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Original Research Paper

Assessment of Surface Runoff and Sediment Yield using WEPP Model

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ABSTRACT

The WEPP model is used to estimate the runoff and sediment yield at the outlet of the watershed. The WEPP model is used because of the hilly nature of the watershed. The slope of the watershed varies from 0 to 30%. The runoff and sediment yield at the downstream end is determined by the process of rainfall and runoff erosivity, sediment detachment, transport, and deposition in overland flow. Overland flow processes are usually conceptualized as a mixture of broad sheet flow (called interrill flow) and concentrated flow (called rill flow). Most often the two flow types are lumped and described as overland flow with computations based on a broad sheet flow assumption. Interrill erodibility and effective hydraulic conductivity were the calibration parameters for the WEPP model. The model calibration and validation has been done by comparing predicted monthly sediment yield and runoff data with observed one. The model predicted the runoff and sediment yield with highest R^2 as 0.953 and 0.911 respectively. The model validation showed closer prediction of runoff and sediment yield with respective R^2 as 0.94 and 0.722 respectively.

INTRODUCTION

A number of erosion based studies were carried out using different models, such as, USLE, CREAMS (Knisel 1980), ANSWERS, AGNPS (Young et al. 1987) and SWRRB-WQ (Arnold et al. 1990), WEPP (Lane & Nearing 1989). The models are quick methods for assessing the sediment yield and runoff and thus help in the conservation plan to reduce erosion. Distributed parameter model, WEPP model was selected in the present study for modelling of runoff and sediment. The use of distributed parameter models gives spatial and temporal variation of outputs, providing estimates of offsite and onsite effects of erosion. Particularly, upland sources contributing to potential problem such as soil erosion can be identified and locations can be prioritized for remedial action. The Water Erosion Prediction Project (WEPP) model (Flanagan et al. 2001), a physically-based erosion prediction software program developed by the US Department of Agriculture (USDA), has proved useful in areas where Hortonian flow dominates, e.g., in forest applications of modeling erosion from in sloped or out sloped roads, or harvested or burned areas by wildfire or prescribed fire (Elliot et al. 1999, Elliot & Tysdal 1999, Elliot 2004, Robichaud et al. 2007). In most natural forests, however, subsurface lateral flow and channel flow is predominant (Luce 1995). When used under such forest conditions, WEPP underestimates subsurface lateral flow and discharge at the watershed outlet (Elliot et al. 1995). WEPP was intended to be applied to agriculture, rangelands and forests (Foster & Lane 1987). A major limitation in hydrology is the lack of availability of adequate data to quantitatively describe a hydrologic process accurately. Rapid parameterization of hydrologic models can be derived using Remote Sensing (RS) and Geographic Information Systems (GIS) as remotely sensed data provide valuable and up-to-date spatial information on natural resources and physical terrain parameters. The study watershed, Olidih is located in Jharia coalfields (JCF) of Damodar valley catchment, which is one of the most important coalfields in India. It is geographically located in Dhanbad district of Jharkhand state, India between 23° 39' to 23° 48' N latitude and 86° 11' to 86° 27' E longitude. The location map of study watershed, Olidih is shown in Fig. 1. The coal basin extends about 38 km in an east-west direction and 18 km in north-south direction, and covers an area of about 450 km^2. This is the most exploited coalfields because of available metallurgical grade coal reserves. The study watershed covers an area of 57 km^2 and has an average annual rainfall of 800 mm. The climate of the study area is semi-arid in nature and experiences frequent droughts resulting in acute shortage of water. The maximum temperature varies between 38°C and 44°C during May and the minimum temperature ranges from 7.2°C to 3.3°C during December and January.

MATERIALS AND METHODS

WEPP is a new generation process-based, soil erosion prediction model based on fundamentals of infiltration theory,

