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Review on Soil Erosion and Runoff Models

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Abstract

Soil erosion runoff is a global environmental problem influenced by both natural and human factors. Modeling provides a quantitative and consistent approach to estimate soil erosion, runoff and sediment yield under a wide range of conditions, and is needed to guide the comprehensive control of soil erosion and run off. Over the years various soil erosion models have been developed. The application of these models is dependent on the soil type and climate of the given area because models differ in complexity and input requirements. This review shows various soil erosion and run off models and their applications, focusing more on the most widely applied models different empirical and process-based models which are Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE) and Water Erosion Prediction Project (WEPP), Ephemeral Gully Erosion Model (EGEM), Lumped Parameter Models (LPMs), Kineros Model, Rainfall-runoff modeling (Original SCS-CN model) and others. The results of this different stud shows that most soil erosion models have been developed for the assessment of rill and interill erosion at plot or catchment scale on agricultural lands and watersheds in terms of estimating mostly soil loss, sediment yield, erodibility (K)values, rainfall factor (R) factors, runoff rates and forecasts of likely impacts. Again, the study indicated that most previous authors on soil erosion assessment used the empirical models due to their limited data and parameter inputs.

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Introduction

Soil erosion is one of the most serious environmental problems in the world today because it threatens agriculture and also the natural environment (Shougang, Na and Ruishe, 2014). Soil erosion has become one of the global environmental hazards that limits today's human survival and restricts global socio-economic sustainable development (Han, Ren, Zhang and Li, 2016). Land degradation due to erosion processes incurs substantial costs both for individual farmers and for society as a whole (Phai, Orange, Migraine, Toan and Vinh, 2006). With growing pressure on natural resources and landscapes, there is an increasing need to predict the consequences of any changes to the environment (Shougang *et al.,* 2014).

They further stated that modeling plays an important role in this by helping our understanding of the environment and by forecasting likely impacts. Soil erosion models are useful to estimate soil loss and runoff rates from agricultural land, to plan land use strategies, to provide relative soil loss indices and to guide government policy and strategy on soil and water conservation (Smith, 1999). Effective modeling can provide information about current erosion, its trends and scenario analysis (Ganasri and Ramesh, 2016). Soil erosion prediction technology began over 70 years ago, but it was in 1965 that the work expanded into the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith, perhaps the foremost achievement in soil erosion prediction (Laflen and Flanagan, 2013).

Since then several models have been developed to simulate soil erosion prediction process. They all consider slope steepness, slope length, vegetative cover, rainfall, soil properties and erosion control methods as parameters which influence erosion (Smith, 1999). Erosion models utilize the various factors that affect erosion to simulate erosion processes in order to predict the levels of erosion in a region (Anejionu, Nwilo and Ebinne, 2013). They opined that insights could be drawn from present and future trends of erosion impacts in a region with these models. Various studies on erosion models have clearly demonstrated that the dominant factor contributing to sediment discharge is the erosive power of rainfall (Phal *et al.*, 2006).

Overview of the process of soil erosion and models

Rainfall induced erosion is a two-phase hydro-geomorphic process that involves the detachment of individual soil particles from the soil surface, and its down slope transportation (see Ellison 1947, Morgan 2005, Hudson 1995). Within a humid environment the rate of erosion is limited by detachment (D), or transport capacity (T)

In general, when the detachment rate exceeds the transport capacity a third phase of deposition occurs. The process of sediment detachment (D) and transport (T), which begins with the impact of raindrop, is dependent on the hydrological processes, and a host of other interacting environmental factors. Rainfall erosivity, the aggressiveness or potential of rain to cause erosion is a function of several properties, and varies with climate.

Effective rainfall erosivity depends on a host of interacting variables. Erodibility defined as the resistance of the soil to detachments by raindrop impact and surface runoff (Bryan *et al.*, 1989) is a function of several soil properties and other interacting environmental factors.

Modeling is a useful tool for erosion scenario assessment that enables the adequate selection of erosion control measures (Moehansyah, Maheshwar and Armstrong, 2004). A wide range of models exists for use in simulating sediment transport and associated pollutant transport and these models differ in terms of complexity, processes considered and the data required for model calibration and model use (Merritt *et al.*, 2003).

