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Review Article

Comparison and Applicability of Selected Soil Erosion Estimation Models

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Abstract: Soil erosion is a globally challenging issue that hinders agricultural productivity by enhancing land degradation and loss to the top fertile soil. Although it is a global issue, its effect is adverse on farmers dwell in developing countries. Hence, providing information on soil loss is crucial to plan and implement appropriate soil and water conservation measures. Accordingly, erosion estimation models were developed and grouped as empirical, conceptual, and physical-based broad umbrella. This review paper primarily is intended to compare the opportunities and limitations of widely implemented soil erosion estimation models and review their applicability by selecting widely used models such as: USLE, RUSLE, SLEMSA, and WEPP. The result of this review revealed that the so reviewed erosion models have been designed to predict soil loss from sheet and rill erosion. Evidence from studies indicated that R/USLE models can be universally used by calibrating to the local environmental conditions. They are simple, requires less data and computational time, however; they are not event responsive and measure soil loss from gully and stream-bank erosion. But, RUSLE model has different parameter calculation procedure than the USLE. This study also depicts the SLEMSA model treats soil erosion factors as a separate entities and is highly influenced by LS factors. The WEPP model has capability to estimate soil loss in a short time scale and out-of-place erosion rates, but; it only works for individual hillslope. Thus, based on the result of this review the following recommendations are forwarded for further study to fill the gaps; upgrading of R/USLE parameters, modification of topographic sub-model of SLEMSA, and revision of essential parameters in WEPP model to estimate erosion from large catchments.

Keywords: Soil Loss, Event-based Erosion, Erosion Models, Model Calibration, Agricultural Productivity

1. Introduction

In the twenty first century, soil erosion is the principal challenging issue that universally threatening the sustainability of natural resources and agricultural productivity [1-3]. Agricultural intensification to fragile and marginal ecosystem due to rising population with varied curiosity [1], overgrazing, land use land cover change, and extensive rainstorms [4] combined any activities that put pressure on land resources are the main driving forces behind. Urbanization, deforestation, inappropriate farming practice, and cultivation without necessary soil and water conservation measures are also direct causes of soil erosion. Based on the finding of Phinzi et al [5], globally about 75 billion tons of the top fertile soil eroded from agricultural land per annum. Its consequence is severe in agrarian peoples of emerging countries, due to unreachability of agricultural technologies, unprivileged economy, and lower capability to overcome soil erosion induced shocks.

The effect of soil erosion becomes a global environmental concern and is widely categorized as the offsite and onsite effects. Its effect extends to the nearly entire latitude of planet earth. Soil erosion contributes to exposure of impermeable subsoil thereby lowering available soil water, loss of nutrient-rich topsoil [1, 6], damage to the aquatic ecosystem, destruction to reservoirs and dams, and ultimately contributes to biological, physical, and chemical land degradation [1]. It also affects afforestation activities through the formation of rills, reduce arable land through gully formation, and limit access to cultivation. It also lessens the arable land through gully formation and affects tree plantation through rill formation thereby limiting the access to cultivation. Ultimately, the effect of soil erosion yields considerable extra input costs leading to huge economic forfeiture in the agricultural industry, painful environmental impacts, and drought.

Thus, soil erosion estimation is crucial to identify erosion-prone areas and to plan and construct suitable soil and water conservation practices. Since experimental determination of erosion is time-taking, expensive, and intensive in manpower [3], numerous models were importantly industrialized by many scholars and had been implemented throughout the world. About 82 soil loss estimation models [7] were developed by researchers. To mention a few, Universal Soil Loss Equation (USLE) [8, 9] and its revised version RUSLE [10], Water Erosion Prediction Project (WEPP) [11], European Soil Erosion Model (EUROSEM) [12], Soil Los Estimation Model for South Africa (SLEMSA) [13], and Chemicals, Runoff, Erosion from Agricultural Management Systems (CREAMS) [14], and Areal Non-Point Source Watershed Environment Response Simulation (ANSWER) [15]. Generally, erosion models are broadly grouped under conceptual, empirical, and physical-based models depending on physical process simulated by the model, based on data dependency of the model, and model algorithm describing these process.

