Chapter 4

IMPLICATION OF IMPROVED CLIGEN ON RAINFALL AND SOIL EROSION SIMULATIONS

4.1 Introduction

CLIGEN, a weather generator for WEPP, went through extensive modifications while the current research was carried out (Yu, 2000). The modification was done to improve CLIGEN in three aspects. The first is the recalculation of an input parameter, 'MX.5P', which controls rainfall intensity generations of CLIGEN. The second is the correction of the unit conversion error in programming codes of CLIGEN. The third is a subsequent adjustment to shorten the extensive increases of simulated rainfall durations.

These unforeseen changes prompted an investigation of their implications on rainfall generations of CLIGEN and, in turn, soil erosion estimations of WEPP. Before using the improved CLIGEN, it is important to understand how the improved CLIGEN perform and simulates weather data in comparison to the previous version. Also, how these changes of CLIGEN affect on previous publications needs to be discussed.

Therefore, this chapter investigates effects of the changes of CLIGEN (from version 4.2 to version 5.2) on rainfall data simulations and soil erosion estimations by WEPP. During the investigation process, WEPP is also calibrated and used for the subsequent simulations of this thesis. Some previous publications have been identified later in this chapter in regard to implications of CLIGEN changes.

4.2 Data Preparation and Method for Model Simulation

Firstly, two CLIGEN input files—original and updated (see Appendix B)—were prepared using more recent rainfall data (Table 3.2) obtained from the Ditchling Road site (Figure 3.2). The original CLIGEN input file for Ditchling Road was used in a study by Favis-Mortlock (1998*a*). This file was originally built with help from Arlin Nicks for David Favis-Mortlock in 1992[1]. The newly prepared CLIGEN input file used event data that have been measured since 1991 (Table 3.2). 'MEAN P' (Table 4.2) and 'MX.5P' (Table 4.3) values of CLIGEN inputs were recalculated using the up-to-date event data. Note that the units for these parameters are in inches, not in millimetres. Only these two parameters were updated because rainfall intensity is closely related to these two parameters. The definition of the 'MX.5P' was revised by Yu (2000), so it was recalculated accordingly in this research.

[1]From personal communication with David Favis-Mortlock on 3 July 2001:

> "My problem was that, in 1992, I did not have any measured intensity data for the area. So, as I recall, I used maps in 'NERC (1975) *Flood Studies Report*, Natural Environment Research Council, HMSO, London' to pick out the maximum x-hour precipitation for each month for the South Downs, where x is something like 6 hours. The 1975 NERC report was based on approximately 30 years of data. I then used a chart constructed from empirical relationships in the 1975 NERC publication—Actually, from data given to me by someone in the old Southern Water company, which data was drawn from the 1975 NERC publication—to convert these values into 0.5-hour maxima. I then sent these 0.5-hour max. values to Arlin. From these he calculated time-to-peak values."

Table 4.1 Weather simulation settings with different CLIGEN versions and inputs for Ditchling Road

	Original Input	Updated Input
CLIGEN v4.1	v4.1+original	v4.1+updated
CLIGEN v5.2	v5.2+original	v5.2+updated

Next, continuous daily climate data for 30 years were generated with CLIGEN version 4.1[2] (old) and version 5.2 (new) using these two input files. As a result, four datasets of simulated climate data were generated (Table 4.1). These climate data were compared in terms of rainfall amount, duration and peak intensity.

Table 4.2 Original and Updated MEAN P (inches) for Ditchling Road

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Original	0.19	0.16	0.17	0.16	0.16	0.20	0.19	0.22	0.23	0.27	0.21	0.20
Updated	0.11	0.11	0.18	0.21	0.17	0.15	0.16	0.13	0.24	0.29	0.19	0.29

Table 4.3 Original and Updated MX.5P (in/hr) for Ditchling Road

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Original	0.63	0.59	0.55	0.55	0.55	0.55	0.55	0.67	0.79	0.93	0.87	0.75
Updated	0.27	0.18	0.23	0.23	0.27	0.33	0.42	0.58	0.43	0.45	0.34	0.30

Using WEPP, soil erosion rates for the same thirty-year period were, in turn, estimated for Woodingdean site (Figure 3.3) with each CLIGEN-generated climate dataset. All other input data for the WEPP simulation were acquired from the previous study by Favis-Mortlock (1998*a*). Runoff and soil loss rates were compared. Kolmogorov-Smirnov (K-S) test was used to test the null hypothesis that the two populations are identical. Results of K-S test are presented in the next section.