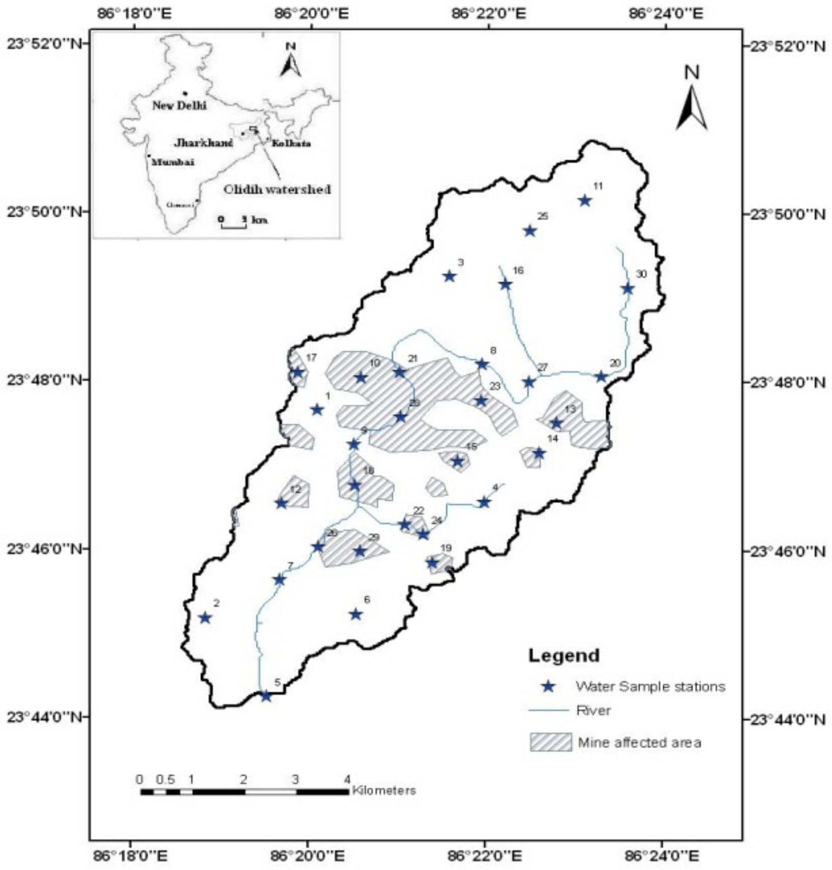

Fig.1: Location map of Olidih watershed.

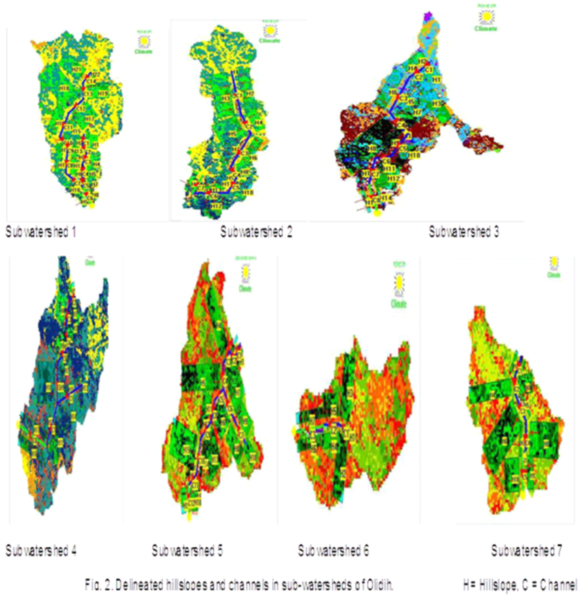

Fig. 2: Delineated hillslopes and channel in sub watersheds of Olidih.

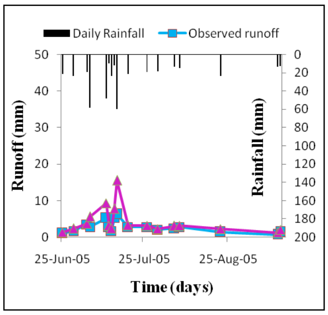

Fig. 3: Observed and simulated runoff for the year 2005 for model calibration.

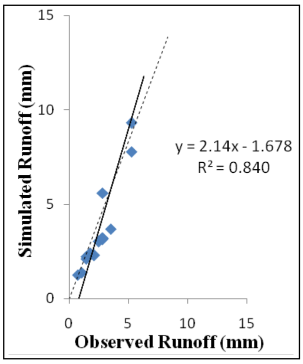

Fig. 4: Comparison between the observed and simulated runoff for the year 2005 for model calibration.

