

WEPS and WEPP Science Commonality Project¹

F.A. Fox, D.C. Flanagan, L.E. Wagner, L. Deer-Ascough²

Abstract

The United States Department of Agriculture, Agricultural Research Service (USDA-ARS) has two independently developed, daily time step, process-based erosion models, one targeted for wind erosion (WEPS - Wind Erosion Prediction System) and one targeted for water erosion (WEPP - Water Erosion Prediction Project). The models currently share little source code or soil, plant, management and climate databases but do simulate many processes internally in a similar manner. The USDA Natural Resource Conservation Service (NRCS) has requested commonality between the two models with respect to model inputs, output formats and the underlying physical science where applicable. Common science and code between WEPS and WEPP will benefit NRCS with consistent wind and water erosion simulation run results and result in lower maintenance, training and support costs. A single erosion model will also encourage continued inter-disciplinary research between wind and water erosion scientists, and allow future scientific enhancements to simultaneously benefit both wind and water erosion simulations. Two approaches facilitating a natural progression toward a unified erosion model are discussed. In a staged approach, each stage will consist of specified commonality elements (control structure, soil hydrologic processes, plant growth, etc.) being completed in a modular manner. The final stage would encompass the complete merging of the two models common components and erosion code under the common control structure in the same program. In a top down approach, a new modeling structure would be designed and populated with complete science modules supporting simulation of both erosion processes.

Keywords. WEPS, WEPP, Wind erosion, Water erosion, Models.

Scope of the Models

Process based simulation of erosion combines a description of the relevant state of the system with the time evolution of external conditions and modeling of the state transition physical processes. In both WEPS and WEPP erosion losses depend on the state of the soil profile, soil surface, growing vegetation and plant residue in interaction with the driving forces of wind and water. Physical processes affecting the system state are: the movement of water in the soil profile; removal of water through evaporation and transpiration; consolidation; aggregation, smoothing and crusting of the soil by water; freezing and thawing; crop growth in response to weather and soil status; residue decomposition; and the agricultural manipulation, amendment and removal of soil, vegetation and residue. Spatially, adjacent regions affect the erosion seen “downstream” by contributing eroded soil and modifying the driving force of either wind or water.

An examination of the individual models reveals that the unique requirements for modeling the two different erosion processes have influenced the selection of process sub-models. The erosion of soil by wind is strongly dependent on the horizontal movement of wind across the soil surface. The soil surface dryness, its aggregate and particle size distribution, and the cascading effect of wind blown soil are important elements in WEPS. WEPS modeling therefore predicts the dryness of the soil surface on an hourly basis, the silhouette density of growing vegetation and standing residue, the soil surface roughness and crust status, the wind energy in time, the flux of soil onto adjacent soil surface elements and the resistance of the dry soil surface aggregates to particle impact. The erosion of soil by water is strongly dependent on the vertical impact of raindrops on the soil surface, the accumulation of water on the soil surface and subsequent overland flow of water. WEPP modeling therefore focuses on the shielding effect of flat residue and vegetative canopy cover, the minute by minute infiltration of water into the soil, the overland and subsurface flow characteristics of the soil, and the resistance of wet soil to raindrop impact and flowing water.

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²Fred. A. Fox Jr., Agricultural Engineer, Wind Erosion Research Unit, USDA-Agricultural Research Service, Manhattan, KS; Dennis C. Flanagan, Agricultural Engineer, National Soil Erosion Research Laboratory, USDA-Agricultural Research Service, West Lafayette, IN; Larry. E. Wagner, Wind Erosion Research Unit, USDA-Agricultural Research Service, Manhattan, KS; Lois A. Deer-Ascough, Agricultural Engineer, Great Plains Systems Research, USDA-Agricultural Research Service, Fort Collins, CO. **Corresponding author:** Fred. A. Fox Jr., Wind Erosion Research Unit, USDA-Agricultural Research Service, 1007 Throckmorton, Kansas State University, Manhattan, KS, 66506; tel: (785) 532-6694; fax: (785) 532-6528; e-mail: <fredfox@weru.ksu.edu>.

Both WEPP and WEPS are constructed with independent process models modifying the system state on a daily basis. The WEPS model (Wagner, 1996) consists of the following distinct elements: **Climate generation** - daily precipitation, temperature, solar radiation; **Wind generation** - hourly wind for 16 cardinal directions; **Hydrology** - daily soil water balance of rainfall, irrigation, plant water use, drainage; **Soil surface water content** - hourly modeling of evaporative flux; **Management** - soil disturbance and biomass manipulation; **Soil** - re-consolidation, re-aggregation of disturbed soil due to rainfall, drying, freeze/thaw, and freeze/dry events; **Crop** - date, water and temperature effects with additions for stem, leaf and reproductive mass partitioning; **Residue decomposition** - surface and subsurface integrating water and temperature effects; **Erosion** - sub-hourly soil movement in saltation, creep, suspension, and pm-10 components.

