagner, Agricultural Engineer, USDA-ARS-NPA, Wind Erosion Research Unit, Manhattan, KS; John Tatarko, Research Assistant Professor, Agronomy Dept., Kansas State University, Manhattan, KS; **Corresponding author**: Dr. Larry E. Wagner, USDA-ARS-NPA, Wind Erosion Research Unit, Throckmorton Hall, Kansas State University, Manhattan, KS 66506; tel.: (785) 532-6807; fax: (785) 532-6528; e-mail: <wagner@weru.ksu.edu>.

and direction to simulate the erosion process. These and other weather variables also are used in WEPS to drive temporal changes in hydrology, soil erodibility, crop growth, and residue decomposition and track the current soil state and surface condition within the model. Stochastic climate generators, WINDGEN (Skidmore and Tatarko, 1990) and CLIGEN (Nicks et al., 1987), are used to provide WEPS with the necessary daily weather data and subdaily wind information.

The simulation region in WEPS is a field or, at most, a few adjacent fields. Areas of the simulation region that have differing soil, management, or cropping conditions are treated as separate subregions. WEPS can output soil loss/deposition over user-selected time intervals from user-specified accounting regions within the simulation region. This allows the WEPS user to obtain output over various spatial scales within the simulation region. WEPS also provides users with individual soil-loss components of creep/saltation, suspension, and PM10 size fractions. These components are particularly useful as an aid in estimating off-site impacts of wind erosion.

Science Model Design

The WEPS computational science model is modular in design and consists of a Main supervisory routine and several submodel components. The Main routine (Tatarko, 1995) handles the time steps in the model, reads the input files, controls the individual submodel routines, and generates the output reports. Each of the individual submodel components likewise performs specific duties within the WEPS model:

1) The Erosion submodel (Hagen, 1995) decides if erosion can occur based on the current surface roughness, quantity of flat and standing biomass, aggregate size distribution, crust and rock cover, loose erodible material on a crust, and soil wetness. If the surface conditions are susceptible and wind speed is sufficient, erosion is computed on a subhourly basis.
2) The Hydrology submodel (Durar and Skidmore, 1995) estimates soil surface wetness; accounts for changes in soil temperature; and maintains a soil-water balance based on daily amounts of snow melt, runoff, infiltration, deep percolation, soil evaporation, and plant transpiration.
3) The Soil submodel (Hagen et al., 1995) tracks changes in soil and surface temporal properties in response to various weather processes like wetting/drying, freezing/drying, freezing/thawing, precipitation amount and intensity, and time.
4) The Crop submodel (Retta and Armbrust, 1995) simulates the growth of crop plants. It can simulate a variety of crops and plant communities, while accounting for water and temperature stresses. It calculates daily biomass production of roots, leaves, stems, and reproductive organs as well as leaf and stem areas.
5) The Decomposition submodel (Steiner et al, 1995) simulates the decrease in crop residue biomass from microbial activity. The decomposition process is modeled as a first order reaction, with temperature and moisture as the driving variables. It maintains separate decomposition pools for residue type (parent material); plant component (stems and roots); location (standing, flat, buried); and residue age.
6) The Management submodel (Wagner and Ding, 1995) simulates the various cultural practices applied to an agricultural field. These include primary and secondary tillage, cultivating, planting/seeding, harvesting, irrigating, burning and grazing operations. Each individual operation is described as a series of processes that reflect the physical changes in the soil, surface, crop, and residue status. The list of operations and dates initiated is maintained in a management/crop rotation input file.

This modular design is intended to allow updating and revising of the science model, or even replaceing specific components and/or sections in the future as our knowledge and understanding of erosion, climate, plant growth, and other processes improve.

