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A COMPARATIVE EVALUATION OF TWO DISTRIBUTED HYDRO-SEDIMENTOLOGICAL MODELS IN THE SEMIARID REGION OF THE STATE OF PARAÍBA, BRAZIL

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Abstract: *The data obtained from two experimental basins, in the semiarid region of the State of Paraíba in the northeast of Brazil, have been used to calibrate and validate two distributed hydro-sedimentological models to simulate the surface runoff and erosion loss occurring in standard plots and micro-basins. The models utilized are, WESP – Water Erosion Simulation Program (Lopes, 1987) and KINEROS 2 - Kinematic Erosion Model 2(Woolhiser et al., 1990). Since both the models are distributed and capable of simulating individual events, they can provide insight into the spatial distribution of the runoff and erosion processes in the experimental units modeled. The present paper describes the steps of calibration and validation of the two models and a comparative evaluation of the performance of the two . The possible existence of scale effects is discussed.*

Keywords: *Runoff-Erosion modeling; WESP; KINEROS2; Semiarid Region; Experimental Basins.*

INTRODUCTION

The knowledge of the amount of surface runoff generated and the associated soil loss caused by rainfall is extremely important for any rational planning of hydrological basins. According to Lal (2001), soil degradation by accelerated erosion is a serious problem and will remain so during the 21st century. These aspects assume a higher level of significance in the case of semiarid regions. The scarcity of water in these regions raises the need to take every possible measure to maximize the runoff yield from the basins and store this water for use during the dry period. The north-eastern region of Brazil that includes what is commonly known as the "polygon of drought", faces two conflicting situations: one in which there is a need to maximize the surface runoff, and the other in which the relatively thin soil cover needs to be protected against erosion and loss of soil nutrients. The solution to this, evidently, lies in the identification of areas within the river basins that are more suitable for either runoff generation or soil conservation. An adequate

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assessment of soil degradation is crucial to propose and implement management practices that assure a sustainable use of soil resources.

In order to evaluate the influence of the human activities as well as various natural factors that could leas to the processes degradation and desertification, such as the processes of runoff generation and soil erosion, experimental basins were installed in a typically semiarid region in the state of Paraíba. Measurements of runoff and erosion under diverse conditions of management have been carried out since 1982. Some of the details of the installations, data collected and the results obtained in the modeling process are presented here in.

The first experimental basin was located in the municipality of Sumé where the mean annual precipitation is 590 mm with a coefficient of variation of about 0.5. The annual class A tank evaporation is about 2900 mm (Cadier et al 1983). The rainfall in the region is highly irregular and is concentrated in about three months of the year between February and May (Cadier & Freitas, 1982). The soil cover is quite thin, underlain by bedrock. The most predominant type of soil is Brown non-calcic vertic soil with gravel and stones. The permeability is only moderate and the natural vegetation is mainly bush and small sized trees.

The Experimental Basin of sumé(EBS) had to be deactivated in the mid nineties as the owner of the farm decided to put the farmland into other uses. In order to continue the studies with the erosion plots and micro-basins, new installations were made at another location, the Experimental Basin of São João de Cariri(EBSJC), located about 80 km away but, within the same hydro-climatic region. The installations in the second basin were carried out progressively, starting with two erosion plots of 100 m^2 in the mid nineties and adding later on 3 micro-basins.

FIELD INSTALLATIONS

The Experimental Basin of Sumé(EBS) was located in a private farm called “Fazenda Nova” forming part of the Umburana sub-basin (10.7 km^2 area) which in itself is a part of the Representative Basin of Sumé (137.4 km^2). More than 85% of the basin is covered by brown non-calcic vertic soils, typical of the Brazilian semiarid regions. The field studies were carried out at different scales: four micro-basins with an area of around 0.5 ha and 9 standard Wicshmeier type erosion plots of 100 m^2 were installed and equipped for the determination of the total runoff and total sediment yield for each of the events of precipitation observed. The four micro-basins were chosen so that they may typically represent the prevailing vegetal cover and the natural slopes. Two of them were located in an area where the natural vegetation had been undisturbed and was typical of the region. The other two micro-basins were located in an area that had been previously cleared and used for cultivation. These two were cleared bare of any remaining vegetal cover to serve as reference conditions for erosion and runoff. During the operation of these basins, they were periodically cleared of any resurgent surface vegetation, thus, maintaining the bare soil surface during the entire period of operation.