In contrast, the WEPP model (Flanagan and Nearing, 1995) is divided into the following processes: **Weather generation** - daily precipitation depth, duration and intensity, temperature, solar radiation, and wind; **Winter processes** - snow accumulation and melting, soil freezing and thawing (hourly time step); **Irrigation** - schedules irrigation based on soil state or fixed user provided schedule; **Infiltration** - Green Ampt equation, precipitation, snowmelt or irrigation event based; **Overland flow hydraulics** - sheet and rill flow; **Water balance** - daily soil water balance of infiltration, irrigation, plant water use, percolation; **Subsurface hydrology** - percolation, lateral flow, resurfacing and tile drainage; **Plant growth** - date, water and temperature effects,

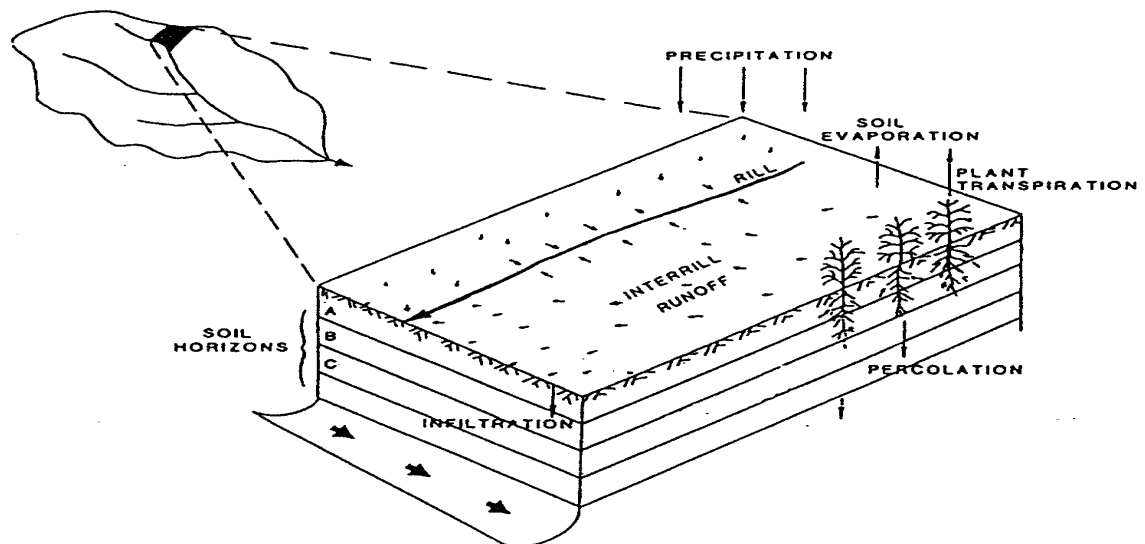


Figure 1. WEPP hillslope profile within a small watershed, showing hydrology processes include precipitation, infiltration, runoff, plant transpiration, soil evaporation, and percolation (from Savabi and Williams, 1995).

separate field crop and rangeland modules; **Residue decomposition** - surface and subsurface integrating water and temperature effects; **Soil** - disturbance by tillage and natural processes; **Hillslope erosion and deposition** - event based calculation of soil detachment and movement in sheet and rill flow; **Watershed channel hydrology and erosion processes** - routing of water and sediment from hillslopes through channel network, and infiltration, runoff and erosion processes in channel segments ; **Watershed impoundment** - routing of water and sediment through impoundments in catchment with removal of sediment through selective deposition. Figure 1 illustrates the various hydrologic processes addressed by the hillslope components of the WEPP model.

The state of the soil, plant, residue system is described by its state variables. These are modified by the process to evolve the system state in time throughout the length of the simulation. Table 1 shows a summary of the elements and state properties tracked in each model.

Control Structure

The main consideration in the structuring of two models is the type of simulation region. The simulation area in wind erosion modeling requires accurate geographic referencing to account for the effect of different wind directions. Water erosion modeling is slope and channel oriented, accounting for the flow and concentration of water moving downslope.

Table 1. Comparison of system elements modeled in WEPS and WEPP

System Element	WEPS	WEPP
Living Plant	masses of root, stem, leaves, reproductive parts, leaf area index, stem area index, canopy cover, plant height, root mass by layer, root depth	canopy height and cover, above ground biomass, leaf area index, grazable forage, harvest index, root mass by layer, root depth
Plant Residue	standing residue mass and height, surface flat residue mass, soil layer buried residue mass and root residue mass, all separated into 3 age pools	standing residue mass and height, flat residue on ridges, flat residue in furrows, buried residue and root residue by layer, with all flat & buried residues separated into 3 age pools
Soil Surface	water content, snow depth and water content, oriented ridges, random roughness, crusting	bare crust, residue covered non-crust, crop canopy covered non-crust, hydraulic conductivity, rill spacing, contour ridges
Soil Layers	water content, bulk density, aggregate size distribution, particle size distribution, hydraulic conductivity, soil water extraction matric potential relationship, temperature	depth to water table, water content, field capacity, permanent wilting point, bulk density, matric potential, porosity
Climatic Inputs	daily precipitation depth, solar radiation, max and min temperature, hourly wind speed and direction	daily precipitation depth, duration and peak intensity, solar radiation, max and min temperature, wind speed
Management Inputs	plant and kill vegetation, cut and remove vegetation and residue, bury, resurface and flatten residue, create random roughness and ridges, apply residue and water	plant and kill vegetation, cut and remove vegetation and residue, bury, resurface and flatten residue, create random roughness and ridges, apply residue and water