WEPS 1.0

WEPS 1.0 is the first public release of WEPS. To meet NRCS's immediate needs for improved capabilities of wind erosion prediction; to allow other users earlier access to WEPS technology; and to facilitate getting that first product "out the door", it was necessary to limit the scope of what WEPS 1.0 would do. Thus, the following design decisions were made:

1) WEPS 1.0 would be released with a graphical user interface to assist users in making WEPS simulation runs. For NRCS users to apply WEPS in the manner expected, they would need to be able to select and modify inputs quickly and easily. Likewise, users want the output presented in a convenient form that is easy to interpret.
2) WEPS 1.0 would use the full WEPS core science model. No separate, "scaled down" version of the WEPS simulation code would be developed. As the WEPS science code evolves, WEPS 1.0 would continue to use the "latest" version of that code. This approach ensures that WEPS 1.0 will benefit from bug fixes and simulation enhancements in the WEPS science code.
3) WEPS 1.0 would handle a single homogeneous subregion, i.e., the simulation region would be represented by only one soil type and management/crop rotation sequence. This allows the WEPS 1.0 developers to focus on the core physical simulation processes in WEPS and not the code to handle multiple subregions.
4) WEPS 1.0 would have only one defined accounting region, the entire simulation field. Because only one subregion is used, the need for additional accounting regions would be limited. This approach also reduces the number of potential output options with which a user is confronted.
5) WEPS 1.0 would provide a limited selection of time scales for output reports: a) biweekly period averages per rotation year; b) monthly averages per rotation year; c) rotation year averages; d) long-term yearly averages; and e) yearly results for a few selected data, such as crop harvest yields.
6) WEPS 1.0 would use the same soil, plant growth, management operation, and climate databases to be used in future WEPS releases. Planning for this level of compatibility with future versions of WEPS should make it easier for WEPS users to upgrade to later, more functional, WEPS releases.
7) WEPS 1.0 would limit wind barrier placement to field boundaries only. This would simplify the graphical user interface code for placing and displaying wind barriers. Also, because WEPS 1.0 would deal with only a single subregion, placing barriers within the simulation region would be of limited benefit.

User Interface

WEPS 1.0 requires the following user input selections to perform a simulation run: 1) site location, which determines the appropriate weather station data records to be used by the climate generators; 2) rectangular site dimensions and orientation with respect to North; 3) dominate soil type; 4) management/crop rotation practices applied to the field; and 5) any wind barriers along the field boundaries (optional). The objective of the graphical user interface is to provide an easy way for a user to make those input selections via choice lists from databases and prebuilt templates. The interface also gives users the ability to modify individual input parameter values for any given simulation run. In addition, the user interface provides a convenient method to select and view desired WEPS output information.

Future WEPS Features

In the future, WEPS will better represent spatially the effects of varying terrain, changing soil types, wind barriers, strip-cropping systems, ridge till, contour-farming practices, and emergency tillage on wind erosion. In addition, WEPS will be expected to more accurately estimate the potential offsite effects of wind erosion on air and water quality, and roadside visibility and possible health consequences. To do so, the following capabilities will need to become available in subsequent versions of WEPS:

1) The ability to simulate more complex sites, which consist of two or more dominant soil types and possibly have different management practices applied to specific areas within the field site. This will be handled in WEPS through the use of multiple subregions or areas representing a single soil type and set of management practices.
2) The ability to specify elevation variations to describe the simulation region terrain more accurately and to better describe deviations in ridge and row directions that are due to the topography and/or shape of the field (contour farming practices and tilling parallel with field boundaries).
3) The ability to handle more advanced wind barriers (those with seasonal changes in height and silhouette area) and erosion traps (regions that are considered to only "collect" moving soil and not be potential transmission sources, e.g. ponds, grass waterways, road ditches) and have them placed anywhere within the simulation region.

Summary

WEPS is a process-based, daily time-step, computer model that predicts soil erosion via simulation of the physical processes controlling wind erosion. WEPS 1.0 is the first implementation of WEPS for use by the USDA-NRCS and is intended primarily for soil conservation and environmental planning. It includes a graphical user interface to allow the user to easily select climate stations, specify field-site dimensions, pick a predominant soil type, and describe any border field wind barriers and management practices applied to an agricultural field.

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