All the micro-basins were equipped with sediment and runoff collectors of 2300 l capacity terminating with a 90^0 triangular weir designed to handle the maximum expected discharge of 270 l/s. Water level recorders were used to register the level of water in the collectors and the head over the weir. Sediments passing with the flow over the weir were sampled by means of a siphon mechanism at three points located at intervals of 10 cm starting from the crest level of the weir. The siphoned sediment water mixture was collected in closed auxiliary cans and the sediment concentration of the outflow of the weir was determined by sampling the accumulated mixture. The amount of sediment retained in the collectors was determined by sampling during several stages of the depletion and clearance of the collectors at the end of each event.

The plots were 22.1 m long and 4.5 m wide and had among them a variety of surface covers and slopes ranging from 3.8 to 9.3%. The runoff and the eroded sediments were directed into a 1000 l ($1m^3$) capacity asbestos cement collection tank with a calibrated bucket inside to collect the small flows. For large runoff when the tank might get full, the overflow was led into a second 1000 l capacity tank that would accumulate only a ninth fraction of the outflow from the first and the remainder was spilled over. Thus for any event, the total runoff was obtained by adding to the full capacity of the first tank, nine times the volume collected in the second. All the tanks were pre-calibrated. In addition to the fixed installations, a weather station and several recording and non recording rain gauges were also installed.

In the case of the Experimental Basin of São João de Cariri(EBSJC), the field installations had not only the same characteristics but also the additional benefit of having a full scale meteorological station that was existent before the installations of the erosion plots. Table 1 provides the characteristics of the four micro-basins and the nine 100 m^2 erosion plots of Sumé as well as the two erosion plots and three micro-basins of São João de Cariri. Further details about the field installations are available elsewhere (Srinivasan & Galvão, 2003).

Table - 1 The Experimental units installed in Sumé and São João de Cariri

Description	**Location**	**Area in m^2**	**Slope in %**	**Surface condition**
Micro-basin 1	Sumé Exp Basin	6,200	7.0	Natural Vegetation
Micro-basin 2	Sumé Exp Basin	10,700	6.1	Natural Vegetation
Micro-basin 3	Sumé Exp Basin	5,200	7.1	Cleared bare
Micro-basin 4	Sumé Exp Basin	4,800	6.8	Cleared bare
Erosion Plot 1	Sumé Exp Basin	100	3.8	Cleared bare
Erosion Plot 2	Sumé Exp Basin	100	3.9	Mulching
Erosion Plot 3	Sumé Exp Basin	100	7.2	Mulching
Erosion Plot 4	Sumé Exp Basin	100	7.0	Cleared bare
Erosion Plot 5	Sumé Exp Basin	100	9.3	Natural Vegetation
Erosion Plot 6	Sumé Exp Basin	100	4.0	Cactus down slope
Erosion Plot 7	Sumé Exp Basin	100	4.0	Cactus on contour
Erosion Plot 8	Sumé Exp Basin	100	4.0	Bare and tilled
Erosion Plot 9	Sumé Exp Basin	100	4.0	Nat. veg. re-grown
Micro-basin 5	S J Cariri Basin	1,800	7.5	Generally bare
Micro-basin 6	S J Cariri Basin	1,600	6.9	Generally bare
Micro-basin 7	S J Cariri Basin	16,300	7.1	Generally bare
Erosion Plot 10	S J Cariri Basin	100	3.4	Cleared bare
Erosion Plot 11	S J Cariri Basin	100	3.6	Cleared bare

COLLECTION OF DATA

The main interest was the volume of the total runoff and the total weight of the sediments, carried off at the outlet, from the micro-basins and the erosion plots, for each of the rainfall events. Except for the 1 m^2 plots, all the data collected were for natural precipitation events only. The runoff from the 100 m^2 plots was obtained by the volume held in the calibrated bucket in the first tank if the bucket didn't spill over, especially, for low outflows. When the bucket overflowed but the first tank didn't, the volume was obtained by adding the capacity of the bucket and the volume spilled into the tank. For the case in which the first tank overflowed, the total volume was obtained by adding nine times the volume held in the second tank to the capacity of the first as mentioned in the previous section.