Empirical models, called data-driven models, are observation-oriented and depend heavily on input accuracy. It is based on an assumption that the underlying conditions remain unchanged for the duration of the study period. They are black-box, meaning very little is known about the internal process (rainfall- runoff) that controls how runoff results are determined [16]. Since they are data-driven, input data are a main source of error because input data distortion produces serious ramifications in the modeled output. According to Beven [17], one of the downfalls of the empirical model is that it may lead to different conclusions than accepted theoretical analysis would suggest. Besides, parameters in empirical models lack physical significance because they employ unrealistic assumptions about the physics of the catchment system: ignore heterogeneity of catchments inputs and characteristics (rainfall and soil types) and ignore the inherent non-linearity in the catchment system. On other hand, small numbers of parameters, fast computation time, cost-effectiveness, and accurate simulation result in long time steps and recreating past runoff values, and simplicity of application makes the empirical model the chosen one for soil erosion modeling. As a result, they are termed as the simplest of all models [18].

Physical models, also called process-based, are based on the understanding of the physics related to the hydrological processes and are defined by wholly measurable parameters and can provide a continuous simulation of the runoff response without calibration [17]. The strong point of the physical model which makes it realistic is the connection between parameters and physical characteristics of the catchment [19]. 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 [20]. They described processes involved with the help of mathematical equations dealing with the laws of conservation of energy and mass [21]. Most of them requires large number of input data and are complicated. In theory, the parameters in process based models are measurable and so are known. In practice however, due to large no of parameters involved and the heterogeneity of the important characteristics of the catchment, these parameters should be calibrated against observed data.

Conceptual models are based on reservoir storage and simplified equations of the physical hydrological process, which provide a conceptual idea of the behaviors in a catchment [22, 19]. It represents the water balance equation with the conversion of rainfall to runoff, evapotranspiration, and groundwater. Each component in the water balance equation is estimated by a mathematical equation. The ease of utilization and calibration made them popular in the modeling community. Besides, the previous calibrated model can be used for different catchments. This model can be best used with limited computation time and catchment characteristics thereby can provide an indication of qualitative and quantitative effects of land use changes without requiring large amount of spatially and temporally distributed data. The main shortfall to the model is that the lack of consideration in spatial variability due to the simplicity of the model and physical meaning in governing equations and parameters. This model takes rainfall and runoff as input and sediment yield as output [20].

This review paper primarily is intended to compare the opportunities and limitations of widely implemented soil erosion estimation models and review their applicability.

2. Soil Erosion Estimation Models

Erosion modeling is vital for erosion scenario assessment that helps to map areas with potential risk and to choose erosion control measures. The information-driven is also very useful in the decision-making context to avoid land acquisition in erosion risk areas. Besides, the formulation of proper soil management for sustainable development requires an explicit inventory and rating of vulnerable areas. Erosion models are selected those that best fit with available data [23], accuracy and simplicity of the model [24], and widely relies on the function that the model needs to serve [18]. However, the available data may not be sufficient and compatible to apply models out of an area for which it was designed. Thus, calibration of the models according to local conditions is necessary [23]. As Merritt et al [25], stated each model type serves a purpose for which it is designed for and as a result a particular type of model is not best in all conditions.

2.1. Universal Soil Loss Equation (USLE)

Early 20th century, soil erosion research was launched in North America and was accelerated after Franklin Roosevelt helped pass the Soil Conservation Act of 1935 (Public Law 74-46). Agriculture and the newly created Soil Conservation Services developed the Universal Soil Loss Equation (USLE) in the 1950s as a tool to predict soil loss and help farmers with conservation planning. The USLE is a lumped empirical field-scale model that predicts soil loss from rill and inter-rill erosion based on 10,000 field plots and small watershed years of erosion data. It was originally published by Wischmeier and Smith [8] for the first time in Agricultural Handbook no. 282 and later it was published by the same authors in Agricultural Handbook no. 537 [9]. Initially, USLE was developed mainly for soil erosion estimation in croplands or gently sloping topography [1]. It is defined as;

$$A=R*K*L*S*C*P \quad (1)$$

Where; A is annual average soil loss per unit area (t ha^{-1} yr^{-1}), R is rainfall-runoff erosivity factor (MJ mm h^{-1} ha^{-1} yr^{-1}), K is the soil erodibility factor (t ha^{-1} MJ^{-1} mm^{-1}), L is the slope length factor (dimensionless), S is the slope steepness factor (dimensionless), C is the land cover and management factor (dimensionless), and P is the soil conservation or prevention practices factor (dimensionless). The figure below adapted from Alewell et al [26] indicates the number of studies and percentage of total publication number per continent using USLE from 1977 to July 2017.