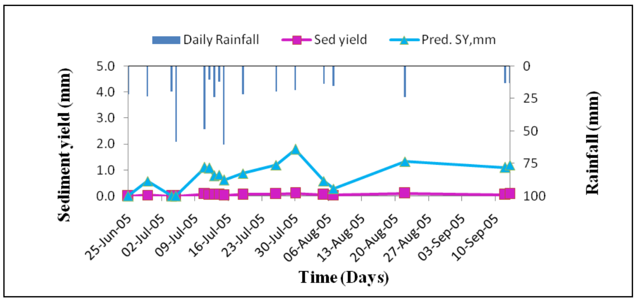

Fig. 5: Observed and predicted sediment yield for the year 2005 for model calibration.

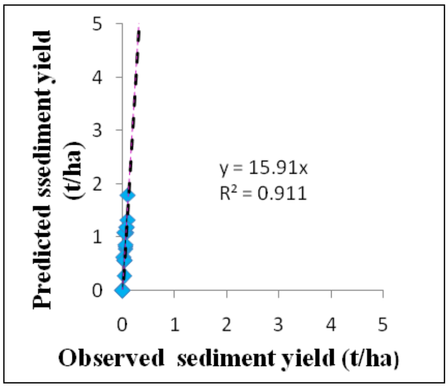

Fig. 6: Comparison between the observed and predicted sediment yield for the year 2005 for model calibration.

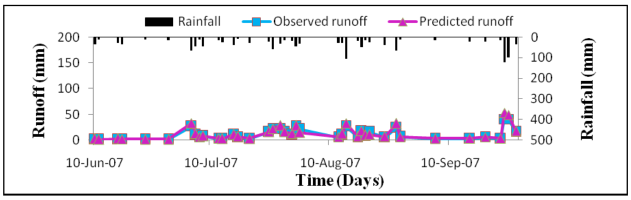

Fig. 7: Comparison between the observed and simulated runoff for the year 200 for model calibration.

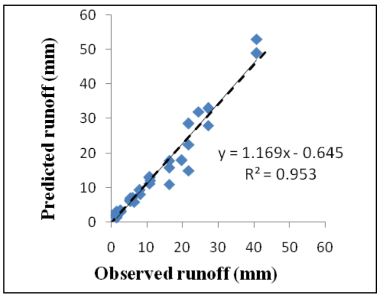

Fig. 8: Comparison between the observed and predicted runoff for the year 2005 for model calibration.

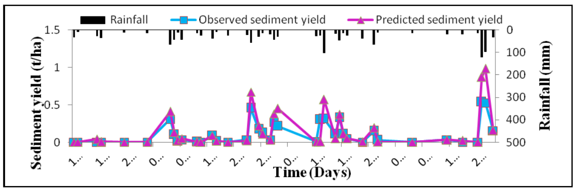

Fig. 9. Observed and predicted sediment yield for the year 2007 for model calibration.

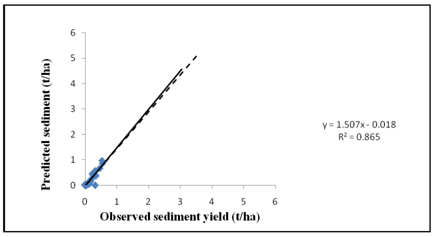

Fig. 10. Comparison between the observed and predicted sediment yield for the year 2007 for model calibration.

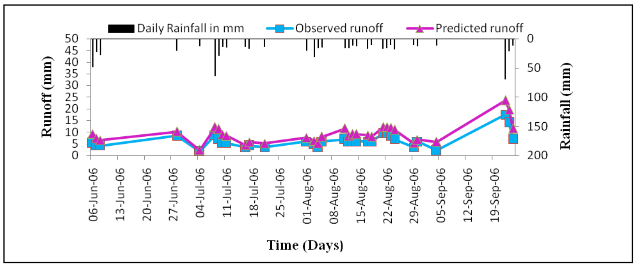

Fig. 11. Comparison between the observed and predicted sediment yield for the year 2006 for model validation.

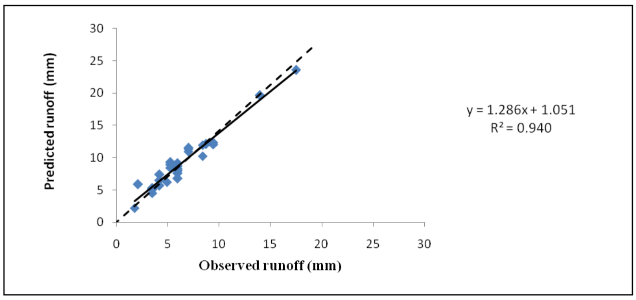

Fig. 12. Comparison between the observed and predicted runoff for the year 2006 for model validation.