In the case of the micro-basins, the total outflow was determined by the volume retained in the collector tank when there was no flow over the weir. For the events in which there was discharge over the weir, the total volume of runoff was obtained by adding the collector tank volume to the outflow-hydrograph volume. The hydrographs were generated from the water level recorder charts for the events and the volume was obtained by planimetering the areas of these hydrographs.

The quantity of sediments produced in each event was determined indirectly by sampling the sediment-water mixture and determining the concentration by weight for each of the representative volumes associated with the sample collected. For the erosion plots of 100 m^2, samples of the sediment-water mixture were collected form the inner bucket of the first tank, the volume retained in the first tank and the volume that overflowed to the second, if this occurred in any event. For micro-basins, the sediment yield was obtained by adding the amount of sediments retained in the collector (obtained by means of taking various samples of the mixture) to the quantity of sediments carried over the weir in suspension. The mean concentration of the sediments in the flow passing through the weir was obtained by sampling the accumulated mixture siphoned into the auxiliary cans. Whenever possible, additional samples were collected directly from the outflow of the weirs in order to obtain a better estimation of the average concentration of the sediments in the spill. In general, the same surface conditions were maintained in the plots 1and 4 as that of the micro-basins 3 and 4.

Since the beginning of the collection of data in 1982, more than 300 events of natural precipitation that produced runoff in at least one of the units of the experimental basins have been registered in the Sumé basin. However, the number of events with very low runoff and erosion rates is far more numerous than that of events with medium to large rates. This bulk of the data obtained from erosion plots has been utilised to evaluate the influence of factors like the surface vegetal cover, slope and cultivation practices. The data from the micro-basins of Sumé and São João de Cariri have been utilized mainly for runoff – erosion modelling with WESP and KINEROS2, for both calibration and validation of the model parameters.

DESCRIPTION OF THE MODELS

Both of the models, KINEROS2 and WESP are similar in their concept and utilize a discrete form of the basin made up of planes and channels. The rainfall excess generated and the eroded sediment are routed sequentially through the planes and channels to the basin exit. While the former uses the Smith & Parlange Equation(Woolhiser et al., 1990) for determining the time variant infiltration rate, the latter uses the Green & Ampt Equation(Lopes,1987). The local erosion rate in both the models is associated with the principal physical agents responsible for the erosion. Thus, on the planes, the local erosion is related to the effect of the impact of the rainfall drops that would loosen the surface soil and cause splash erosion on the one hand and to the shear stress of the surface flow caused by the precipitation excess. The net sediment transport is determined from a mass balance after allowing for the flux of sediment entering the section and the local deposition and/or erosion rates. In the channel elements, effect of the raindrop impact is considered to be negligible and only the erosion due to flow shear stress on the erodible bed is considered. Mass balance equation is utilized to determine the net efflux of the sediment from a given section. Thus, the net erosion rate from the basin or the contributing element is the sediment efflux obtained at the outlet at which a hydrograph and a sedimentgraph can be generated. The total volume of runoff generated and the mass of sediment eroded by each event of precipitation are obtained from a numerical integration of these graphs. Given below are the principal equations utilized in the two models in order to identify the parameters that affect significantly the runoff volume and the net sediment production, whose variability with the scale is also discussed in this study.