They noted that choice of a suitable model structure relies heavily on the function that the model needs to serve. Numerous erosion models such as Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE), Coordination of Information on the Environment (CORINE), Water Erosion Prediction Project (WEPP), Pan-European Soil Erosion Risk Assessment (PESERA), Kinematic Runoff and Erosion Model (KINEROS), and Erosion Potential Model (EPM) have been developed and applied in various regions of the world (Anejionu *et al.*, 2013).

According to Smith (1999), the most widely applied soil loss models are the USLE, its improved version the Revised Universal Soil Loss Equation (RUSLE), and the Soil Loss Estimation model of Southern Africa (SLEMSA). Other widely applied models include: the Morgan, Morgan and Finney model (MMF), Agricultural Non-Point Source Pollution (AGNPS), Areal Nonpoint Source Watershed Environment Response Simulation (ANSWERS) and Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS) (Jaramilo, 2007). ANSWERS and CREAMS are basically conceptual and event based models (Ganasri and Ramesh, 2016).

According to Merritt *et al.*, (2003) each model type serves a purpose, and a particular model type may not categorically be considered more appropriate than others in all situations. In their review of soil erosion and transport models, they summarised the various soil erosion models (Table 1).

Erosion Models Listing

Soil erosion computer models use mathematical expressions to represent the relationships between various factors and processes occurring on the landscape.

These factors generally include topography, meteorological variables, soil properties, and land use and land cover features. One classification of models distinguishes between theoretical or physically based models and empirical models. However, most erosion models are of a hybrid type including both theoretical and empirical components (Haan *et al.*, 1994).

Soil erosion models fall into three main categories, depending on the physical processes simulated by the model, the model algorithms describing these processes and the data dependence of the model: Empirical or Statistical; Conceptual; and Physics based models (Merrit, Letcher, and Jakeman, 2003). They further stated that empirical models are the simplest of all models as they can be implemented in situations with limited data and parameter inputs, and are particularly useful as a first step in identifying sources of sediment and nutrient generation.

Examples of empirical models include the Universal Soil Loss Equation (USLE) and its derivates (Revised Universal Soil Loss Equation, RUSLE and Modified Universal Soil Loss Equation, MUSLE) (Tesfahunegn, 2011).

In conceptual models, sediment producing factors such as rainfall and runoff are treated as inputs to the system and sediment yield is output (Chandromohan, Venkatesh, and Balchand, 2015). Agricultural Non-Point Source Pollution (AGNPS) developed in 1985 to evaluate potential problems on agricultural watersheds is an important example of conceptual models (Jaramilo, 2007).

Physically-based models

Physically based models provide an understanding of fundamental sediment producing processes and have the capability to access the spatial and temporal variations of sediment entrainment, transport and deposition processes (Chandramohan *et al.*, 2015). They described processes involved with the help of mathematical equations dealing with the laws of conservation of energy and mass (Morgan, 2005).

An important and commonly used example of this model is the Water Erosion Prediction Project (WEPP). Most models predict soil erosion based on the major factors of soil erosion, these factors are: rainfall erosivity represented by R, soil erodibility represented by K, topography represented by LS, and land use and management represented by C and P (Lee and Lee, 2006) as shown in the equation

$$A=RKLSCP$$

Physically based models are generally the most scientifically robust and flexible in both input and output and are based on an understanding of the physical processes that cause erosion and are therefore applicable to a wide range of soils, climatic and land use conditions (Lily, Grieve, Jordan, Baggaley, Birnie, Futter, Higgins, Hough, Jones, Noland, Stutter and Towers, 2009).

They further asserted that this however, means that they are often difficult to parametise. Similarly, Ganasri and Ramesh (2016) agreed that physically-based models are data intensive and the amount of data needed is not readily available.

Empirical models

Examples of empirical models include the Universal Soil Loss Equation (USLE) and its derivates (Revised Universal Soil Loss Equation, RUSLE and Modified Universal Soil Loss Equation, MUSLE) (Tesfahunegn, 2011).

According to Smith (1999), empirical models are of great benefits in many situations given that they are largely the only models that could be run with little available data.