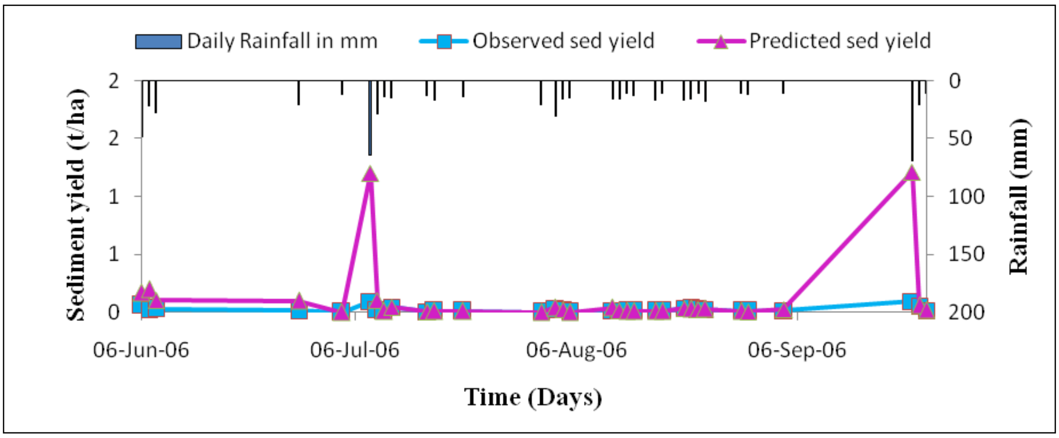

Fig. 13. Observed and predicted sediment yield for the year 2006 for model validation.

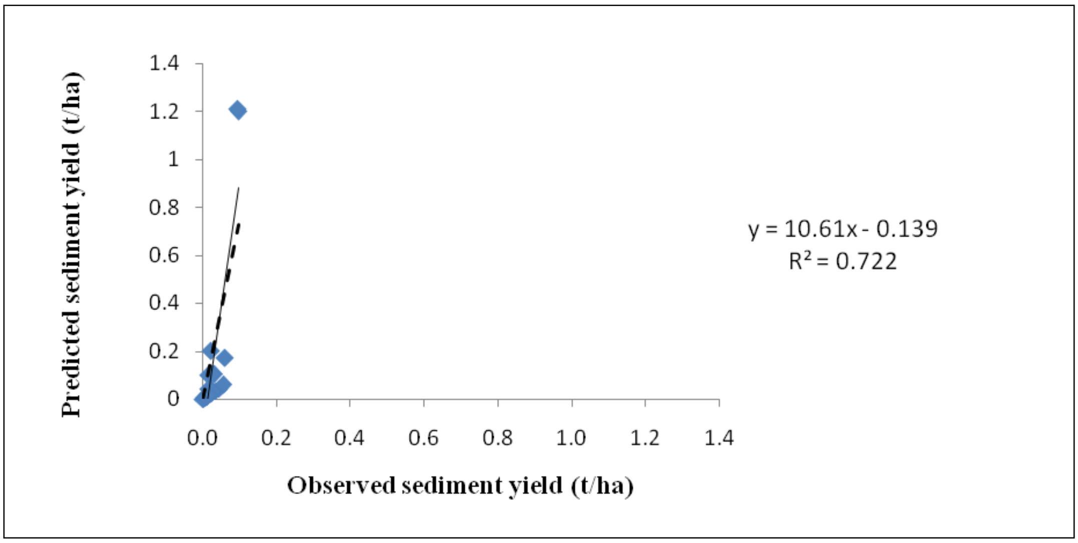

Fig. 14. Comparison between the observed and predicted sediment yield for the year 2006 for model validation.

Table 1: Number of hillslopes and channels delineated in each sub-watershed.