[2]There is virtually no difference between version 4.1 and 4.2 although version 4.2 was the one Yu (2000) found error in.

4.3 Implication on Rainfall Data Simulation

4.3.1 Rainfall Amount

Generated annual rainfall amounts for 30 years were within the range of the reported annual rainfall amounts (750 and 1000 mm) in the area (Figure 4.1). The annual rainfall amounts generated by two input files were not significantly different (K-S test, $p < 0.05$). Although two versions of CLIGEN resulted in a slight difference in annual rainfall amounts in year 17 (Figure 4.1), the differences between two versions of CLIGEN were not statistically significant (K-S test, $p < 0.05$).

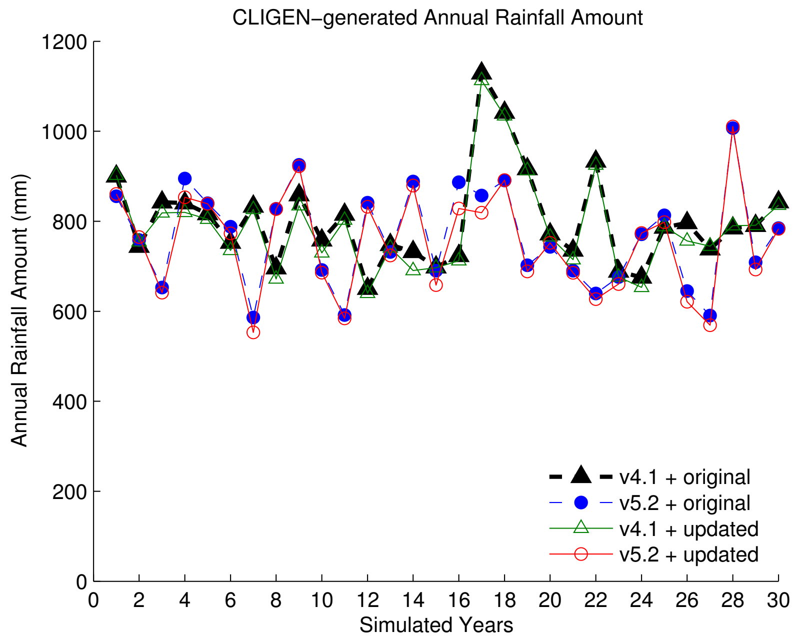


Figure 4.1 Simulated annual rainfall amount using two versions of CLIGEN with original and updated input files.

4.3.2 Rainfall Duration

Contrastingly, simulated annual rainfall durations using two versions of CLIGEN exhibited noticeable differences. Old version of CLIGEN generated identical annual rainfall durations even though two different input files (original and updated) were used (Figure 4.2). New CLIGEN generated markedly different rainfall durations when the same set of CLIGEN input files were used (Figure 4.2) (K-S test, $p < 0.05$).

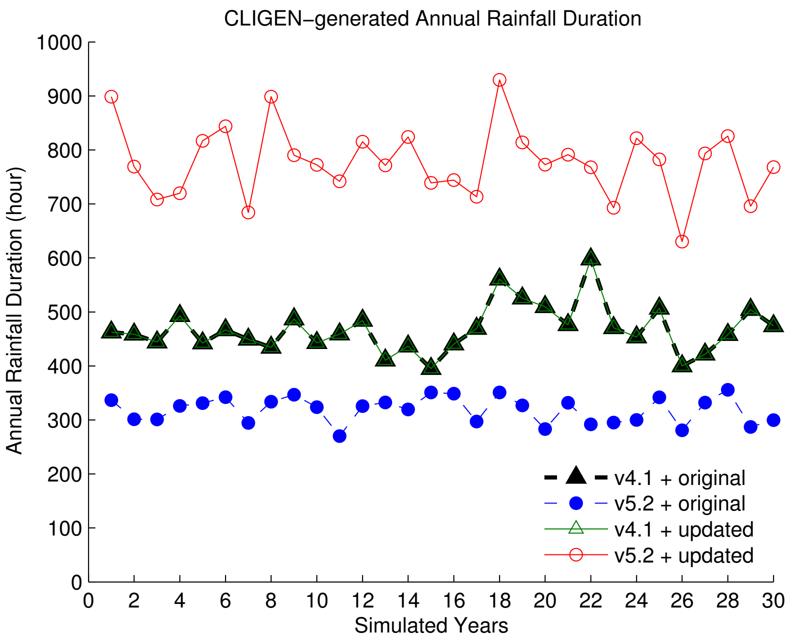


Figure 4.2 Simulated annual rainfall duration using two versions of CLIGEN with original and updated input files.