In WEPS, the simulation region is defined as a planar shape, the simplest version a rectangle. Topographic effects have not yet been added. Multiple adjacent subregions are in the code but not yet tested. Subregions are defined as an area of uniform state variables. Barriers can be placed around and within the simulation region. The erosion model then grids the entire simulation region and calculates the effect of the wind on an hourly basis. When the wind velocity exceeds the threshold wind velocity defined by the surface conditions, soil movement is modeled. The state variables for the simulation region are updated on a daily basis. In multiple subregion simulations, movement of soil is tracked across subregion boundaries, impacting erosion in downwind subregions.

In WEPP, the simulation regions are defined in terms of a watershed, divided into representative hillslope profiles (Figure 1), which may be composed of spatially variable overland flow elements placed from the top of the slope to the bottom of the slope. While the watershed is defined by a geographic boundary, the hillslope profiles are not specifically geographically placed but are represented as a singular rectangular region whose slope profile is similar to multiple non-rectangular regions and whose area sums to the areas represented. While this is efficient computationally, it can make it difficult to relate erosion estimates back to specific geographic field locations. A grid based model structure for WEPP has been discussed, but not developed. Some new approaches of using digital elevation data within a Geographic Information System (GIS) and making soil erosion estimates on all flow paths within a watershed allow geo-referencing of WEPP soil detachment and deposition values (Cochrane and Flanagan, 1999).

Commonality

Moving toward a common model for both wind and water erosion can take two paths. A commonality in science approach would seek to extend the best of both models to account for all of the state variables needed for both erosion models in a progressive manner. In contrast, a commonality in control structure approach would start with the development of a unified modeling structure and continue with the integration of the best science from both models.

Commonality in Science

Improvements in model science would be integrated into both model structures giving both models the benefit of the extended and improved science. Integration of the improved science into the separate erosion models would be done as resources in the individual projects were available. In the end, these common science components would be placed into a unified control structure and calculate both wind and water erosion losses in

the same simulation run. Under this scenario, the MODular Soil Erosion System (MOSES), which is designed to provide a common interface for separate models would also need to be modified to accommodate the increasing demands of the science modifications in the two models. This approach would have the immediate benefits of improved science commonality in both models.

Such a staged approach is expected to provide the immediate benefits of improved science in the respective erosion models. The individual models under MOSES would share more code until both models contained all the elements to support both erosion calculations. While expected to require more implementation effort, immediate results would be apparent in the working models. The unification of individual science elements would than be accomplished in staged manner under the control of the MOSES interface, with a completely unified control structure being the last stage of implementation.

Commonality in Control Structure

In contrast, a commonality in control structure approach would start with the development of a unified modeling structure. Issues of hillslope versus gridded area would be addressed at this design stage, as well as the creation of an easily extensible data structure. State variables could then be clearly separated out from inputs of material properties and externally driven time varying inputs such as climate and management operations. With an extensible modeling control structure additional science improvements could be easily incorporated. Advances in erosion science would be more easily incorporated. More sophisticated plant growth models could be inserted to modify plant material state variables. Some management operations could be made dependent on the system state and scheduled when conditions were correct, allowing a more physically based modeling of tillage, planting and harvest operations.

The control structure approach has the advantage of allowing the overall modeling environment to be designed rather than evolved. Vestigial elements in evolved code can reduce program efficiency, increase code size and introduce confusion into the modification process. Enough experience has been gained in the development of both models to highlight the desired features of a complete erosion model.

Summary

In both WEPS and WEPP, many of the same processes are modeled to simulate the impact of specific management practices on wind or water erosion. Movement toward a common model can be achieved either through an evolutionary common science integration process or through a top down control structure design and implementation project. Presently, the two directions are being evaluated in light of the expected use of the erosion prediction models and consideration of the resources required for implementation.

References

Cochrane, T.A. and D.C. Flanagan. 1999. Assessing water erosion in small watersheds using WEPP with GIS and digital elevation models. *J. Soil and Water Conserv.* 54(4):678-685.

Flanagan, D.C. and M.A. Nearing (eds.). 1995. *USDA-Water Erosion Prediction Project: Hillslope Profile and Watershed Model Documentation*. NSERL Report No. 10, USDA-ARS National Soil Erosion Research Laboratory, West Lafayette, Indiana.

Hagen, L.J., L.E. Wagner, J.T. Tatarko eds. 1995. *WEPS Technical Documentation*. SWCS WEPP/WEPS Symposium. Ankeny, IA.

Wagner, L.E. 1996. An overview of the wind erosion prediction system. Proceedings of the International Conference on Air Pollution from Agricultural Operations. Midwest Plan Service. pp 73-78.