Sub Watersheds	1	2	3	4	5	6	7
No. of Hill Slopes	22	15	14	20	19	17	10
No. of Channels	13	7	8	10	12	8	5

hydrology, soil physics, plant science, and hydraulics and erosion mechanics (Nearing et al. 1989). It is a continuous simulation model for predicting daily soil loss and deposition from rainfall, snowmelt and irrigation. It consists of nine components, climate generation, winter processes, irrigation, hydrology, soil, plant growth, and residue decomposition, hydraulics of overland flow, erosion and deposition. The surface hydrology component of WEPP computes the surface runoff and peak discharge using the kinematics wave equation. 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, and it uses a steady state sediment continuity equation as a basis for the erosion computations. The major inputs to WEPP model are climate, slope, soil and cropping management data files. The climate file (.cli) for the study site was created for 2005-2007 using WEPP's auxiliary stochastic climate generator, CLIGEN (Nicks et al. 1995). CLIGEN requires daily observed precipitation, and maximum and minimum temperatures, acquired from the National Climatic Data Center (NCDC). The slope file (.slp) is built either within the interface slope file builder, or by hand. The required information includes slope orientation, slope length and slope steepness at points down the profile. The WEPP model allows user to simulate many types of non-uniformities on a hillslope through the use of

Table 2: Sub-watershed wise calibrated parameters of WEPP model.

Soil Parameters	Parameters for different sub-watersheds						
	1	2	3	4	5	6	7
Interrill erodibility (kg s m^{-4})	4.73× 10^6	5.1× 10^6	5.85× 10^6	5.5× 10^6	5.01× 10^6	4.85× 10^6	5.01× 10^6
Effective hydraulic conductivity(mm h^{-1})	12.87	14.84	10.38	13.57	9.82	7.98	9.82

Overland Flow Elements (OFEs). Each OFE on a hillslope is a region of homogeneous soils, cropping and management. The soil file (.soil) can be created either through soil file builder in the WEPP interface or through the use of a text editor. The soil window customizes the soil properties like percentage of sand, silt, clay, organic matter, cation exchange capacity, soil erodibility etc. WEPP internally creates a new set of soil layers based on the original parameters set values. Similar to the slope file, soil parameters must be input for each and every OFE on the hillslope profile and for each channel in the watershed even if the soil on all OFE_s is the same. For different sub-watershed number of channels and manning's roughness coefficient are given as inputs to the channel input files. Other WEPP channel input parameters are actual width, shape and depth. Channel location and lengths were obtained from the Survey of India topographic map of the study watershed at the scale of 1:50000. Hillslopes are defined as a set of grid cells in the DEM that drain to the left, right or to the top of individual channels. If the channel is a secondary channel, meaning that the junctions of two other channels create it, then there will be one hillslope to the left and another one to the right of the channel, but no hillslope draining to top of the channel. The hillslopes delineated from WEPP model are shown in Fig. 2.

The number of hillslopes and channels in each sub-watershed has been discretized from WEPP model is presented in Table 1. The management input file (.rot) contains the largest number of input parameters like crop and tillage information. These data include date of use, planting date, types of crops harvest date, residue management, etc. Paddy and maize are the main crops grown in Olidih watershed. The model output files, sediment yield and runoff summary information can be obtained in text form as well as graphical form.

RESULTS AND DISCUSSION

The WEPP model was calibrated with the observed daily runoff and sediment yield measured at the watershed outlet for the year 2005 and 2007. The input data, such as rainfall, temperature, relative humidity, wind velocity and land use/cover pertaining to the year 2005 and 2007 were used as input to the model during calibration. The required calibrated parameters are presented in Table 2. Input data for each hillslopes of each sub-watershed were entered into the respective model files and the model was run to get the daily output.

The predicted runoff included a contribution from both hillslopes and channels. The observed and simulated daily runoff values of Olidih watershed for the calibration period (June to September, 2005 and 2007) were plotted graphically (Figs. 3 and 7). It is observed from the figure that the simulated runoff values are higher than observed. Regression analysis was performed between the observed and simulated runoff values and the best-fit line is also shown in Figs. 4 and 8. A high value of (0.840 and 0.953) coefficient of determination (R^2) indicates a close relationship between the observed and simulated runoff. R^2 value is higher in case of 2007 where as it is lower in case of 2005. The R^2 value is higher due to high rainfall intensity. The observed and predicted sediment yield values of Olidih watershed for the calibration period (June to September, 2005 and 2007) were plotted graphically (Fig. 5 and 9). It is observed from the figure that the simulated runoff values are higher than the observed ones. A high value of coefficient of determination (R^2) 0.911 and 0.865 as shown in Figs. 6 and 10 indicate a close relationship between the observed and simulated runoff. The predicted values of sediment yield are very close to the observed one, in case of the year 2005.