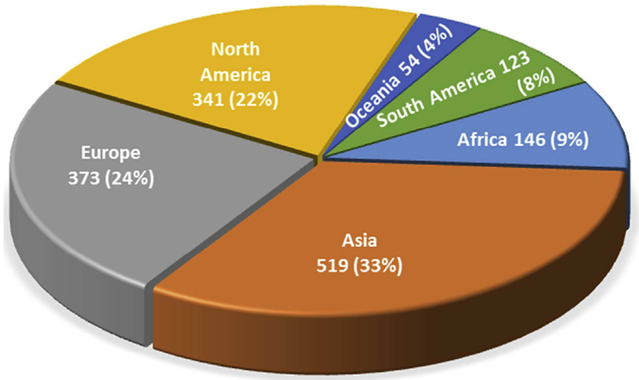

Figure 1. *Number studies and publication used USLE.*

2.1.1. Rainfall Ersosivity Factor (R)

The R-factor measures the impact of rainfall on erosion and it is designed to represent the input that drives the sheet and rill erosion process through climatic factors. It quantifies the capacity of rainfall to cause the detachment and transport of soil particles by the action of the impact of water droplets and by runoff. It was defined as the product of the total kinetic energy multiplied by the maximum 30 min rainfall intensity (EI_{30}) [9]. Several adopted formulas have been developed to calculate the annual erosivity factor based on available local data for different countries and its calculation involves long-term data collection [27].

2.1.2. Soil Erodibility Factor (K)

The K factor expresses the susceptibility of a soil type to erosion and is usually regarded as the rate of soil loss per erosion index unit [9]. It is highly related to the soil physical properties and hence affected by soil texture (percentage of sand, silt, and clay), organic matter content, soil structure index, and the soil permeability index which is used in soil erodibility estimation [28, 27].

2.1.3. Topographic Factor (LS)

Topographic Factor (LS) is the slope length-gradient factor that represents the effect of topography on soil erosion rates [29] and it is defined as the estimated ratio of soil loss per unit area from a field slope to soil loss from a 22.1 m length of uniform 9% slope [9]. It can be jointly calculated from the following equation.

$$LS=(\lambda/22.13)^{m} (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065) \quad (2)$$

Where LS is the slope length factor (unitless), λ is slope length (m), θ is the angle of the slope (degrees), and m is an exponent based on slope gradient.

2.1.4. Cropping Management Factor (C)

According to Jazouli et al [30], the C-factor represents the effect of cropping and management practices on erosion rate. It has a close linkage to land use types and is a reduction factor in soil erosion vulnerability. It is defined as the ratio of soil loss from land cropped under specific conditions to the corresponding loss from clean-tilled, continuous fallow. The value of C depends mainly on vegetation type, stage of growth, and cover percentage. The C-factor ranges between 1 and 0. C equal to 1 indicates no cover present and the surface is treated as barren land, whereas C near zero indicates very strong cover effects and well-protected soil.

2.1.5. Support Practice Factor (P)

The P-factor reflects the effect of contouring and tillage practices on soil erosion. The numerical value of the P-factor is always between 0 and 1 according to the management of agricultural land. The P-factor value near 0 indicates good conservation practice, and the value near 1 indicates poor conservation practice.

USLE has several limitations though the simplicity of the equation and availability of parameters made the model comparatively easy to use. Like many empirical models, it is not event responsive, predicts only annual soil loss since it ignores the processes of rainfall, runoff, and how these processes affect the erosion, along with the heterogeneity in inputs like vegetation cover and soil types [25]. They also stated that the USLE model is not event-based as a result the model cannot identify those events most likely to result in large-scale erosion. Wischmeier and Smith [9], asserted that it cannot be recommended to apply the equation to purposes for which it was not intended. According to Morgan [21], since the USLE model was initially designed to estimate erosion from inter rill and rill erosion, it should not be used to estimate sediment yield from drainage basins or to predict gully or stream-bank erosion. This author also reported that attention should be given while using the model to estimate the contribution of hillslope erosion to basin sediment yield because it does not estimate deposition of material or incorporate a sediment delivery ratio. In his view, he concluded that the model cannot be used to estimate soil loss from an individual storm since the equation was developed to estimate long-term mean annual soil loss.