In his opinion, their disadvantages are that they: (1) are based on statistical analysis of important factors in the soil erosion process and yield only approximate and probable outcome; (2) are not practical for the prediction of soil loss on an event basis; (3) estimate soil erosion on single slope, instead of within catchments; (4) do not represent the process of sedimentation; (5) are restricted to sheet and/or rill erosion; and (6) soil losses and gains over neighboring areas are not considered.

Advantage, are generally the simplest of all types of models, Are primarily based on the analysis of observations and seek to characterize response from these data, Less data requirement, Less computational requirement, High level of spatial and temporal aggregation, Many are based on analysis of catchments data using stochastic techniques, Parameter values many be obtained by calibration/ more often from calibration at experimental sites. And Empirical models are particularly useful as first step in identifying source of sediment and nutrient generation.

Limitation of empirical models

The limitation includes: Employ unrealistic assumptions about the physics of the catchment system: Not event responsive: ignoring the – processes of rainfall- runoff in the catchment being modeled. Based on assumption of stationarity: it is assumed that the underlying conditions remain unchanged for the duration of the study period and Make no inferences as to the process at work.

Conceptual models

Conceptual models provide an indication of the qualitative and quantitative effects of land use changes, without requiring large amounts of spatially and temporally distributed input data (Merritt *et al.*, 2003). Placed somewhere in between empirical and physically based models, conceptual models reflect the physical processes governing the system but describe them with empirical relationships, e.g., Agricultural Non-Point Source (AGNPS) (Tesfahunegn, 2011). According to him, these models have the inherent limitations of the empirical models and also require relatively detailed data for calibration.

In conceptual models, sediment producing factors such as rainfall and runoff are treated as inputs to the system and sediment yield is output (Chandromohan, Venkatesh, and Balchand, 2015). Agricultural Non-Point Source Pollution (AGNPS) developed in 1985 to evaluate potential problems on agricultural watersheds is an important example of conceptual models (Jaramilo, 2007).

Different type of models used for soil erosion and runoff measurement

Universal Soil Loss Equation (USLE)

The USLE (Wischmeier and Smith, 1978) is the most widely used and accepted empirical soil erosion model. It was developed for sheet and rill erosion based on a large set of experimental data from agricultural plots. Yet, the equation was derived on single agricultural plots and is only valid when applied to an area up to 1 ha. The USLE equation takes into account slope length (L factor), steepness (S factor), climate (R factor), soils (K factor), cropping (C factor) and management (P factor).

This model was specifically designed and tested to predict the average annual soil movement from a given field plot under specified land use and management conditions. The USLE has been enhanced during the past 30 years by a number of researchers. MUSLE (Williams, 1975), RUSLE (Renard *et al.*, 1996; Stone *et al.*, 2000), ANSWERS (Beasley *et al.*, 1989) and USPED (Mitasova *et al.*, 1996) are based on the USLE and represent an improvement of the former. The use of the USLE and its derivatives is limited to the estimation of gross erosion, and lack the capability to compute deposition along hill slopes, depressions, valleys or in channels.

Moreover, the fact that erosion can occur only along a flow line without the influence of the water flow itself restricts direct application of the USLE to complex terrain within GIS. The history of the development of the USLE and its modifications can be found in Peterson *et al.*, (1979), Lane *et al.*,(1992) and Renard *et al.*, (1997).

Universal Soil Loss Equation (USLE) The USLE is an empirical soil model developed by Wischmeier and Smith, (1978). Originally, USLE was developed mainly for soil erosion estimation in croplands or gently sloping topography (Ganasri and Ramesh, 2016).

The USLE quantifies soil erosion as the product of six factors representing rainfall and runoff erosivity (R), soil erodibility (K), slope length (L), slope steepness (S), cover and management practices (C), and supporting conservation practices (P) (Renard and Freimund, 1994). This empirical equation is based on the statistical analysis of more than 10,000 plot-years of data of sheet and rill erosion on plots and small watersheds (Roose, 1977). The equation is:

$$A = RKSLCP$$

in which erosion (A) is the estimated soil loss per unit area, R is the rainfall-runoff erosivity Σfactor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the cover management factor, and P is the supporting practices factor (Wischmeier and Smith, 1978).

