Chapter 6

EFFECT OF CONTINUOUS AND DISCONTINUOUS STORM

6.1 Introduction

As indicated previously, effective rainfall duration (D, minute), which is one of four parameters that describe rainfall characteristics in CLIGEN data, is calculated by discarding no-rain periods within storm duration and only rainfall periods within storm duration are aggregated into a "gapless" rainfall storm. By removing no-rain periods, actual rainfall duration is reduced so that average intensity of rainfall storm is increased. Consequently, the removal of no-rain periods, which is termed as Within-Storm Gaps (WSGs) for this research, may have effects on erosion modelling.

Therefore, this chapter examines the effect of the removal of WSGs on runoff and soil loss estimations. Continuous (without WSGs) and discontinuous (with WSGs) storms are distinguished by the existence of WSGs within the storm duration. Three process-based models—WEPP, EUROSEM and an additional model, RillGrow—were used in this chapter. Runoff and soil loss rate were estimated by these models and the outputs were examined in terms of their relationships to WSGs.

WEPP and EUROSEM have shown contrasting results in the previous chapter. Thus, RillGrow was exerted here with an intention to strengthen the model estimation results by increasing the number of model predictions. Although the outputs from three erosion models may still give three very different results—this actually was the case—employing all three models may also give a stronger argument that the removal of WSGs does (or does not) have an impact on runoff and soil loss simulations. The main aim of this investigation is to find out whether WSGs influence runoff and soil loss generations. The more important question is, however, how WSGs influence runoff and soil erosion. This is more difficult to answer even when a single erosion model is used.

6.2 Simulation Data and Methods

Event rainfall recorded on 11 October 2000 at Southover station (S) (see Table 3.2) was selected because this event was a distinctive storm with a large amount of rainfall. The event also includes a number of WSGs in the total storm duration. The total rainfall amount of the storm is 89.9 mm. This event is considered to be responsible for the severe flood incidents in the study region (Boardman, 2001).

Only breakpoint data type, which retains WSGs, was used in this chapter because CLIGEN data remove WSGs by its design specification. Also, temporal scale of 15-min was used as discussed in the previous chapter, Chapter 5. Hyetographs of the original rainfall event and the modified rainfall event, in which WSGs are removed, are shown in Figure 6.1. The rainfall intensities for each 15-min interval were maintained the same (Figure 6.1). Total duration of the data with WSGs was 1230 minutes and 885 minutes without WSGs.

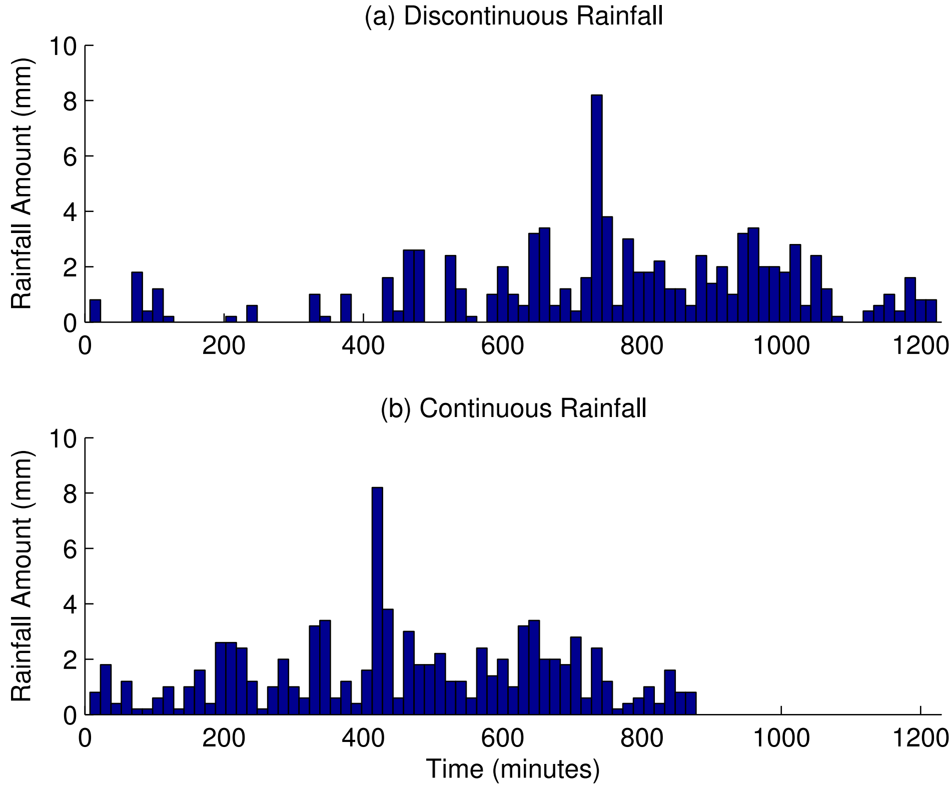
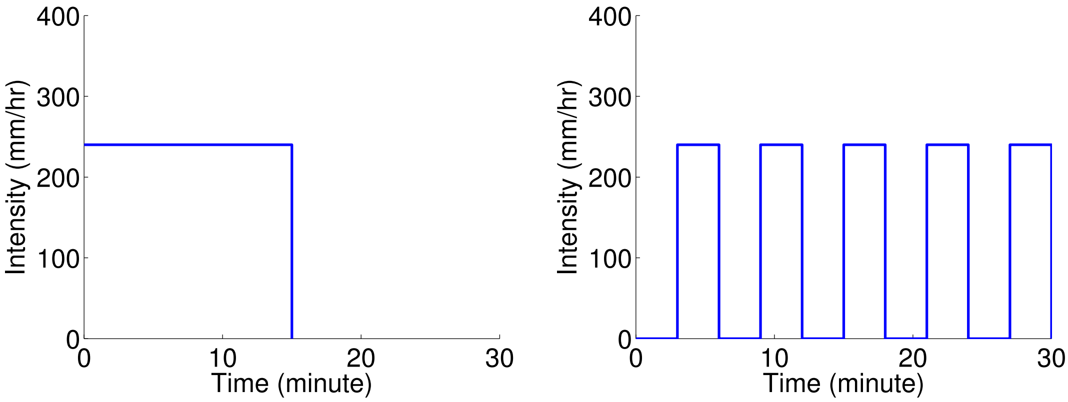