But, now a day, the USLE modeling has been further advanced to meet numerous special requirements and specific needs. E.g., Bagarello et al [31] adapted USLE-type models for event-based soil erosion modeling. The model has also been used in all kind of extreme ecosystem types and for various management scenarios, e.g. from volcanic soils in Chile with a Mediterranean climate by Stolpe [32] to the possible mitigation impact of organic farming on soil erosion rates from mountainous monsoonal watersheds in South Korea by Arnhold et al [33] or the comparison of conventional with organic farming in northern Bavaria [34].

Table 1. *Characteristics and applicability of models [35].*

Model	Spatial Scale	Temporal Scale	Data Demand	Output	Overland Sediment			In-Stream Sediment			Gully Erosion	Rainfall-Runoff
					Gen.	Trans.	Dep.	Gen.	Trans.	Dep.		
USLE	Hillslope	Annual	High	Erosion	Yes	No	No	No	No	No	No	No
RUSLE	Hillslope	Annual	High	Erosion	Yes	No	No	No	No	No	No	No
SLEMSA	Catchment	Annual	High	Soil loss, sheet erosion	Yes	No	No	No	No	No	No	No
WEPP	Small Catchment	Event	Medium	Erosion, sediment yield, runoff	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

Where: Gen.=Generation; Trans.=Transportation; Dep.=Deposition.

2.2. Revised Universal Soil Loss Equation (RUSLE)

Several changes occurred with RUSLE including new rainfall-runoff erosivity values, a sub factor approach for calculating land cover, and new slope and soil erodibility algorithm. It is a revised empirical model of USLE that conserves the basic structure of the USLE concerning the main equation and having similar factors that determine the loss of soil through erosion. The RUSLE model differs in that the calculation of factors follow different procedure involving treatment in the computer and is a more accurate estimate of soil loss [23, 10]. It is a powerful tool for predicting erosion rates in large areas and estimating sediment production, which can become a sediment harvest in watersheds, farmlands, and pastures where runoff occurs as a result of greater rainfall than infiltration [37]. However, Renard et al [38] pinpointed that the RUSLE model was not initially designed for natural forested areas, where no overland runoff occurs or where it is limited and other types of erosion such as stream bank and gully erosion are not included, but it is focused on determining erosion loss on landscapes where significant overland runoff occurs such as clear land. This empirical method is designed for estimating average annual soil erosion caused by raindrop impact and associated overland flow from sloped fields in agricultural systems and rangelands [10], based on the following equation:

$$A=R*K*LS*C*P \tag{3}$$

Renard et al [38] stated the main difference of RUSLE from USLE regarding erosivity of precipitation; the new tendency of the R-factor to reduce its value in flat places of regions with intense rains, since the water retention at the surface when runoff occurs reduces rainfall erosivity; the fact that part of the calculation of the factor R involves a seasonal distribution to allow the weighting of the value of the soil erodibility, K, and the coverage factor and cultural practices to be weighted. For this purpose, files with climate data were developed for climatically homogeneous areas, called city codes, which integrate information on the number of days without soil ice formation, monthly precipitation and temperature, and the distribution of rainfall over periods of 15 days. It should be noted that the program provides space to add data sets provided by the user, which should allow its easy use in other regions of the world. Brown and Foster [39] formulated a new equation to calculate the unit of the kinetic energy of rain as following:

$$e_m=0.29\ [1 - 0.72^{(-0.0521\ _{m})}] \tag{4}$$

Where; e_m is the maximum unit kinetic energy when the intensity tends to infinity, in MJ ha^{-1}, I_m the maximum rainfall intensity in mm h^{-1}.