The model predicts rainfall based on rainfall erosivity (R factor) and soil erodibilitty (K factor). Bols (1978) proposed a formula for calculating the R factor in

Indonesia in a model

$$R = 2.5P2100/(0.073P+0.73)$$

Where P = Annual precipitation in millimetres and R is in MJmmha-1hr-1yr-1 The soil erodibility index is calculated with the following equation (Roose, 1977):

$$K = A/R \times SL \times 2.24$$

where A is the erosion in tons per hectare, R is the rainfall erosivity index, SL is the topographic factor, and 2.24 the coefficient necessary to go from metric units (t/ha) to English units (t/acre).in which erosion (A) is the estimated soil loss per unit area, R is the rainfall-runoff erosivity Σfactor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the cover management factor, and P is the supporting practices factor (Wischmeier and Smith, 1978).

As with most empirical models, the USLE is not event responsive, providing only an annual estimate of soil loss as it ignores the processes of rainfall, runoff, and how these processes affect erosion, as well as the heterogeneities in inputs such as vegetation cover and soil types (Merritt *et al.,* 2003). They asserted that the model is not event-based and as such cannot identify those events most likely to result in large-scale erosion. Applying the equation to purposes for which it was not intended, however, cannot be recommended (Wischmeier 1978). Since it was designed for interrill and rill erosion, it should not be used to estimate sediment yield from drainage basins or to predict gully or stream-bank erosion (Morgan, 2005).

The Revised Universal Soil Loss Equation(RUSLE)

The RUSLE is an empirical equation for predicting long-term average soil erosion from agricultural fields under specific cropping and management practice (Renard *et al.,* 1991). Because the RUSLE is an empirical equation, its application is dependents on field data and the equations are valid within the limit of data from which it was developed. Indeed, a major criticism of the model is that its rainfall erosivity factor is not suited for capturing the erosivity of intense precipitation events, which are common in the humid tropics (Jeje, Ogunkoya and Adediji 1997, Lal 1990, Odemerho 1990, Stocking and Elwell 1976).

The RUSLE has been revised to more accurately estimate soil loss from both crop and rangeland areas (McCool, Foster, Renard, Yoder, and Weesies, 1995). The RUSLE maintains the basic structure of the USLE but is a computerized version that incorporates the results of additional research and experience obtained since the 1978 publication of USLE by Wischmeier and Smith (Renard and Friedmund, 1994). The equation is:

$$A = R.K.L.S.C.P$$

where A is the computed soil loss, R is the rainfall-runoff erosivity factor plus a factor for any significant runoff from snow melt expressed in MJ mm ha-1h-1yr-1; K is the soil erodibility factor – the soil-loss rate per erosion index unit for a specified soil as measured on a standard plot which is defined as a 72.6-ft (22.1m) length of uniform 9% slope in continuous clean-tilled fallow expressed in tha-1 MJ mm-1; L is the slope length factor – the ratio of soil loss from the field slope length to soil loss from the field slope length to soil loss from a 72.6-ft length under identical conditions; S is the slope steepness factor – the ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions; C is the cover management factor – the ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow; andP is the supporting practices factor – the ratio of soil loss with a support practice like contouring, strip cropping, or terracing to soil loss with straight-row farming up and down the slope (Ganasri and Ramesh, 2016).

The product of these factor values gave the expected soil loss in tha- 1yr-1 (A), depending on the dimensions used in the climate and soil factor (Le Roux, 2005). Like in the USLE, rainfall erosivity and soil erodibility are major factors in soil erosion prediction using the RUSLE model. Lee and Lee used the Toxopeus equation, which is well known for its superiority in Korea (Korea Institute of Construction Technology (KICT) (1992), was used to calculate rainfall erosivity factor, R as follows;

$$R = 38.5+0.35\times Pr$$

where, R is rainfall erosivity factor (in MJmmha−1yr−1) and Pr is the annual average rainfall (in mmyr−1).Le Roux (2005) in his study used the modified Fournier’s Index developed by the FAO (Arnoldus, 1980) to estimate the R-factor values for each of the rainfall zone due to insufficient rainfall intensity data. The equation is given as:

$$R = 0.0302 \times (RI)1.9$$

Where RI = Σ (MR)2/AR, MR is monthly rainfall in mm, and AR is annual rainfall in mm.