The KINEROS2 model

The infiltration rate f_c (m/s) is calculated in the model utilizing the equation proposed by Smith & Parlange(Woolhiser et al.,1990):

$$f_c = K_s\left[1 + \frac{\alpha}{e^{\alpha I/B} - 1}\right] \tag{1}$$

in which, K_s is the saturated hydraulic conductivity of the soil, α is a soil type parameter varying from 0 to 1, t is the elapsed time(s) and $B = (G + h)(\theta_s - \theta_i)$, a factor representing the combined effect of the Capillary Potential G (m), the depth of flow h (m) and the moisture storage capacity of the soil, $(\theta_s - \theta_i)$, in which, θ_s is the saturation volumetric water content (m^3/m^3) and θ_i is the initial water content of the soil.The model takes into account the effect of recovery of the infiltration capacity of the soil in intervals without rainfall or without runoff during an event. Additional details about the soil moisture redistribution and the calculation of the infiltration capacity have been presented by Smith et al (1993). The descriptions of the surface flow on planes and concentrated flow in channels in the model are based on the equations of Saint-Vennant for one-dimensional flow. The numerical solutions of these are based on the kinematic wave approximations.

Erosion in planes and channels

The general equation that describes the sediment flux in planes and channels is the mass balance equation(Bennett, 1974):

$$\frac{\partial(AC_s)}{\partial t} + \frac{\partial(QC_s)}{\partial x} - e(x,t) = q_s(x,t) \tag{2}$$

in which, C_s is volumetric concentration of the sediment in the flow(m^3/m^3), Q is the discharge (m^3/s), A is the cross sectional area of the flow (m^2), e is the volumetric soil erosion rate per unit width (m^2/s) and q_s is the lateral influx of the sediments per unit length of the channel (m^3/s/m). On the planes, the erosion rate (e) is considered to be made up of two components: the erosion resulting from the raindrop impact (e_s), and the erosion or deposition resulting from the effects of the flow shear stress and gravity (e_h) as indicated by Eq.(3).

$$e = e_s + e_h \tag{3}$$

The erosion due to raindrop impact is given by:

$$e_s = c_f e^{-c_h h} i^2 \tag{4}$$

in which i is the intensity of rainfall (m/s), c_f is a coefficient to be determined by calibration, that is related to the properties of the surface soil and $e^{-c_h h}$ is the factor that represents the effect of the surface flow in reducing the impact. The parameter c_h is fixed in the model as being equal to 656. The erosion due to shear is expressed as:

$$e_h = c_g \left(C_m - C_s\right) A \tag{5}$$

in which, C_m is the maximum concentration at the equilibrium capacity of transport, C_s is $C_s(x,t)$ the actual concentration of sediments in the flow dependent on position and time, and c_g is a sediment transfer coefficient (s^{-1}), obtained from the relation:

$$c_g = c_o \frac{v_S}{h} \text{ if } C_s \le C_m \text{ (erosion) or } c_g = \frac{v_S}{h} \text{, if } C_s > C_m \text{ (deposition)} \tag{6}$$

where, c_o is a coefficient that reflects the soil cohesion and v_s is the fall velocity (m/s).

The model utilizes the Engelund and Hansen(1967) equation for calculating the transport capacity of the flow with the inclusion of a critical value of the unit stream power $\Omega = uS$ equal to 0.004 m/s, where, u is the velocity of flow and S is the energy slope. The simulation of erosion and transport in the channel elements is carried out the same way as on the planes excepting that the effect of raindrop impact on erosion is ignored and the lateral influx of the sediments from planes q_s turns out to be very significant.

The model WESP

The infiltration rate f_c (m/s) is calculated in WESP utilizing the Green and Ampt Equation, that may be expressed as (Lopes, 1987):

$$f_c = K_s \left[1 + \frac{N_s}{I}\right] \tag{7}$$

in which, K_s is the saturated hydraulic conductivity of the soil (m/s), I is the cumulative infiltration (m) and N_s is the Capillary Potential (m) of the soil. This can be expressed as:

$$N_s = \left(\theta_s - \theta_i\right) G \tag{8}$$

in which G is the effective capillary potential at the wetting front and the other terms are as defined earlier. The time for ponding or the beginning of runoff is determined for the unsteady rain and the precipitation excess is routed along the planes and channels to the exit. The flow on plane elements and in channels is described in this model by the same equations as in KINEROS2.