Proper validation of the calibrated model is essential to understand the performance of the model without change in the input files except the climatic parameters. Therefore, after proper calibration, the model was validated for the months of June to September for daily runoff and sediment yield using the data of monsoon season for the year 2006. The graphical plot between observed and simulated runoff and sediment yield is shown in Figs. 11 and 13. The value of R^2 is high as 0.94 (Fig. 12) in case of runoff, but in case of sediment yield it is very low as 0.722 (Fig. 14). The sediment yield is very high when the rainfall is high in two peak events as shown in Fig. 13.

The difference between observed and predicted runoff and sediment yield is very high due to the availability of large scale pits in the Olidih watershed. The amount of soil erosion is high but it does not contribute to the outlet of watershed. This could be the reason of low coefficient of determination.

CONCLUSIONS

The model predicted runoff and sediment yield with highest R^2 as 0.953 and 0.911 respectively. The model validation showed closer prediction of runoff and sediment yield with respective R^2 as 0.94 and 0.722 respectively. The results estimated using WEPP model could not give a closer estimate to the observed values due to abrupt changes in rainfall for the year 2005-2007. These three years were deficit, normal and high rainfall. The other reason for poor prediction could be due to the coal mine area. A large amount of runoff and sediment yield accumulates in the available mine pits.

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REFERENCES

Arnold, J G., Williams, J R., Nick, A D. and Sammons, N. B. 1990. SWRRB: A basin scale simulation model for soil and water resources management. Texas A and M University Press, College Station, pp. 125.

Elliot, W. J. 2004. WEPP internet interfaces for forest erosion prediction. Journal of American Water Resource Association, 40: 299-309.

Elliot, W. J. and Tysdal, L. M. 1999. Understanding and reducing erosion from in sloping roads. J. Forum, 97: 30-34.

Elliot, W. J., Hall, D. E. and Graves, S. R. 1999. Predicting sedimentation from forest roads. J. Forum, 97: 23-29.

Elliot, W. J., Robichaud, P. R. and Luce, C. H. 1995. Applying the WEPP erosion model to timber harvest areas. In: Proc. ASCE Watershed Manage Conf., August 14-16, 1995. San Antonio, pp. 83-92.

Flanagan, D. C., Ascough, J. C., Nearing, M. A. and Laflen, J. M. 2001. The water erosion prediction project (WEPP) model. In: Harmon, R. S., Doe, W. W., III (Eds.), Landscape Erosion and Evolution Modeling. Kluwer Academic/Plenum Publishers, New York, pp. 145-199.

Foster, G. R. and Lane, L. J. 1987. User Requirements: USDA-Water Erosion Prediction Project (WEPP). NSERL Rep. No. 1, Natl. Soil Erosion Res. Lab., USDAARS, West Lafayette, IN, pp. 43.

Knisel, W. G. 1980. CREAMS: A Field Scale Model for Chemicals, Runoff and Erosion USDA, Washington D.C. 643.

Lane, L. J. and Nearing, M. A. 1989. WEPP profile model documentation. NSERL Report No. 2. Ind.: USDA-ARS National Soil Erosion Research Laboratory, W. Lafayette.

Luce, C. H. 1995. Forests and wetlands. In: Ward, A. D., Elliot, W.J. (Eds.), Environmental Hydrology. Lewis Publishers, Boca Raton, FL, pp. 253-283.

Nearing, M. A., Foster, G. R., Lane, L. J. and Finkner, J. R. 1989. A process-based soil erosion model for USDA-water erosion prediction project technology. Trans. ASAE, 32(5): 1587-1593.

Nicks, A. D., Lane, L. J. and Gander, G. A. 1995. Chapter 2: Weather generator. In: USDA Water Erosion Prediction Project Hillslope and Watershed Model Documentation. D.C. Flanagan and M.A. Nearing, eds. NSERL Report No. 10. West Lafayette, Ind.: USDA ARS National Soil Erosion Research Laboratory.

Robichaud, P. R., Elliot, W. J., Pierson, F. B., Hall, D. E. and Moffet, C. A. 2007. Predicting postfire erosion and mitigation effectiveness with a web-based probabilistic erosion model. Catena, 71: 229-241.

Young, R. A., Onstad, C. A., Bosch, D. D. and Anderson, W. P. 1987. AGNPS: An agricultural nonpoint source pollution model: A large watershed analysis tool. USDA Cons. Res. Rept., 35, pp. 77.