Using WEPP-Software in order to help preserving forest biodiversity in Romania

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Abstract Preserving biodiversity is a task that needs time and money to be accomplished. So using specialized technology helps saving valuable resources, in order to direct them exactly where they are needed.

The objective of the Water Erosion Prediction Project is to develop a water erosion prediction technology for being used by organizations that are interested in long-term prediction of water erosion, helping through this preserving biodiversity. The main parts of WEPP are: Weather Generation, Winter Processes, Irrigation, Infiltration, Water Balance, Plant Growth, Residue Decomposition Soil Parameters and Hillslope Erosion and Deposition, components that help simulating water erosion along a slope while using a large range of parameters in order to have a precise result.

Preserving biodiversity must be a priority in Romania, in order to compensate the destroying, fragmenting, and degradation of natural habitats, the climate-changing and the overexploitation of some species in the last decades. Although more and more money is directed to preserve the natural habits, through natural disasters a lot of work is destroyed. It would be easier to have precise predictions so efforts can be directed to avoid disasters and help preserve valuable plant and animal species. One of the most frequent disasters in the soil-erosion through water on slopes, which can destroy big vegetation areas, so the biodiversity is compromised. Instead of spending lots of money for reconstruction, afforestation etc., it would be easier to have precise predictions of soil-loss quantity in time. Such prediction technology is the USDA - Water Erosion Prediction Project (WEPP).

The Basics of WEPP

The USDA - Water Erosion Prediction Project (WEPP) model represents a new erosion prediction technology based on fundamentals of stochastic weather generation, infiltration theory, hydrology, soil physics, plant science, hydraulics, and erosion mechanics. The hillslope or landscape profile application of the model provides major advantages over existing erosion prediction technology. The most notable advantages include capabilities for estimating spatial and temporal distributions of soil loss (net soil loss for an entire hillslope or for each point on a slope profile can be estimated on a daily, monthly, or average annual basis), and since the model is process-based it can be extrapolated to a broad range of conditions that may not be practical or economical to field test. In watershed applications, sediment yield from entire fields can be estimated. Figure 1 depicts a small watershed on which the WEPP erosion model could be applied.

Figure 1 Schematic of a small watershed which the WEPP erosion model could be applied to. Individual hillslopes (1 to 5), or the entire watershed (composed of 5 hillslopes, 2 channel segments, and 3 impoundments) could be simulated.

Processes considered in hillslope profile model applications include rill and interrill erosion, sediment transport and deposition, infiltration, soil consolidation, residue and canopy effects on soil detachment and infiltration, surface sealing, rill hydraulics, surface runoff, plant growth, residue...
decomposition, percolation, evaporation, transpiration, snow melt, frozen soil effects on infiltration and erodibility, climate, tillage effects on soil properties, effects of soil random roughness, and contour effects including potential overtopping of contour ridges. The model accommodates the spatial and temporal variability in topography, surface roughness, soil properties, crops, and land use conditions on hillslopes. In watershed applications, the model allows linkage of hillslope profiles to channels and impoundments. Water and sediment from one or more hillslopes can be routed through a small field-scale watershed. Almost all of the parameter updating for hillslopes is duplicated for channels. The model simulates channel detachment, sediment transport and deposition. Impoundments such as farm ponds, terraces, culverts, filter fences and check dams can be simulated to remove sediment from the flow.

The WEPP erosion model computes soil loss along a slope and sediment yield at the end of a hillslope. Interrill and rill erosion processes are considered. Interrill erosion is described as a process of soil detachment by raindrop impact, transport by shallow sheet flow, and sediment delivery to rill channels. Sediment delivery rate to rill flow areas is assumed to be proportional to the product of rainfall intensity and interrill runoff rate. Rill erosion is described as a function of the flow's ability to detach sediment, sediment transport capacity, and the existing sediment load in the flow.

The appropriate scales for application are tens of meters for hillslope profiles, and up to hundreds of meters for small watersheds. For scales greater than 100 meters, a watershed representation is necessary to prevent erosion predictions from becoming excessively large.

Overland flow processes are conceptualized as a mixture of broad sheet flow occurring in interrill areas and concentrated flow in rill areas. Broad sheet flow on an idealized surface is assumed for overland flow routing and hydrograph development. Overland flow routing procedures include both an analytical solution to the kinematic wave equations and regression equations derived from the kinematic approximation for a range of slope steepness and lengths, friction factors (surface roughness coefficients), soil textural classes, and rainfall distributions. Because the solution to the kinematic wave equations is restricted to an upper boundary condition of zero depth, the routing process for strip cropping (cascading planes) uses the concept of the equivalent plane.