The Agricultural Non-Point Source model (AGNPS)

It is a non-point source pollution model developed by the US Department of Agriculture, Agricultural Research Service (USDA-ARS) in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service (SCS) in the USA (Young, Onstad, Bosch and Anderson, 1989). They reported that it is an event based model that simulates runoff, sediment and nutrient transport from agricultural watersheds. The model was developed to predict and analyse the water quality of runoff from rural catchments ranging from a few to over 20 000 hectares (Merritt *et al.,* 2003).

They noted that the model utilises components of existing models in its structure including the RUSLE for predicting soil loss ingrid cells.

The Agricultural Non-Point Sources Pollution (AGNPS) model is a mathematical model based on the functional relationships between the influential factors in the drainage basin (Nugroho, 2003). The AGNPS model can simulate surface runoff and sediment and nutrient transport in a drainage basin dominated by agricultural activity (Young, Onstad, Bosch and Anderson, 1995).

Runoff in a catchment is simulated using the SCS curve number method, an empirical rainfall-runoff modelling technique developed in the United States by the Soil Conservation Service (SCS) (1972). The AGNPS model can be applied in the planning stage of drainage basin management, so that environmental degradation and critical land can be identified and analysed (Nugroho. 2003). The greater data requirements and computational complexity of AGNPS compared with empirical models must be weighed against the added modelling capabilities of the model (Merrit *et al.,* 2003).

The AGNPS model can be applied in the planning stage of drainage basin management, so that environmental degradation and critical land can be identified and analysed (Nugroho. 2003). The greater data requirements and computational complexity of AGNPS compared with empirical models must be weighed against the added modeling capabilities of the model (Merrit *et al.*, 2003)

Water Erosion Prediction Project (WEPP)

The Watershed Erosion Prediction Project (WEPP) is a physics-based model developed in the United States in an initiative between the Agricultural Research Service, the Soil Conservation Service, the Forest Service in the Department of Agriculture and the Bureau of Land Management in the US Department of the Interior (Natural Science and Engineering Research Laboratory (NSERL) (1995). The overall package contains three computer models: a profile (hillslope) version, a watershed version and a grid model (Morgan, 2005).

The hillslope version of WEPP contains nine components: weather generation, winter processes, irrigation, surface hydrology and water balance, subsurface hydrology, soils, plant growth, residue decomposition, overland-flow hydraulics, and erosion (Pieri, Bitelli, Wu, Dun, Flanagan, Pisa, Ventura and Salvatorelli, 2006). They reported that the WEPP model requires four input files: topography, climate, soil and management. The erosion model within WEPP applies the continuity equation for sediment transport down slope in the form (Foster & Meyer 1972):

$$dQs/dx = Di + Df$$

Where Qs is the sediment load per unit width per unit time, x is the distance downslope, D*i* is the delivery rate of particles detached by interrill erosion to rill flow and D*f*is the rate of detachment or deposition by rill flow.

The basic output contains the runoff and erosion summary on a storm-by-storm, monthly, annual and average annual basis (Merritt *et al.*, 2003). One difference between the WEPP model and other models is that the sediment continuity equation is applied within rills rather than using uniform flow hydraulics (Han *et al.*, 2016). They reported that further study on the spatial variability of soil and vegetative cover is needed to successfully model larger area.

Developed by the USDA, the WEPP model (Flanagan and Nearing, 1995) is intended to replace the USLE family models and expand the capabilities for erosion prediction in a variety of landscapes and settings. This model is a physically based, distributed parameter, single-event simulation erosion prediction model. Processes within the model include erosion, sediment transport and deposition across the landscape and in channels via a transport equation. The WEPP model, in its current form, does not facilitate the integration with raster-based GIS.

The WEPP is a process- and computer-based model and is part of a new generation of prediction technology (Flanagan and Nearing, 1995). It is used for hill slopes and watersheds based on fundamental principles of overland flow dynamics, infiltration, evaporation, evapotranspiration, erosion mechanics, percolation, drainage, surface ponding, interception of rainfall and runoff by plant, residue decomposition, soil consolidation, and tillage and soil management. It uses climate data from a robust file to account for mean daily precipitation, maximum and minimum temperature mean daily solar radiation, and mean direction and speed of wind, and other climate factors. WEPP can predict soil erosion on a storm event and continuous basis for diverse tillage and cropping systems (e.g., crop rotations, terracing, contouring, strip cropping).