New CLIGEN with updated input file generated greatly increased rainfall durations, almost 2.5 times longer on average than with original input file. The rainfall duration (v5.2 + updated) was over 1.5 times longer on average in comparison to the rainfall duration generated by old CLIGEN with both original and updated input files. New CLIGEN with original input file generated the shortest annual rainfall durations among the four series. This means that, unlike old version, new version of CLIGEN is sensitive to the change of two CLIGEN input parameters (i.e. MEAN P and MX.5P), particularly to the change of MX.5P. Great differences in rainfall durations mean that rainfall intensities also differ greatly between the simulated rainfall data.

4.3.3 Monthly Maxima of Daily Peak Rainfall Intensity

Next, monthly maxima of daily peak rainfall intensity series generated by CLIGEN were compared in order to examine effects of extreme intensity events. The results are shown in Figure 4.3. Kolmogorov-Smirnov test indicates that old CLIGEN was not sensitive to the changes of input files (See Figure 4.3(a) and 4.3(c), $p < 0.05$). In contrast, using original and updated input files with new CLIGEN resulted in two significantly (K-S test, $p < 0.05$) different distributions of monthly maxima of daily peak rainfall intensity (See Figure 4.3(b) and 4.3(d)). New CLIGEN generated fewer high-peaked rainfall intensity events than the old version (Figure 4.3(a)(c) and 4.3(b)(d)). There were, for example, only nine monthly maxima of daily peak intensity over 100 mm/hr during 30 years of the simulation period when new CLIGEN and updated input file were used (Figure 4.3(d)). The magnitude of the monthly maxima of the daily peak intensity seems to be in a similar range for all four cases although the frequency of such high values may vary depending on versions of CLIGEN and input files.

Mean monthly maxima of daily peak intensity were compared in Figure 4.4. Old CLIGEN with two input files generated generally high mean monthly values through out most of months in comparison to new CLIGEN. The effect of different input files was very small on old CLIGEN for simulating mean monthly maxima of daily peak intensity. Old CLIGEN generated highest mean monthly maxima of daily peak intensity in October and lowest values in June with both input files. In contrast, new CLIGEN generated significantly different mean monthly maxima of daily peak intensity with two input files (K-S test, $p < 0.05$). Much greater mean monthly maxima of daily peak intensity were generated with v5.2 + original than with v5.2 + updated. With original input file, new CLIGEN (v5.2) showed a peak in November and a low in May.