The WEPP model includes components for weather generation, frozen soils, snow accumulation and melt, irrigation, infiltration, overland flow hydraulics, water balance, plant growth, residue decomposition, soil disturbance by tillage, consolidation, and erosion and deposition. The model includes options for single storm, continuous simulation, single crop, crop rotation, irrigation, contour farming, and strip cropping.

1.1. Weather Generation

The climate component (Nicks, 1985) generates mean daily precipitation, daily maximum and minimum temperature, mean daily solar radiation, and mean daily wind direction and speed. The number and distribution of precipitation events are generated using a two-state Markov chain model. Given the initial condition that the previous day was wet or dry, the model determines stochastically if precipitation occurs on the current day. A random number (0-1) is generated and compared with the appropriate wet-dry probability. If the random number is less than or equal to the wet-dry probability, precipitation occurs on that day. Random numbers greater than the wet-dry probability give no precipitation. When a precipitation event occurs, the amount of precipitation is determined from a skewed normal distribution function. The rainfall duration for individual events is generated from an exponential distribution using the monthly mean durations. Daily precipitation is partitioned between rainfall and snowfall using daily air temperatures. Daily maximum and minimum temperatures and solar radiation are generated from normal distribution functions.

A disaggregation model has been included in the climate component to generate time-rainfall intensity (breakpoint) data from daily rainfall amounts. That is, given a rainfall amount and rainfall duration, the disaggregation model derives a rainfall intensity pattern with properties similar to those obtained from analysis of breakpoint data. The breakpoint rainfall data are required by the infiltration component to compute rainfall excess rates and thus runoff.

1.2. Winter Processes

The winter processes which the WEPP model simulates are frost and thaw development in the soil, snow accumulation and snow melting. In order to make more accurate predictions, the average daily values for temperature, solar radiation, and precipitation are used to generate hourly temperature, radiation and snow fall values. The soil frost subcomponent is based on fundamental heat flow theory. The frost/thaw subcomponent assumes that heat flow in a frozen or unfrozen soil or soil-snow system is unidirectional. Snow and soil thermal conductivity and water flow components are considered as constants. The soil frost subcomponent outputs values for hourly frost depth, thaw depth and the cumulative number of freeze-thaw cycles. This subcomponent predicts frost and thaw development for various combinations of snow, residue and tilled, and/or untilled soil. Adjustments to infiltration and erodibility parameters are made based on the frost or thaw location in the soil profile, and the soil moisture content.

The snow accumulation subcomponent estimates the depth of the snow on the ground on a daily or hourly basis. Snow fall increases the snow
pack, while warming temperatures and rainfall consolidate (increase the density) of the snow pack. Snow drifting calculations are not made in the current WEPP model version.

The snow melt subcomponent is based on a generalized snow melt equation developed by the U.S. Army Corps of Engineers (1956, 1960), as modified by Hendrick et al. (1971), to adapt it for use with readily available meteorological and environmental data. This equation was further modified by Savabi et al. to make it compatible with a grid-based model. The snow melt equation incorporates four major energy components of the snow melt process: air temperature, solar radiation, vapor transfer, and precipitation. The following assumptions are made for snow melt calculations: 1) any precipitation that occurs on a day when the maximum daily temperature is below 0°C is assumed to be snowfall; 2) no snow melt occurs if the maximum daily temperature is below -2.8°C; 3) the snowpack does not melt until the density of the snow is greater than 0.35 g.cm3; 4) the surface soil temperature is 0°C during the melt period; and 5) the albedo of melting snow is approximately 0.5.

1.3. Irrigation

The irrigation component of the WEPP hillslope profile version accommodates stationary sprinkler systems (solid-set, side-roll, and hand-move) and furrow irrigation systems. Four irrigation scheduling options are available: 1) no irrigation, 2) depletion-level scheduling, 3) fixed-date scheduling, and 4) a combination of the second and third options. The first option is the default option for irrigation in WEPP. For the second option, the decision of whether irrigation is necessary is determined by calculating the available soil water depletion levels for the entire soil profile and for the current root depth and comparing to an allowable depletion level. This is conducted on a daily basis. For the fixed-date scheduling option, specific irrigation dates are read into the model from a user-created data file. The fourth option is included primarily to allow a pre-planting irrigation and leaching of salts from the root zone. Parameters for depletion-level and fixed-date scheduling are read from individual data files.