Erosion in planes and channels

The sediment flux in both the plane and channel elements is determined by the mass continuity equation as in the case of KINEROS2. However, the erosion rates are calculated utilizing relatively simpler relationships and the processes of erosion and deposition are considered to be simultaneously possible. The erosion due to raindrop impact is given by:

$$e_s = K_i i r_e \qquad (9)$$

in which, K_i is a parameter representing the susceptibility of the soil for raindrop erosion by impact (kg.s/m^4); i is variable rainfall intensity (m/s), and r_e (m/s) is the rainfall excess that can vary with space and time.

The erosion due to shear on the planes is expressed as:

$$e_h = K_r \tau^{1,5} \qquad (10)$$

in which, K_r is a soil erodibility parameter due to flow shear (kg.m/N^{1,5}s) and τ is the effective shear stress on the soil surface varying with time and space with flow depth (N/m^2).

The deposition rate is considered to be proportional to the mean concentration of the sediments in the flow (Lopes. 1987) and is given by the expression:

$$d = \varepsilon_p v_s C_s \qquad (11)$$

in which, ε_p is a non dimensional coefficient that depends on the soil and fluid properties, v_s is the fall velocity of the sediment particles (m/s) and C_s is the mean concentration of the sediments in transport at the section, being a function of time and space (kg/m^3).

The erosion rate in the channels (e_h), is based on the excess of shear stress (τ) over the critical value (τ_c) for the bed sediments and is given by the equation:

$$e_h = a(\tau - \tau_c)^{1,5}\text{, for } \tau \geq \tau_c \qquad \text{and, } e_h = 0\text{, for } \tau \leq \tau_c \qquad (12)$$

in which a is a parameter of erodibility for channels(kg.m^2/N^{1,5}.s). The critical shear stress τ_c (N/m^2), is given by the relation:

$$\tau_c = \delta(\gamma_s - \gamma)D \qquad (13)$$

in which, δ is a non-dimensional coefficient of critical shear stress, γ_s and γ are specific weights of the sediments and water respectively (N/ m^3), and D is the sediment size (m).

The deposition rate of the sediments in channels is expressed by:

$$d = \varepsilon_c T_W v_s C_s \qquad (14)$$

in which, ε_c is a coefficient of deposition for channel flow (non-dimensional); T_W is the top width of the flow section (m) and the other terms are as defined earlier.

CALIBRATION OF THE MODEL PARAMETERS

The two models described earlier were utilized to simulate the runoff and erosion processes based on the runoff and erosion data from the Experimental Basins of Sumé and São João de Cariri. Parameters that could not be directly measured, adopted as recommended values or otherwise estimated were calibrated. The calibrated values were validated in the same unit utilizing part of the data not utilized for calibration

Parameters of the KINEROS2 model

Based on the soil type prevalent in the Representative Basin of Sumé,the soil type parameter α the capillary potential *G* and the porosity were fixed at 0.85, 260 mm and 0.398, respectively. In the case of EBSJC, the capillary potential *G* was fixed at 330 mm and the other parameters were kept the same. The soil cohesion parameter c_0 in Eq. (6), was found to be not very sensitive and was fixed at 0.01for both planes and channels in EBS, while in EBSJC it was optimized as 0.01 for planes and 0.0001 for channels. The remaining parameters that were pre-chosen, either by measurement or according to the field conditions, were the soil particle diameter, Manning´s roughness coefficient for planes and channels as well as the saturated hydraulic conductivity of the soil. These values are shown in Table 2 for the micro-basins (Mb) and erosion plots (EP) that were almost bare in the two experimental basins, listed in Table 1.