The soil erodibility factor, K, has been updated by integrating equations to calculate its value for soils with little data, such as lack of information on the fraction of sand or organic matter, and with a textural composition given by a classification system different from that used in the USA. According to Renard et al [38], the RUSLE model also includes equations to estimate the K value in conditions not covered by the nomogram, such as volcanic soils and with a high content of organic matter.

Recently, different studies have tried to incorporate other forms of erosions into the RUSLE like study held in Indonesia by Penning de et al [40] where the equation below was used to estimate the total annual yield Y in ton ha^{-1} yr^{-1} for a 130,000-ha watershed:

$$Y=A * SDR + Gl + Sb + Rs + LI \tag{5}$$

Where A (ton ha^{-1} yr^{-1}) is annual soil loss, SDR is sediment delivery ratio, Gl, Sb, Rs and L1 are gully, stream bank, roadside, and other forms of erosion respectively in ton $ha^{-1}yr^{-1}$. Jaramillo [36], in his study, argued that the last parameters are difficult to calculate and require complex measuring techniques and therefore it is uncertain if the addition of these sub-factors improves the accuracy of the soil loss estimates in a practical manner. Moreover, McCool et al [41] devised additional changes in RUSLE which is the incorporation of rock fragments on and in the soil, a common occurrence on western US rangelands and croplands in many areas of the world. They stated that rock fragments on the soil surface are treated like mulch in the C-factor, while K is adjusted for rock in the soil profile to account for effects on runoff.

According to Igwe et al [18], the major factors in predicting soil loss using RUSLE are rainfall erosivity and soil erodibility like that of USLE. As at USLE, at RUSLE the values of factor P are the least accurate and generally represent the general effects of conservation practices. But, in RUSLE values of the P factor were also developed, which reflect conservation practice in the pasture. Jaramillo [36], stated that as an empirical model RUSLE does not take into account runoff or the processes of detachment, deposition, or transport of sediment.

Table 2. *Average annual soil loss predicted by USLE, RUSLE, and WEPP in United States [42].*

Sites	Av. Soil Loss (kg/m^2)	USLE Soil Loss (kg/m^2)	RUSLE Soil Loss (kg/m^2)	WEPP Soil Loss (kg/m^2)
Bethany	5.77	2.38	2.01	2.38
Castana	7.65	14.58	10.23	11.63
Clarinda	5.50	4.72	6.01	4.17
Clemson	5.79	8.18	8.36	5.72
Geneva	2.29	2.08	2.20	0.84
Guthrie	2.26	2.85	2.02	3.45
Hayes	0.31	0.67	0.47	0.46

2.3. The Soil Loss Estimation for South Africa (SLEMSA)

SLEMSA was designed as a framework for the development of local soil loss models that take into account local environmental conditions in South Africa for data obtained from Zimbabwe [13]. According to Devia et al [21], this model was also intended to evaluate the erosion resulting from different farming systems so that appropriate conservation measures could be recommended, the technique has been adopted throughout the countries of Africa continent particularly South Africa [44, 45]. According to Breetzke et al [43], SLEMSA was developed on the basis of the USLE and is an attempt to adapt the USLE model to an African environment. It operates through a set of control variables such as rainfall energy, vegetation intensity, etc. the value for which are fairly easily determined and which have some rational physical meaning. These control variables form the input to three sub-models which, when combined, give an estimate of soil loss. The equation was developed by Elwell [13]:

$$Z = K \times X \times C \quad (6)$$

Where Z is predicted mean annual soil loss (t ha^{-1}yr^{-1}), K is mean annual soil loss (t ha^{-1}yr^{-1}) from a standard field plot, 30 m long, 10 m wide, at 2.5° slope for the 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. The K factor accounts for soil erodibility (F) and rainfall energy (E). According to Elwell [46], erodibility value F was modified according to management practices that influence soil properties. Using the F values, values of K are derived from the equation:

$$\ln K = b \ln E + a \quad (7)$$

$$E = 9.28 P - 8.838 \quad (8)$$

Where a=2.884 – 8.1209 F, b=0.74026 – 0.09436 a, E is mean annual rainfall energy in Jm^{-2} and P is mean annual precipitation in mm.