1.4. Infiltration

The infiltration component of the hillslope model is based on the Green and Ampt equation as modified by Mein and Larson (1973), with the ponding time calculation for an unsteady rainfall (Chu, 1978). The infiltration process is divided into two distinct stages: a stage in which the ground surface is ponded with water and a stage without surface ponding. During an unsteady rainfall, the infiltration process may change from one stage to another and shift back to the original stage. Under a ponded surface the infiltration process is independent of the effect of the time distribution of rainfall. At this point the infiltration rate reaches its maximum capacity and is referred to as the infiltration capacity. At this stage rainfall excess is computed as the difference between rainfall rate and infiltration capacity. Depression storage is also accounted for. Without surface ponding, all the rainfall infiltrates into the soil. The infiltration rate equals the rainfall intensity, which is less than the infiltration capacity, and rainfall excess is zero.

1.5. Water Balance

The water balance and percolation component of the hillslope model is based on the water balance component of SWRRB (Simulator for Water Resources in Rural Basins) (Williams and Nicks, 1985), with some modifications for improving estimation of percolation and soil evaporation parameters. The water balance component maintains a continuous balance of the soil moisture within the root zone on a daily basis. Redistribution of water within the soil profile is accounted for by the Ritchie evapotranspiration model (Ritchie, 1972) and by percolation from upper layers to lower layers based on a storage routing technique (Williams et al., 1984). The water balance component uses information generated by the weather generation component (daily precipitation, temperature, and solar radiation), infiltration component (infiltrated water volume), and plant growth component (daily leaf area index, root depth, and residue cover).

1.6. Plant Growth

The plant growth component simulates plant growth for cropland and rangeland conditions. The purpose of this component is to simulate temporal changes in plant variables that influence the runoff and erosion processes. The cropland plant growth model is based on the EPIC model (Williams et al., 1984) and predicts biomass accumulation as a function of heat units and photosynthetically active radiation. Potential growth is reduced by moisture and temperature stress. Crop growth variables computed in the cropland model include growing degree days, mass of vegetative dry matter, canopy cover and height, root growth, leaf area index, plant basal area, etc. The cropland plant growth model accommodates mono, double, rotation, and strip cropping practices.

The rangeland plant growth model estimates the initiation and growth of above- and below-ground biomass for range plant communities by using a unimodal or a bimodal potential growth curve. Range plant variables computed in the rangeland model include plant height, litter cover, foliar canopy cover, ground surface cover, exposed bare soil, and leaf area index. Range management practices such as herbicide application, burning and grazing may be simulated. This component is vital for biodiversity because it helps simulating the influence of different plant-types on slopes in different conditions, so it will easier to see what will happen with these precise slopes in time.

1.7. Residue Decomposition

The residue decomposition component estimates decomposition of flat residue mass (residue mass in contact with the soil surface), standing material (residue mass standing above ground), submerged
residue mass (residue mass that has been incorporated into the soil by a tillage operation), and dead root mass. Decomposition parameters must be specified in the management input file. The decomposition component partitions total residue mass at harvest into standing and flat components based upon harvesting and residue management techniques. The model also sets the initial stubble population at harvest equivalent to the plant population calculated in the plant growth component.

1.8. Soil parameters

Soil parameters that influence hydrology and erosion are updated in the soil component, and include: 1) random roughness, 2) oriented roughness, 3) bulk density, 4) wetting-front suction, 5) hydraulic conductivity, 6) interrill erodibility, 7) rill erodibility, and 8) critical shear stress. Random roughness is most often associated with tillage of cropland soil, but any tillage or soil disturbing operation creates soil roughness. Random roughness decay following a tillage operation is predicted in the soil component from a relationship including a random roughness parameter and the cumulative rainfall since tillage. A random roughness parameter is assigned to a tillage implement based upon measured averages for an implement. Oriented roughness results when the soil is arranged in a regular way by a tillage implement. In WEPP hillslope applications, oriented roughness is the height of ridges left by tillage implements, which can vary by a factor of two or more depending upon implement type. Ridge decay following tillage is computed from a relationship including a ridge height parameter and the cumulative rainfall since tillage. A ridge height value is assigned to a tillage implement based on measured averages for that implement.