With exception of v5.2 + updated, all three simulations show generally high mean

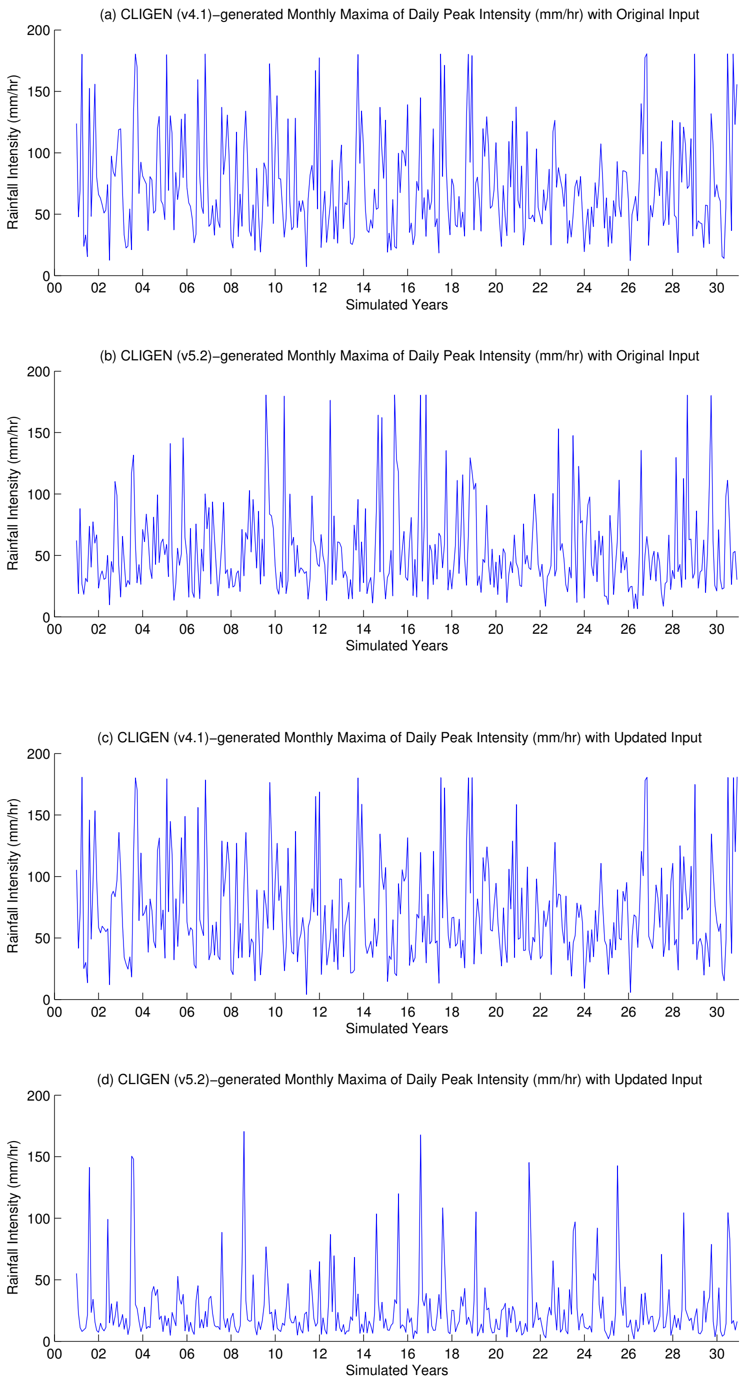


Figure 4.3 Simulated monthly maxima of daily peak rainfall intensity using two versions of CLIGEN with original and updated input files. (a) CLIGEN v4.1 with original input file; (b) CLIGEN v5.2 with original input file; (c) CLIGEN v4.1 with updated input file; (d) CLIGEN v5.2 with updated input file.

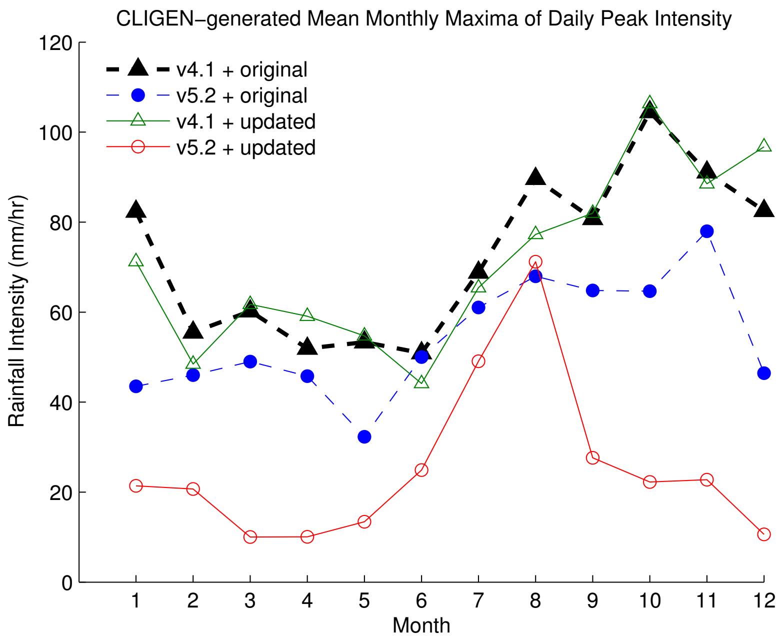


Figure 4.4 CLIGEN-generated mean monthly maxima of daily peak intensity using two versions of CLIGEN with original and updated input files

monthly maxima of daily peak intensity in October and November and low mean monthly maxima of daily peak intensity in April, May and June. When new CLIGEN with updated input file were used for the simulation, the monthly pattern was very different from that of the other three combinations. This combination (v5.2 + updated) showed relatively high mean monthly maxima of daily peak intensity during the summer months (June, July and August) with a distinctively high peak in August (Figure 4.4). Generally low mean monthly maxima of daily peak intensity in the rest of months were simulated with lowest mean monthly maxima of daily peak intensity in March and April (Figure 4.4). With updated input file and new CLIGEN, more high intensity events were simulated in the summer than the autumn or winter in comparison to the other simulation combinations.

