Print

Proceedings

Modelling the Effects of Internal Rainfall Structure on Soil Erosion.

V.M. Castillo[1], V. Alvarez[1], M. Martínez-Mena[1], P. Strauss[2] and J. Albaladejo[1]
[1] *Department of Soil and Water Conservation. CEBAS-CSIC. Murcia (Spain).*
[2] *Institute for Land and Water Management. Federal Agency for Water Management. Austria*
email: victor@cebas.csic.es

Abstract

In semiarid environments most of erosion in a year occurs in a small number of events. These events are characterized by short and intense rain showers whose temporal pattern affects the runoff response and soil erosion. Event based soil erosion models such as EUROSEM and KINEROS attempt to assess soil erosion risk by simulating these dominant events. Simulation results are highly dependent on rain intensities pattern.

We studied the effect of temporal pattern of rain intensities within an event on soil erosion in a semiarid Mediterranean by using the data collected on two experimental plots (15 m x 5 m) since 1988 until 2004, and by a modelling approach. First, the influence of rain characteristics (depth, maximum intensities at different time intervals, length of dry period within the storms and time location of peak intensity) on runoff and soil losses has been tested for both natural and disturbed plot. Results revealed that the tested parameters have different influence depending on the plot analysed.

EUROSEM model was used to simulate the effects of internal rainfall structure. The model was run under two different rain input series: the measured series and a synthetic rainfall events series, generated by the RAINGEN system, which maintain the statistical properties of recorded series.

Résumé

Dans les environnements semiarides la plupart d'érosion se produit d'ici un an dans un petit nombre d'événements. Ces événements sont caractérisés par les douches de pluie courtes et intenses dont le affecte la réponse de ruissellement et l'érosion de sol. Les modèles d'érosion a échelle d'événement de sol comme EUROSEM et KINEROS essaient d'évaluer le risque d'érosion de sol en simulant ces événements dominants. Les résultats de simulation dépendent hautement du modèle temporel d'intensités de pluie.

Nous avons étudié l'effet de dessin temporel d'intensités de pluie dans un événement sur l'érosion de sol dans une Méditerranée semiaride en utilisant les données recueillies sur deux parcelles expérimentales (15 m x 5 m) depuis 1988 jusqu'en 2004 et par modélisation. D'abord, l'influence de caractéristiques de pluie (la profondeur, les intensités maximums à de différents intervalles de temps, la longueur de période sèche dans les tempêtes et l'endroit de temps d'intensité maximale) sur la érosion du sol et le ruissellement a été examiné pour la parcelle avec végétation et la parcelle dégradée. Les résultats ont révélé que les paramètres évalués ont la différente influence selon la couverture végétale.

Le modèle EUROSEM a été utilisé pour simuler les effets de structure interne de précipitations. Le modèle a été dirigé sous deux différente série de pluie : la série

Print

Proceedings

mesurée et des séries de précipitations produit par le système de RAINGEN, ce qui maintiennent les propriétés statistiques des séries enregistrées

Introduction

In semiarid environments most of erosion in a year occurs in a small number of events. These events are characterized by short and intense rain showers whose temporal pattern affects the runoff response and soil erosion. Event based soil erosion models such as EUROSEM and KINEROS attempt to assess soil erosion risk by simulating these dominant events. Rainfall data of high temporal resolution are necessary to use the model. On the other hand, simulation results are highly dependent on the rainfall intensity pattern. Such type of data is generally available to potential users limiting the use of event based models for assessing long-term erosion risks.

As a first approach, the influence of basic rainfall information on soil losses was evaluated. If the influence of selected basic rainfall parameters was sufficiently high, a set of rainfall input data could be chosen according to the distribution function of these rainfall characteristics at a specific location (Strauss et al., 1999). Storm design models are able to generate synthetic rainfall series that reproduce statistitical properties of recorded rainfall and provide a input data set for event-based soil erosion models.

Study area and data set

We have studied the effects of internal rainfall structure on soil erosion in Santomera Field Site that has been established and run by CEBAS since November 1988. The Field Site consists of two experimental plots 5m-wide by 15-m long with a collector system at the lower end to record runoff and soil loss. A data logger stored stage recorder and rainfall data at 1-min intervals during storm. Soil losses are estimated from sediment concentration measured in five manual samples multiplied by runoff. At the beginning of the period of study plant cover was removed from one of the plots (plot D) while the natural plant cover was maintained in plot N.

341 runoff-generating events were selected from the daily rainfall data set to study the relationship between rainfall and runoff, of which 70 also produced sediments and were used to analysis effects of rainfall characteristics on soil erosion. In order to test the proposed storm design model, we chose the events which produced most of the losses of the soil (90%) during 15-year period of records. Events were separated by 6 hours of less than 1.5 mm precipitation amount and were truncated at 95% of their final energy to avoid long tails of low intensities.