Morgan [21], stated that both SLEMSA and RUSLE use similar parameters to estimate soil loss. But, according to this author, the notable difference that exists between the models is the definition of K as the rate of soil loss per unit of erosivity. He reported that in SLEMSA the K-factor is dependent on rainfall energy, to which it is exponentially rather than linearly related, as well as the dimensionless soil erodibility index F. He additional stated that SLEMSA has an advantage over R/USLE in that SLEMSA treats the soil erosion factors as separate entities since interactions between model components can cause complications in RUSLE model.

The applicability of SLEMSA in the mountainous areas indicated that the estimate of soil loss is very sensitive to variation in slope steepness (S) and rainfall energy (E). The model has a weakness in the apparent over-estimation of soil loss values resulting from collinearity between the slope steepness (S) and slope length (L) factors. The problem intensifies with increasing slope steepness, which indicates that the topography sub-model should be modified if it is to improve the predictive ability of SLEMSA in rugged terrain.

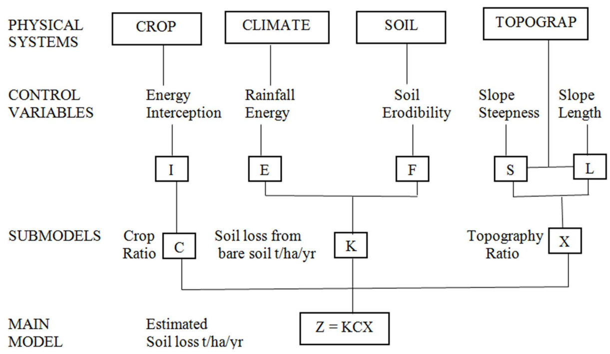

Figure 2. *The structure of SLEMSA model [47, 23].*

The structure above depicts that the model is composed of four components namely the physical system, the control variable, the sub-models, and the main model, each of them treated separately. The variable that defines the crop influence on erosion is the percentage of rain energy intercepted, the climate is defined by the energy of precipitation, the soil by its erodibility index, and the topography by the degree of slope or inclination of the land and the length of the land hillside [23]. According to Elwell [47], for SLEMSA any practice that has an influence on soil properties, such as tillage or other treatment, is taken into account in the soil system and any other factor related to culture is integrated into the culture system, arguing that this approach differs in concept from USLE in that tillage and cultivation are both parts of the factor of cultures and cultural practices, C.

Table 3 indicate that soil loss estimated by SLEMSA is greater than that estimated by USLE. USLE underestimated the soil loss for the various management practices as compared to the SLEMSA values. The differences between some of the values of soil losses estimated by the two methods can be attributed to the differences in the sensitivity of the two models to their input factors.

Table 3. *Comparison of soil loss estimated using USLE and SLEMSA in Makurdi, Nigeria [48].*

Treatment	Measured soil loss (t/ha/yr)	SLEMSA	USLE
2015			
T1	31.8	20.84	18.38
T2	4.25	5.00	0.5
T3	2.62	5.00	0.03
T4	4.6	3.75	1.89
T5	9.19	7.50	5.29
2016			
T1	13.9	16.49	6.015
T2	0.12	3.96	0.096
T3	0.00	3.96	0.009
T4	0.49	2.97	0.481
T5	1.83	5.94	1.732

(T1) bare fallow; (T2) 4 t ha-1 surface mulch + maize; (T3) 8 t ha-1 surface mulch + maize; (T4) maize + cowpea; (T5) maize.

2.4. The Water Erosion Prediction Project (WEPP)

The R/USLE models have been used for several decades for predicting long-term mean soil loss throughout the world. According to Kinnell [49], through time it has been recognized that predicting soil losses in a short time scale is necessary and this has led to the development of the WEPP model. The WEPP model is developed by the United States Department of Agriculture as a process-based succession of USLE. This model was developed using data from 50 experimental cropland and rangeland plots to accurately model the underlying hydrologic processes that contribute to soil erosion [50]. According to Flanagan and Nearing [51], the WEPP model is a daily simulation model that estimates the loss of the soil and sediment delivery from sheet and rill erosion for an individual hillslope or small watershed. They also dictated that the model has both hydrological and soil erosion components including erosion and deposition, soil disturbance by tillage, weather generation, frozen soil, residue decomposition, snow accumulation and melt, plant growth, irrigation, water balance, infiltration, and overland flow hydraulics. The hydrological component of the model computes the variables of peak flow rate, its effective duration, and the effective intensity of the precipitation. WEPP is based on a steady-state sediment continuity equation that describes sediment transport down slope [52]:

$$\frac{dQs}{dx} = D_f + D_i \tag{9}$$

Where x is the distance downslope (m), Qs is the sediment load per unit width per unit time (kg s^{-1} m^{-1}), Df is the rate of detachment or deposition by rill flow (kg s^{-1} m^{-2}), and Di is the delivery rate of particles detached by inter rill erosion to rill flow (kg s^{-1} m^{-2}).