Table2. Basic pre-fixed parameters of the erosion plots(EP) and micro-basins(Mb)

Exp. Unit.	EP 1	EP 4	Mb 3	Mb 4	EP 10	EP 11	Mb 5	Mb 6	Mb 7
D_{50} (mm)	0.85	0.89	0.50	0.50	0.40	0.38	0.46	0.48	0.49
Manning´s n	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.03	0.03
K_s (mm /h)	3.5	3.5	3.5	3.5	4.0	4.0.	4.0	4.0	4.0

The initial soil moisture not only affects the runoff, but also, varies from event to event depending on the antecedent conditions. The erosion parameter c_f also depends on the initial soil condition and hence, both of these parameters had to be obtained by an event by event calibration of the data from the erosion plots and the micro-basins. All the micro-basins were transformed into a set of discrete plane and channel elements. The representative soil size was taken to be 0.50 mm for all of them, while the saturated hydraulic conductivity was fixed at 3.5 mm/h for EBS units and 4.0 mm/h for EBSJC units respectively. The Manning roughness factor was fixed at 0.03 for all the channel elements and 0.02 for the plane elements. Thus, it was possible to calibrate most of the events registered in the Experimental Basins and the mean values of the parameters could be established for each of the plots and micro-basins with almost bare soil. The mean values of the parameters thus obtained are shown in Table 3.

Table 3. Summary of the results of calibration for the erosion plots and micro-basins

Plot / Micro-basin	EP1	EP 4	Mb 3	Mb 4	EP10	EP 11	Mb 5	Mb 6	Mb 7
Total number of events	215	189	105	97	179	179	160	116	116
Mean value of S_i	0.76	0.75	0.76	0.68	0.75	0,76	0.52	0.53	0.61
Variation of c_f	10^5 to 10^8	10^5 to 10^8.	10^6 to 10^{11}	10^5 to 10^8	10^6 to 10^{10}	10^6 to 10^{10}	10^6 to 10^{10}	10^6 to 10^9	10^6 to 10^{10}
Mean value of N_s	13.41	11.35	29.46	25.89	38.48	27.31	41.49	35.28	25.18
Mean value of K_r	1.631	1.943	1.786	1.786	0.887	0.648	0.768	0.768	0.768
Mean value of *a*	------	------	0.022	0.022	------	------	0.021	0.016	0.010

.Parameters of the WESP model

The calibration and validation of the WESP model utilizing the data from the Experimental Basin of Sumé (Srinivasan and Galvão, 2003)have been carried out on several occasions and the results have been available elsewhere (Srinivasan and Galvão, 1995, Srinivasan et al.,2003, Santos et al 1999), and hence, those results will be considered in the discussions. However, the application of WESP for the erosion plots and micro-basins of the São João de Cariri Experimental Basin (EBSJC) has been carried out and included in the present study.

In the application of WESP, the parameters that have been subject to calibration are N_s , K_r and a of Equations 8, 10 and 12 respectively. The first one influences the infiltration rate and hence the runoff, the second one the erosion on planes and the last one, the erosion in channels. N_s depends on the initial saturation of the soil and hence must be calibrated for each event. The splash erosion parameter K_i in Eq. (9) was found to be insensitive and its value was pre-fixed for all the units. The soil erodibility parameter K_r was calibrated in the erosion plots and the parameter a was calibrated in the micro-basins. The mean values of the calibrated parameters are shown in Table 3. Since the parameter a is utilized only with the channel elements of WESP, its value would be inexistent for the erosion plots as seen in Table 3.

RESULTS AND DISCUSSION

The calibrated models were validated in the same erosion plot or micro-basin for which the parameters were calibrated, especially, in the units of EBSJC. In the case of EBS, the parameters calibrated in Micro-basin 4 (Mb 4) were utilized in Mb 3 including the event by event initial saturation of the soil for 24 significant events. A comparison between the simulated and observed runoff as well as the simulated and observed erosion values, with the model WESP, are shown in Figs.1 and 2. This being a cross validation of the parameters, the results are very encouraging.