Figure 6.1 15-min rainfall data used for the investigations of effects of continuous and discontinuous rainfall on soil erosion. (a) original 11 October 2000 event ;(b) modified 11 October 2000 event after removing WSGs

Then, WEPP and EUROSEM were used to simulate runoff and soil loss using these breakpoint data.

A separate set of continuous and discontinuous rainfall data were prepared for RillGrow simulations. Because RillGrow simulates runoff and soil loss in great detail temporally and spatially, a rainfall event with a relatively short duration—to reduce computational time—and a number of high intensity peaks with a constant intensity were intentionally prepared (Figure 6.2). For this designed storm, constant intensity was used because it made the shape of the storm simple. Also, it minimises any unforeseen modelling interference from the changes of WSIV.



(a) Continuous **(b)** Discontinuous

Figure 6.2 Continuous and Discontinuous rainfall for RillGrow simulations. Both storms have the same total rainfall amount of 65.5 mm. Rainfall durations for continuous (a) and discontinuous (b) rainfall are 15 minutes and 30 minutes, respectively.

Simulated runoff and soil loss rates by WEPP, EUROSEM and RillGrow using the prepared rainfall data are presented in the next section.

6.3 Simulation Results

WEPP simulation result WEPP-estimated runoff amounts for continuous and discontinuous rainfalls are shown in Table 6.1. WEPP generated less runoff with discontinuous rainfall than with continuous rainfall. WEPP-estimated runoff decreased 10 percent when estimated with a discontinuous rainfall than with a continuous rainfall. However, for soil loss, WEPP estimated more soil loss with discontinuous rainfall than with continuous rainfall. The soil loss estimated by WEPP increased 4.6 percent with discontinuous storm in comparison to the soil loss rate with continuous storm.

EUROSEM simulation result EUROSEM-estimated runoff and soil loss rates for continuous and discontinuous rainfall are shown in Table 6.2. EUROSEM generated a lesser amount of runoff with discontinuous rainfall than with continuous rainfall. Also, less soil loss was estimated by EUROSEM with discontinuous rainfall than with

Table 6.1 WEPP-estimated runoff and soil loss with continuous and discontinuous rainfall for each hillslope

	Runoff (mm)	Soil loss (t/ha)
Continuous	38.1	47.4
Discontinuous	34.3 (−10.0)	49.6 (+4.6)

Figures in ( ) are the % changes from the result with a continuous storm.

continuous rainfall. Runoff and soil loss rates estimated by EUROSEM decreased 11.9 and 12.7 percent, respectively, with discontinuous storm in comparison to those with a continuous storm.

Table 6.2 EUROSEM-estimated runoff and soil loss with continuous and discontinuous rainfall for each hillslope

	Runoff (mm)	Soil loss (t/ha)
Continuous	28.7	11.0
Discontinuous	25.3 (−11.9)	9.6 (−12.7)

Figures in ( ) are the % changes from the result with a continuous storm.