The advantage of WEPP over other erosion models is that it can estimate erosion for single hillslopes (hydrologic units) and the whole watershed which comprises various hillslopes. It simulates soil erosion at different temporal (daily, monthly, annual basis) and spatial (hillslope, small, medium, and large watersheds) scales. It simulates rill and interrill erosion over hillslopes and sediment transport and deposition in channels and impoundments interaction with surface cover conditions, soil properties, surface roughness, and soil management.

The main components of the model are Weather conditions, Winter processes, Irrigation practices, Infiltration dynamics, Overland flow hydraulics, Water balance, Plant growth, residue decomposition, Soil parameters, Hillslope erosion and deposition, Watershed channel hydrology and Watershed impoundment component(Flanagan and Nearing, 1995)

The WEPP model is under continuous improvement and integration with other technological advances. Now, WEPP is being linked to GIS through the Geospatial interface for WEPP (GeoWEPP), which allows the simulations based on digital sources (e.g, internet sources) of readily available geo-spatial information such as digital elevation models (DEM), climate data, soil surveys (e.g., USDANRCS data), precision farming, and topographical maps using the Arcview software (Renschler, 2003).

The GIS component allows the selection, manipulation, and parameterization of potential input parameters for the simulations at small and large-scale land areas of interest. The expansion of traditional WEPP and its combination with GIS add flexibility of WEPP. The GeoWEPP is a variant of the traditional WEPP and its further development would permit the simulation of distribution, extent, and magnitude of soil erosion at larger spatial scales and represent an improved approach for land use planning and soil and water conservation

Ephemeral Gully Erosion Model (EGEM)

The EGEM was specifically developed to predict gully formation and erosion based on physical principles of gully bed and side-wall dynamics (Woodward, 1999; Foster and Lane, 1983). Common erosion models such as USLE, RUSLE, and WEPP do not include direct options for predicting gully erosion.

The EGEM considers the dynamic processes of concentrated flow responsible for gully incision and head cut development. The EGEM is one of the few process-based models to predict gully erosion. The Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS) is another model that can predict gully erosion by accounting for the shear of flowing water, runoff and sediment transport capacity, and changes in channel bed and side dimensions. The EGEM is a development of the Ephemeral Gully Erosion Estimator (EGEE) (Laflen *et al.*, 1986).

The EGEM consists of two major components: hydrology and erosion. The hydrologic component is estimated using the runoff curve number, drainage area, watershed slope and flow depth, peak runoff discharge, and runoff volume. The erosion component is based on the width and depth of ephemeral channels. The EGEM can predict gully erosion for single storms or seasons or cropstage periods.

Lumped Parameter Models (LPMs)

LPMs use averaging techniques to lump the influences of non-uniform spatial processes of a given area, such as a basin-averaged precipitation for runoff computation. The initial focus of most LPMs such as RUSLE and SLEMA was to estimate long term average annual soil erosion at the field scale. In the late 1960’s and 1970’s the on- and off-site impacts of agricultural management practices and soil erosion on water quality and soil productivity became a major concern (Renschler and Harbor 2002). This stimulated the development of a number of LPMs that included routines for evaluating the effect of different agricultural practices on nutrient loss, ground water pollution, and crop productivity. Later models were to some extent based on process description, they retained essentially an empirical base. Examples include the ANGPS, CREAMS, GLEAMS and the EPIC models

Kineros Model

Kineros, as a physical model, examines the amount of runoff and erosion and simulates routing of surface runoff at the catchment scale. In this model, the movement of water is evaluated using kinematic wave estimate of Saint-Venant equations and the resulted runoff is estimated based on the Horton equation. In line with this equation, there is an occurrence of runoff whenever the infiltration speed is lower than the rainfall intensity.

Infiltration equations employed in Kineros are according to the Smith and Parlange (1978) infiltration model (Memarian *et al.,* 2013).

In Kineros model, watershed is separated into several sub-catchments, each of which is simulated based on similar surface flow planes and channels. In each sub-watershed, surface flow planes are in the form of rectangle and regular surfaces with similar input parameters. The parameters of model may be changed from one plane/channel to another, but the specifications in each element are assumed to be similar.