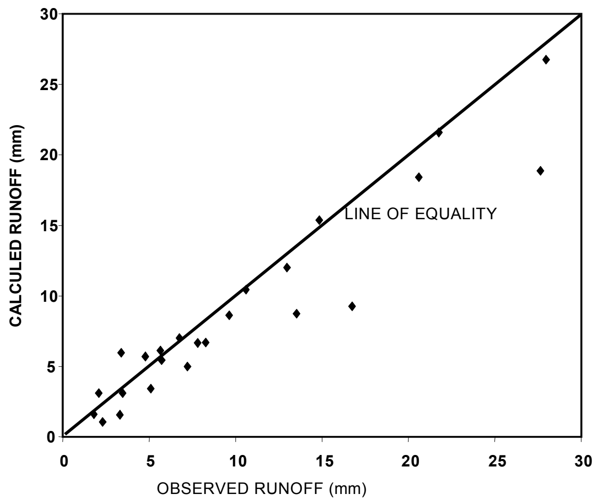

Fig. 1. Comparison of Simulated and Observed Runoff in Mb 3

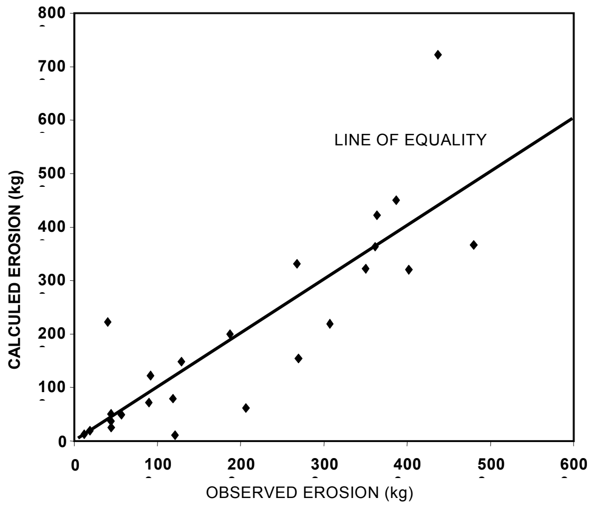

Fig. 2. Comparison of Simulated and Observed Erosion in Mb 3

With the exception of 3 events, the calculated runoff agrees quite well with the observed ones. In the case of erosion, the dispersion is large compared with runoff. However, it may be noted that the dispersion is quite uniform around the line of equality and the precision of the observed values of erosion is much lower than that of runoff. The former is estimated by the sampling of sediment concentrations and the latter is almost directly measured. Under these conditions, the simulations may be considered to be more than satisfactory.

In the case of the plots and micro-basins of the EBSJC, the calibrated parameters of WESP were validated by simulating the events not used in the calibration process as well as by simulating the entire set of events with the average value of the erosion parameters. When the entire set was simulated, the performance was evaluated by the coefficient of determination R^2 between the simulated erosion values and the observed series of erosion, event by event. In all cases, the value of R^2 exceeded 0.90 thus indicating a very satisfactory simulation of erosion the erosion values. In the case of the 3 micro-basins of EBSJC, the values of R^2 obtained for Mb 5, Mb 6 and MB 7 were, 0.98, 0.99, and 0.96 respectively, while for the two erosion plots EP 10 and EP 11, the corresponding values were 0.996 and 0.995.The results were very much similar with the model KINEROS2. The values of R^2 in the case of the erosion plots EP 10 and EP 11 were both 0.99 and for the micro-basins Mb 5, Mb 6 and Mb 7, the R^2 values were 0.94, 0.91 and 0.90 respectively. Thus, both WESP and KINEROS2 resulted in highly satisfactory simulations of the erosion values in the experimental units of both BES and BESJC.

Noting that the initial soil saturation S_i of the KINEROS model and N_s of the WESP that contains the initial soil saturation, it is necessary either to calibrate or determine this value by field measurements in order to simulate adequately the runoff. The total sediment yield from a precipitation event depends on the true runoff hydrograph generated and hence, admitting the initial saturation at an average value would lead to large errors and distortions. Thus, for the purposes of the comparative evaluation of the models, only the erosion parameters, namely, c_f and c_o of the KINEROS2 model and K_i, K_r and a of the WESP model were maintained at their average value in the validation process in order to compare the simulated and observed sediment production in the experimental unit. The validation was effected by simulating the events not used in the calibration process as well as by simulating the entire set of events with the average value of the erosion parameters. The results showed that in both the cases the two models were highly satisfactory.