RillGrow simulation result RillGrow-estimated soil loss rates for continuous and discontinuous rainfall are shown in Table 6.3. RillGrow generated slightly more runoff with discontinuous rainfall than that with continuous rainfall. With discontinuous rainfall, runoff increased 0.2 percent in comparison to runoff estimated with continuous rainfall. The simulated runoff amounts were in fact almost the same. This is because no infiltration was considered during the simulation. Thus, every rain ran off the edge of the simulated plot. The infiltration component of RillGrow2 was inactive. The current version of RillGrow, which is version 6, has resolved the problem and has a working infiltration component (personal communication with the developer, D. Favis-Mortlock, on 31 January 2012).

Yet RillGrow estimated slightly less soil loss with discontinuous rainfall than with continuous rainfall. The soil loss rate was decreased one percent with the discontinuous storm in comparison to the soil loss rate with the continuous storm.

Despite the changes in runoff and soil loss, magnitudes of the change were much smaller than changes observed in the WEPP and EUROSEM results.

Table 6.3 RillGrow-simulated runoff and soil loss with continuous and discontinuous rainfall

	Totals lost from edges (litre†)	Soil loss (t/ha)
Continuous	471.5	91.2
Discontinuous	472.4 (+0.2)	90.3 (−1.0)

† Because of the model output parameter, total volumes of runoff was presented in litre. Figures in ( ) are the % changes from the result with a continuous storm.

6.4 Discussion

Breakpoint or CLIGEN data Using breakpoint data for a erosion simulation prevents the loss of WSG information from the original data. Therefore, it is reasonable to choose breakpoint data over CLIGEN data for studies similar to the current research which investigates effects of rainfall intensity changes on soil erosion in great detail. However, using breakpoint data for continuous long-term simulation, for example, is realistically almost impractical since preparing such inputs for erosion modelling is a very labour intensive and tedious task. Regardless to say that temporally high resolution data may well not be always available for a long period too. Thus, for some cases, CLIGEN data, which removes WSGs from original rainfall data, are inevitably chosen for erosion modelling studies. This investigation showed the effect of removing WSGs during rainfall duration on erosion simulations.

Effect of removing WSGs on EUROSEM results By removing WSGs, we are unintentionally creating a rainfall event with higher average intensity than the original average intensity as total storm duration becomes shortened. This means that, first of all, the time given for the erosion simulation is decreased so that smaller values of time-related parameters such as runoff duration are used for other relevant process calculations. This may have an effect on, for example, the time allowed for runoff initiation and development. Secondly, the increased average intensity may increase on the erosional power of rain storm. Thus, amounts of soil detachment and soil particles carried away by surface flow could be increased. Depending on the dominant process, runoff and soil loss could increase or decrease together.

Removing WSGs during a storm duration may result in, for example, increased runoff and soil loss rates in comparison to those simulated with the original rainfall because of increased erosive power of storm being more dominant than the time reduced. This seemingly was the case for EUROSEM simulations (Table 6.2).

EUROSEM showed significant impacts of WSGs on estimated runoff and soil loss. By maintaining WSGs, runoff was simulated with almost 12% smaller amount than by removing WSGs. This reduction in runoff was corresponded with decreased soil loss which was almost 13% smaller than that of continuous storm. These results imply that if runoff and soil loss are estimated by EUROSEM, the result could vary over 10% depending the existence of WSGs in breakpoint data. This figure, of course, may well be specific to the storm that have been used here. In order to find a more general magnitude of the impact, a further investigation may be needed. Also, the relationship between magnitudes of changes and proportions of WSGs in storms may need to be investigated. Nevertheless, even without any further test, it is clear that WSGs do have impacts on EUROSEM-estimated runoff and soil loss. WEPP and RillGrow showed rather different results from the EUROSEM results, however.

RillGrow without infiltration component First of all, simulation results from RillGrow runs showed very small differences between continuous and discontinuous rainfall. In fact, the differences in runoff and soil loss between two rainfalls were almost negligible. This, as mentioned previously, could have been the result of the infiltration component not having been activated in RillGrow. Thus, infiltration was not considered for the RillGrow simulations.

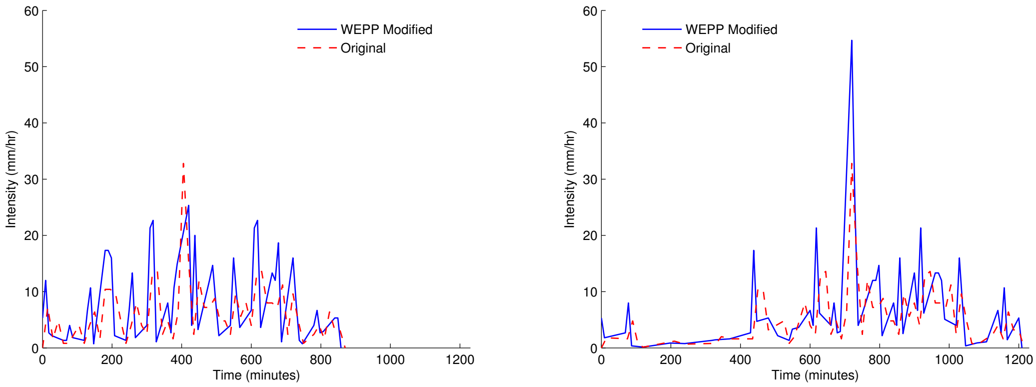
In comparison to RillGrow, however, the other two models, which have working infiltration components, showed some degrees of changes in runoff and soil loss. This implies that infiltration component plays an important role in making the differences in the simulated runoff and soil loss rates. Thus, without the working infiltration component, RillGrow2—the version of RillGrow that was used in this investigation—was assumed to be not sensitive to WSGs.