Results

Effects of rainfall characteristics on runoff and soil erosion

The basic characteristics selected to represent the effects of rainfall on runoff and soil erosion were: (i) event duration; (ii) rainfall depth; (iii) maximum rain intensity at 5 min.; (iv) maximum rain intensity at 10 min; (v) maximum rain intensity at 30 min; (vi) precipitation amount fallen before the 10-min maximum rainfall intensity peak; (vii) location of maximum rainfall depth; (vii) location of maximum rainfall intensity peak;

(viii) average duration of dry periods within the storm; and (ix) maximum duration of dry periods within the storm.

The Spearman correlation coefficient was used to test the influence of rainfall characteristics on runoff and erosive response (Tables 1 and 2).

Table 1 Spearman’s rank correlation between precipitation variables and runoff and erosive response in plot D. (Only variables with significant relationship are showed. **Bold** significant $p<0.05$; Rest significant $p<0.10$)

	Duration	Rainfall depth	30-min maximum intensity	10-min maximum intensity	5-min maximum intensity	Rainfall before rain intensity peak	Average duration of dry periods
Runoff coefficient (%)	**-0.34**		**0.41**	**0.44**	**0.47**		
Runoff (mm)		**0.38**	**0.62**	**0.60**	**0.63**	**0.40**	**-0.36**
Sediment (g m^{-2})	-0.23	0.25	**0.46**	**0.49**	**0.52**	**0.35**	**-0.31**
Sediment concentration (gl^{-1})	**-0.28**		**0.42**	**0.46**	**0.49**	**0.33**	**-0.27**

Table 2 Spearman’s rank correlation between precipitation variables and runoff and erosive response in plot N. (Only variables with significant relationship are showed. **Bold** significant $p<0.05$; Rest significant $p<0.10$)

	Duration	Rainfall depth	30-min maximum intensity	10-min maximum intensity	5-min maximum intensity	Rainfall before rain intensity peak	Average duration of dry periods
Runoff coefficient (%)				**0.27**	**0.29**		
Runoff (mm)		**0.52**	**0.42**	**0.40**	**0.42**	**0.40**	-0.23
Sediment (g m^{-2})			**0.41**	**0.44**	**0.47**	**0.31**	**-0.29**
Sediment concentration (gl^{-1})	**-0.27**		**0.40**	**0.45**	**0.47**	**0.30**	**-0.29**

Generation of synthetic rainfall

Raingen 1.0 (Strauss et al., 2001) generates internal rainfall structure (rainfall intensities) of independent single rainstorm events. The basic concept of generating internal rainfall structure is relying on a simple scaling model. proposed by Koutsoyiannis and Foufoula-Georgiou (1993). Based on the observation that two different ranges of scaling between event amount and event duration existed for a set of investigated rainfall stations, this concept has been extended into a .two step simple scaling model.. The scaling model has been coupled with a Mixed Exponential distribution to generate event amounts and a Weibull distribution to generate event duration so that it is now possible to generate any desired number of rainfall events.

The results obtained are shown in Table 3. A Kolmogorov-Smirnov test was used to prove the goodness of fit. The null hypothesis that the two samples of data are identically distributed could not be rejected.

Table 3 Statistics of observed and simulated rainfall characteristics

Variable		Standard deviation	Maximum	Minimum	25-percentil	50-percentil	75-percentil
Rainfall depth (mm)	observed	27.7	117.8	6	10.1	22	38
	simulated	7.1	38.4	15.3	17.3	20.1	24.4
Duration (min)	observed	347	1034	13	108	358	751
	simulated	237	834	6	49	121	285
5-min maximum intensity (mm h^{-1})	observed	35.9	129.6	4.8	14.4	40.8	80.4
	simulated	70.1	236.5	13.4	22.1	57.1	138
10-min maximum intensity (mm h^{-1})	observed	28.3	92.4	4.8	12.6	30.6	61.8
	simulated	42.5	145.3	10.6	20.23	46.3	93
30-min maximum intensity (mm h^{-1})	observed	13.5	44.8	3.2	8.3	19.6	32.5
	simulated	17.6	62.6	10.4	14.4	28.8	47

Conclusions

The main rainfall characteristic controlling runoff and erosive response in semiarid environments is rain intensity. Differences in the role played by rainfall depth and duration have been found depending on plant cover. In vegetated plot rainfall depth controls runoff response but not erosive. On the contrary, either rainfall depth or duration have an influence on soil erosion in bare plot.

The use of a storm design model, RAINGEN, has allowed us to generate a synthetic rainfall series which follow the same distribution than the original records. These data can be used a input series to simulate soil erosion losses with a event-based model

Acknowledgement.
Financial support from Spanish National Plan for Research and Development (CGL2004-04949-CO2-01/HID) and Spanish Ministry for Environment (Programa RESEL)

References

Koutsoyiannis. D and E. Foufoula-Georgiou 1993 A scaling model of a storm hyetograph. *Water Res.Res.* 29 2345-2361.

Strauss, P., Konecny F. and W.F.H. Blumm 1999 Rainfall input generation for the Europena Erosion Model. *Hydrology and Earth System Sciences* 3(2) 213-222.

Strauss, P., Konecny F. and S. Zach 2001 *RAINGEN 1.0 A system for generating internal rainfall structure of rainfall events.* Institute for Land and Water Management. Federal Agency for Water Management. Petzenkirchen. Austria.