The variation of the parameters S_i and c_f in the erosion plots and micro-basins is presented in Table 3 . The former has a basic role in runoff generation, as it affects the infiltration rate, while the latter determines the impact erosion rate. KINEROS2 model features a process of soil moisture redistribution during intervals of no rainfall and thus seems capable of a rapid recovery of the infiltration capacity. In the case of WESP, there is no such provision for recovery unless every cessation of rainfall is considered as the end of an event. As a result, KINEROS tends to under estimate the runoff volumes in simulations. The model WESP, however, tended to generate recession flows over much longer periods when compared with KINEROS2 model. In terms of sediment production, the model WESP tended to simulate values higher than those of KINEROS2, in spite of the fact the former has 3 erosion parameters subject to calibration or adjustment. The most likely explanation for this feature is that WESP does not use the condition of a maximum transport capacity of the flow to limit erosion by shear. In KINEROS2 the erosion at any time occurs only if the maximum transport capacity of the flow has not yet been reached.

The effect of scale was seen on the parameters of both the models in spite of both of them being process based models. The capillary potential G of the KINEROS2 model was fixed at 260 mm for the erosion plots and micro-basins of Sumé based on the type of soil, for the Experimental Units of São João de Cariri, this value had to be increased to 330 mm, even though there is not any great difference between the two soil types. The difference may however, be due to the varied land use in the two basins. In the case of WESP, the parameter N_s includes the variation of the initial soil moisture and possible variation of G with it and hence varies from event to event in any case. However, the variation of the initial soil moisture is the main factor determining the runoff generation in both the models.

The parameter that showed the clearest sign of the scale effect was the splash erosion parameter c_f . It showed a consistent trend of variation with the surface cover in the case of erosion plots and micro-basins. Even though, the parameter presented a range of variation for each scale, this range of variation in itself could be used to relate the mean value to the basin scale. While it varied from 10^5 to 10^{10} in the erosion plots, it varied from 10^6 to 10^{11} in the micro-basins. This seems to point towards a possible scale effect on the parameter c_f, the confirmation of which can only come from a wider application of the model in different sized basins. In the case of the parameter K_i of the WESP model, the insensitivity of this parameter that led to the fixing of it at a single value, precludes any speculation about the scale effect on this.

The studies indicate that the runoff and-erosion processes even in small experimental basins are quite complex. The varying conditions of the soil in the region affect significantly the runoff and erosion rates from event to event. However, the large protective influence of the native vegetation against surface erosion is note worthy and any indiscriminate clearance of land for agricultural purposes may eventually lead to a total loss of surface soil and nutrients resulting in an unproductive land. The land slope affects the erosion rate much more than the runoff and the popular method of planting down the slope instead of on contoured terraces results in very high runoff and erosion.

CONCLUSIONS

It was found that both kineros2 and wesp models are capable of simulating runoff and erosion for individual events of precipitation quite well for the data collected in erosion plots and micro-basins. The effect of infiltration recovery during breaks in a rainfall event built into kineros2 tends to reduce the runoff compared with wesp. The capillary potential parameter of wesp and kineros were different in the two basins ebs and ebsjc, it was not possible to relate it definitively to the small differences in the soils and hence, was considered to be mainly due to the differences in land use. The parameter that showed a trend of the scale effect was the splash erosion parameter c_f of kineros2 but a similar effect could not be seen with the insensitive parameter k_i of wesp. In comparative terms**,** the process based model WESP utilised for simulation of runoff and erosion, provided results with lesser dispersion in the simulated erosion values and appears to be a potentially useful tool for estimating runoff and erosion from basins of similar characteristics in the semiarid region of Brazil. While KINEROS2 limits the erosion to the capacity of transport by the flow, WESP considers erosion and deposition as simultaneous phenomena and the two processes are independent. This explains the closer agreement of WESP with the observed erosions than those simulated by KINEROS2. This phenomenon needs to be further verified in other areas.

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