Bulk density reflects the total pore volume of the soil and is used to update several infiltration related variables, including wetting front suction. Adjustments to bulk density are made due to tillage operations, soil water content, rainfall consolidation, and weathering consolidation. The approach to account for the influence of tillage operations on soil bulk density is a classification scheme where each implement is assigned a surface disturbance value ranging from 0 to 1, which is similar to the approach used in EPIC (Williams et al., 1984).

Effective hydraulic conductivity is a key parameter in the WEPP model that controls the prediction of infiltration and runoff.

The interrill erodibility parameter is a measure of the soil resistance to detachment by raindrop impact. Because the soil is disturbed for the cropland erodibility tests and not for rangeland tests (Laflen et al., 1987; Simanton et al., 1987), algorithms for adjusting the interrill erodibility parameter are different for cropland and undisturbed rangeland soils. Adjustments to the interrill erodibility parameter on croplands are made to account for root biomass, freezing and thawing, canopy cover, residue cover and sealing and crusting. Adjustments to the interrill erodibility parameter on rangeland are made to account for freezing and thawing.

The rill erodibility parameter is a measure of the soil resistance to detachment by concentrated rill flow and is often defined as the increase in soil detachment per unit increase in shear stress of the flow. Critical shear stress is a threshold parameter defined as the value above which a rapid increase in soil detachment per unit increase in shear stress occurs. As for the interrill erodibility parameter, different relationships are used for adjustment of the rill erodibility parameter and critical shear stress on cropland and rangeland soils. These adjusting equations include the effects of incorporated residue and roots, scaling and crusting, and freezing and thawing.

1.9. Hillslope Erosion and Deposition

Soil erosion is represented in two ways for WEPP overland flow profile applications: 1) soil particle detachment by raindrop impact and transport by sheet flow on interrill areas (interrill delivery rate), and 2) soil particle detachment, transport and deposition by concentrated flow in rill areas (rill erosion). Calculations within the erosion routines are made on a per unit rill width basis and subsequently converted to a per unit field width basis.

Interrill delivery rate is modeled as proportional to the product of rainfall intensity and interrill runoff rate. The mathematical function describing interrill delivery rate also includes parameters to account for the effects of soil roughness, slope steepness, and adjusted soil erodibility on interrill detachment and transport. Detachment due to rainfall occurring during periods when infiltration capacity is greater than rainfall intensity is not considered to contribute to interrill detachment.

Rill erosion is modeled as a function of the flow's capacity to detach soil, transport capacity, and the existing sediment load in the flow. Net soil detachment in rills occurs when hydraulic shear stress exceeds critical shear stress and when sediment load is less than sediment transport capacity. Net deposition occurs when sediment load is greater than sediment transport capacity. Sediment transport capacity and sediment load are calculated on a unit rill width basis. Sediment load is converted to a unit width basis at the end of the calculations. Sediment transport capacity is calculated as a function of x (distance downslope) using a simplification of a modified Yalin (1963) equation.

Conditions at the end of a uniform slope through the endpoints of the given profile are used to normalize the erosion equations. Distance downslope is normalized to the total slope length. The slope at a point is normalized to the uniform slope. Shear stress is normalized to shear stress at the end of the uniform slope. Sediment load is normalized to transport capacity at the end of the uniform slope.

The erosion and deposition component has
four dimensionless parameters: one for interrill sediment delivery to rills, two for rill detachment, and one for rill deposition. The normalized sediment continuity equation is solved analytically when net deposition occurs but it is numerically integrated when detachment occurs.

Conclusions

If implemented, WEPP will help predict possible effects that water erosion has on slopes so actions can be taken to avoid these effects if they are not helpful in preserving biodiversity. Because it was created to be used in the United States of America there are some small technical problems that can appear while using it in Romania. The main components contained in WEPP are specially designed for the weather and soil on the North-American continent, so the source files used by the software have to be changed for use outside America. Also there must be found the correspondence between the soil nomenclatures used by WEPP (US. nomenclatures) and those used in Romania.

Using WEPP in Forestry will bring advantages for preserving forest ecosystems on slopes through its possibilities for studying long-term effects of water erosion. It also can be used in agriculture for simulating effects that different types of cultures have to soil.

In order to help preserve biodiversity nowadays modern technology is a must, so implementing WEPP will bring big advantages and save valuable financial resources.

References

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