According to Merritt et al [25], the basic outputs of the WEPP model contain the runoff and erosion summary on a storm-by-storm, monthly, annual and average annual basis. The one basic difference between the WEPP and the R/USLE models is that the sediment continuity equation is applied within rills rather than using uniform flow hydraulics [53]. It is also considered that the WEPP model estimates out-of-place erosion rates, including sediment harvesting in the slope profile and its enrichment rate, as well as on-site erosion rates, such as removal rates and deposition.

In their application of the WEPP model, Han et al [53] observed that the WEPP-simulated runoff and sediment yield predictions were relatively consistent with the measured values at slope scale but at watershed scale both the simulated values of runoff and erosion were higher than the measured. Chandramohan et al [20] noted that the model under-predicted soil loss because of the large data requirement and many number of model parameters related to soil and crop management which is impractical to collect or measure in studies of large scale. Its major advantage over empirical models is that being a physically-based model, it takes into account processes/events that influence erosion.

Table 4. *Comparison on the efficiency of USLE and WEPP on soil loss prediction in Nith Watershed, Canada [54].*

Basin	Area (ha)	Measured soil loss (t)	USLE soil loss (t)	USLE (% error)	WEPP soil loss (t)	WEPP (% error)
A	3.27	68.70±15.67	99.84	45	63.29	8
B	2.69	53.64±11.62	79.52	48	46.20	14
C	0.48	10.52±4.24	6.21	41	4.56	57
D	0.73	10.46±3.57	13.10	25	7.92	24
E	1.09	16.20±7.20	22.34	38	16.37	1
Total:	8.48	159.52	222.50	39	139.22	13

3. Conclusion and Recommendation

This paper discussed soil loss estimation models and their applicability by reviewing previous studies conducted by different authors on soil erosion models. Several authors concurred that R/USLE models are routinely applied throughout the world due to their universality, simplicity, and ease of application. However, some studies argued that models have to be wisely adapted and calibrated to the local environmental conditions. Previous authors agreed that R/USLE models can be applied in different areas of the land by validating for the place under study. But, they cannot be used to simulate erosion from gullies and streambanks. The R/USLE models predict only long-term soil loss but cannot be used to estimate event-based erosions. Authors report that USLE predicts only sheet and rill erosion and neither the process of flow nor that of transporting materials. On the other hand, some authors agreed that the RUSLE model is more accurate than USLE and has different procedures of calculation to determine parameters. Similar to USLE, the RUSLE model as an empirical model does not take into account runoff or the process of erosion.

Studies conducted on SLEMSA agreed that initially SLEMSA was developed to adapt the USLE model to African conditions. SLEMSA differs in concept from the USLE in that tillage and cultivation are both parts of the factor of cultures and cultural practice, C. The study held on SLEMSA also depicts that it uses similar parameters to estimate erosion with that of RUSLE. But, unlike RUSLE, the SLEMSA model has a different definition regarding the K factor. Authors that studied the WEPP model agreed that the model is accurate to predict erosion for a short period in the small watershed but it cannot be used on a large scale. They also concurred that the WEPP model varies from R/USLE in that the sediment continuity equation is applied within the rill than using the uniform flow hydraulics. Thus, based on the result obtained from this review, it is concluded that evaluated models have limitations on their applicability. Based on the result of this review the following recommendations are forwarded; parameters used in R/USLE needs to be upgraded so that streambank and gully erosions will be considered to estimate total soil loss from a given area, the topographic sub-model of SLEMSA should be modified to enable the model to accurately estimate soil loss form rugged terrain, and necessary parameter should be incorporated in WEPP model to estimate erosion from large catchments.

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