The more improved version of RillGrow, which is in version 6, has functioning infiltration component (personal communication with D. Favis-Mortlock in December 2011).

Modification of original breakpoint data by WEPP WEPP estimated more soil loss with discontinuous rainfall than with continuous rainfall even though runoff was decreased when simulated with discontinuous rainfall. This was unexpected. If average rainfall intensity of a rainfall storm is increased keeping the amount unchanged, the increased average intensity is expected to produce more runoff and, in turn, more soil loss than low average intensity. However, the opposite results were observed from the WEPP simulation result.

By examining WEPP outputs thoroughly—including the WEPP outputs from the previous chapter, Chapter 5, it was found that WEPP actually misinterpreted the intensity of the original breakpoint data, and modified the original intensity information before using them for estimating runoff and soil loss.

WEPP reconstructed a "new" rainfall storm based on the original breakpoint data when the temporal scale of rainfall data shorter than an hour were used. This "WEPP-modified" rainfall storm had the same accumulated rainfall amounts and the number of breakpoints from the original data, but the time increments for each data point were changed. By changing the original time increments, WEPP, in effect, changed the original rainfall intensity information. The differences between the original breakpoint data and the "WEPP-modified" breakpoint data are illustrated in Figure 6.3. WEPP decreased intensity peaks of continuous rainfall while it increased intensity peaks of continuous rainfall as seen in Figure 6.3.



(a) Continuous

(b) Discontinuous

Figure 6.3 Original rainfall intensity and WEPP-modified rainfall intensity for discontinuous and continuous rainfall.

The peak intensity of continuous rainfall was decreased from 32.8 mm/hr to 25.3 mm/hr (Table 6.4). This is about a 23% decrease in the peak intensity. The rainfall amount and total duration of continuous rainfall were kept almost the same so that the average rainfall intensity for the original data and WEPP-modified data were almost the same (Table 6.4). Also, the peak intensity of discontinuous rainfall was increased from 32.8 mm/hr to 54.7 mm/hr (Table 6.4). The peak intensity was increased about 67%. Since the rainfall amount and total duration of discontinuous rainfall were kept almost the same too, the average rainfall intensity for the original data and WEPP modified data were almost the same. These details are summarised in Table 6.4.

Table 6.4 Detailed summary of original and wepp-interpreted storm intensity (mm/hr)

	Continuous		Discontinuous	
	Peak	Average	Peak	Average
Original	32.8	6.2	32.8	4.4
Wepp-interpreted	25.3	6.3	54.7	4.5
Change (%)	-22.9		+66.8	

+/- denotes increase or decrease

This finding poses a serious problem and, as far as only WEPP is concerned, has a substantial impact on our ability to investigate impacts of rainfall intensity changes not only in the future but also in the present. Without ability to process original intensity information, it is very likely to end up with invalid results similar to the WEPP simulation result shown in this chapter (see Table 6.1).

6.5 Conclusion

Within-Storm Gaps (WSGs) have impacts on runoff and soil erosion simulated by WEPP and EUROSEM except RillGrow. RillGrow showed almost no changes in runoff and soil erosion simulation results because of the lack of functioning infiltration component. Although it was not evident whether WSGs had positive or negative effects on runoff and soil erosion estimations, removing WSGs from original rainfall data affected the model simulation results. Thus, it is not recommended to remove WSGs from the original rainfall data in order to maintain the original rainfall intensity information. It is a best practice to use rainfall data which have all necessary information for modelling.

Analyses of outputs from WEPP simulations revealed a new problem. WEPP modified original rainfall intensity information and simulated erroneous results (Table 6.1. This is because that WEPP constructs a “WEPP-modified” rainfall data based on original rainfall data when breakpoint data with a time scale shorter than 60-min temporal scale is used for WEPP simulations. Particularly, peak rainfall intensity and the shapes of rainfall storm are altered. This clearly is a major problem for current research and for our ability to predict erosion. This is also a major model fault for WEPP. This means that, even if 15-min breakpoint rainfall data—as suggested in the previous chapter—are used for WEPP simulations, rainfall data, which WEPP actually uses for the simulation, have different rainfall intensity from the original data.