These specifications mainly include hydraulic attributes of soil, rainfall properties, topography, geometric shape of earth and land use and land cover characteristics. In this model, surface flow plane is created based on the general slope of the earth through selecting maximum and minimum altitudes of the area. The channels with specific slope and assumed trapezoidal shape are speared towards the basin outlet (Memarian *et al.*, 2013). In the conceptual model of overland flow, small scale changes of infiltration and micro topography are parameterized and considered in the simulation.

Rainfall-runoff modeling (Original SCS-CN model)

The SCS-CN method is based on the principle of the water balance and two fundamental assumptions (Mishra and Singh, 2002). The first assumption is that the ratio of direct
runoff to potential maximum runoff is equal to the ratio of infiltration to potential maximum retention. The second assumption states that the initial abstraction is proportional to the potential maximum retention. The water balance equation and the two assumptions are expressed mathematically:

$P = I\text{a} + F + Q \ldots(1)$

$Q/P\text{-}Ia = F/S \ldots(2)$

Where P is the total precipitation (mm), Ia is the initial abstraction before runoff (mm), F is the cumulative infiltration after runoff begins (mm), Q is direct runoff (mm), S is the potential maximum retention (mm), and λ is the initial abstraction coefficient. Combination of Eqs. (1) and (2) leads to the popular form of the original SCS-CN method:

$Q = P\ (P - I\text{a})\ 2\text{a}+S$ for $P > I\text{a}$

$Q = 0$, for $P \leq I\text{a}$ …(3)

The parameter S can vary in the range of $0 \leq S \leq \infty$, and it is directly linked to the curve number CN:

$S = 25400/\ \text{CN} - 254$…(4)

Where the CN is a dimensionless variable, and it depends on land use, hydrological soil group, hydrologic conditions, and antecedent moisture conditions.

The Soil Loss Estimator for Southern Africa (SLEMSA) model

SLEMSA is similar in structure to that of the RUSLE using similar parameters (Le Roux, 2005). SLEMSA was developed largely from data from the Zimbabwe Highveld to evaluate the erosion resulting from different farming systems so that appropriate conservation measures could be recommended, the technique has since been adopted throughout the countries of Southern Africa (Morgan, 2005). The equation is (Elwell 1978):

Z = K x C

where Z is predicted mean annual soil loss (t ha-1yr-1), K is mean annual soil loss (t ha-1yr-1) from a standard field plot, 30m long, 10m wide, at 2.5° slope for a soil of known erodibility (F) under a weed-free bare fallow, X is a dimensionless combined slope length and steepness factor and C is a dimensionless crop management factor.

Soil erosion computer models use mathematical expressions to represent the relationships between various factors and processes occurring on the landscape. There are two types of models empirical and process based models. Physically based models are generally the most scientifically robust and flexible in both inputs, output, and are based on an understanding of the physical processes that cause erosion and are therefore applicable to a wide range of soils, climatic and land use conditions. Empirical models are of great benefits in many situations given that they are largely the only models that could be run with little available data. Examples of empirical models include the Universal Soil Loss Equation (USLE) and its derivates (Revised Universal Soil Loss Equation, RUSLE and Modified Universal Soil Loss Equation, MUSLE). Commonly used example of process-based model is the Water Erosion Prediction Project (WEPP).

Different models their Owen advantages and dis advantages. such as empirical models Are generally the simplest of all types of models, are primarily based on the analysis of observations and seek to characterize response from these data, less data requirement, less computational requirement, high level of spatial and temporal aggregation, manyare based on analysis of catchments data using stochastic techniques, parameter values many be obtained by calibration/ more often from calibration at experimental sites. Employ unrealistic assumptions about the physics of the catchment system. some of disadvantages are Not event responsive: ignoring the – processes of rainfall- runoff in the catchment being modeled, based on assumption of stationary: it is assumed that the underlying conditions remain unchanged for the duration of the study period, make no inferences as to the process at work.

Generally, models is important to estimate the soil loss by erosion and run off and it is important to understand the driving force of erosion, to evaluate the on-site and off-site effect of erosion on crop production and soil and water pollution, to identify the strategy of control it, and it is important to assess the performance of the SWC practice to reduce erosion.

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