4.4 Implication on Runoff and Soil Erosion Simulation

Before starting investigations on effects of improved CLIGEN on WEPP simulations, initial tests of WEPP were carried out with weather generated by new CLIGEN with updated input file. The tests revealed that uncalibrated WEPP overestimates mean soil loss by about 630% in comparison to observed soil losses from the study area (Table 4.5). This erosion rate is considered undesirably high for the study site so that calibrations is considered essential. Thus, WEPP was calibrated by adjusting hydrological and erosional parameter values. The adjusted parameters were shown in Table 3.4. Simulated runoff and soil loss rates using uncalibrated and calibrated WEPP are presented in Table 4.4 and 4.5. There were no measured runoff data available for the site although annual soil loss data for a short period were acquired from Favis-Mortlock (1998*a*).

Table 4.4 Simulated annual average runoff (mm) on hillslopes (D-L) using CLIGEN-generated (v5.2) weather with updated input

	D	E	F	G	H	I	J	K	L	Mean
uncalib.	106.7	105.3	106.5	106.0	106.1	107.1	107.8	108.0	108.8	106.9
recalib.	74.2	72.9	73.9	73.6	73.4	74.3	74.8	75.2	75.9	74.2

Table 4.5 Simulated annual average soil loss (t/ha) on hillslopes (D-L) using CLIGEN-generated (v5.2) weather with updated input

	D	E	F	G	H	I	J	K	L	Mean
uncalibrated	49.4	42.9	76.1	96.5	117.5	111.1	105.3	84.1	79.7	84.7
recalibrated	3.4	3.2	11.1	18.2	23.7	21.3	17.3	9.8	7.9	12.8
measured[a] (m^3/ha)	3.4	7.8	13.7	17.5	21.4	9.6	11.6	11.2	8.1	11.6

[a] over the periods of 1985-1986 (From Favis-Mortlock, 1998*a*)

Why Calibrate? It is paramount to test and calibrate a model before using it in the subsequent investigation of this research. When a erosion model is used for soil loss estimations, it is important to note that the relationship of model inputs and outputs is non-linear (Favis-Mortlock and Boardman, 1995; Jetten *et al.*, 1999). For example, say, we ran a erosion model with *Input A* and got *Output B* (Figure 4.5). Then, in order to find possible effects of changes ininputs, we may change *Input A* to *Input A'*. When the model was run with *Input A'*, the responding model output should be *Output B'* if the model has a linear relationship between inputs and outputs. However, because of the non-linear relationship, the responding output may be rather unknown *Output B"* (Figure 4.5). This means that, unless model inputs and outputs are identified and the model is calibrated against known output values, it may be difficult to measure the extent of changes in model predictions. This is because we may not know where unknown *Output B"* has arrived from. Therefore, it is very unlikely that non-calibrated models will lead to reasonable simulation results.

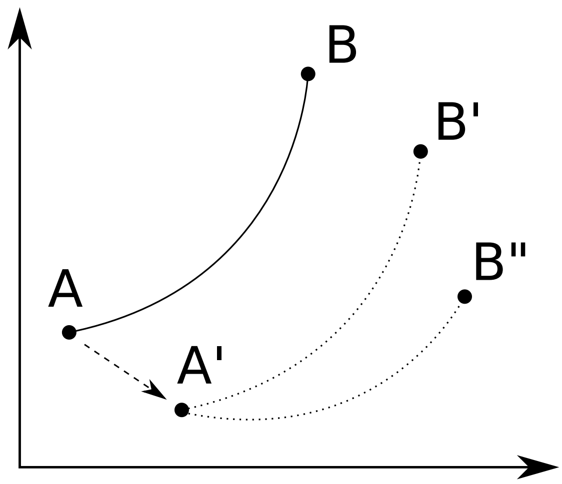


Figure 4.5 A graphical representation of non-linear responses of a erosion model

WEPP simulated annual runoff and soil loss rates using four CLIGEN-generated weather series are shown in Figure 4.6 and Figure 4.7, respectively.

Annual runoff and soil loss rates were not significantly affected by the use of weather datasets that have been generated by old CLIGEN (v4.1) with two input files (original and updated). Annual runoff (Figure 4.6a and Figure 4.6b) and annual soil loss rates (Figure 4.7a and Figure 4.7b) were almost identical between the two configurations (v4.1 + original and v4.1 + updated). Mean annual runoff and soil loss rates estimated using

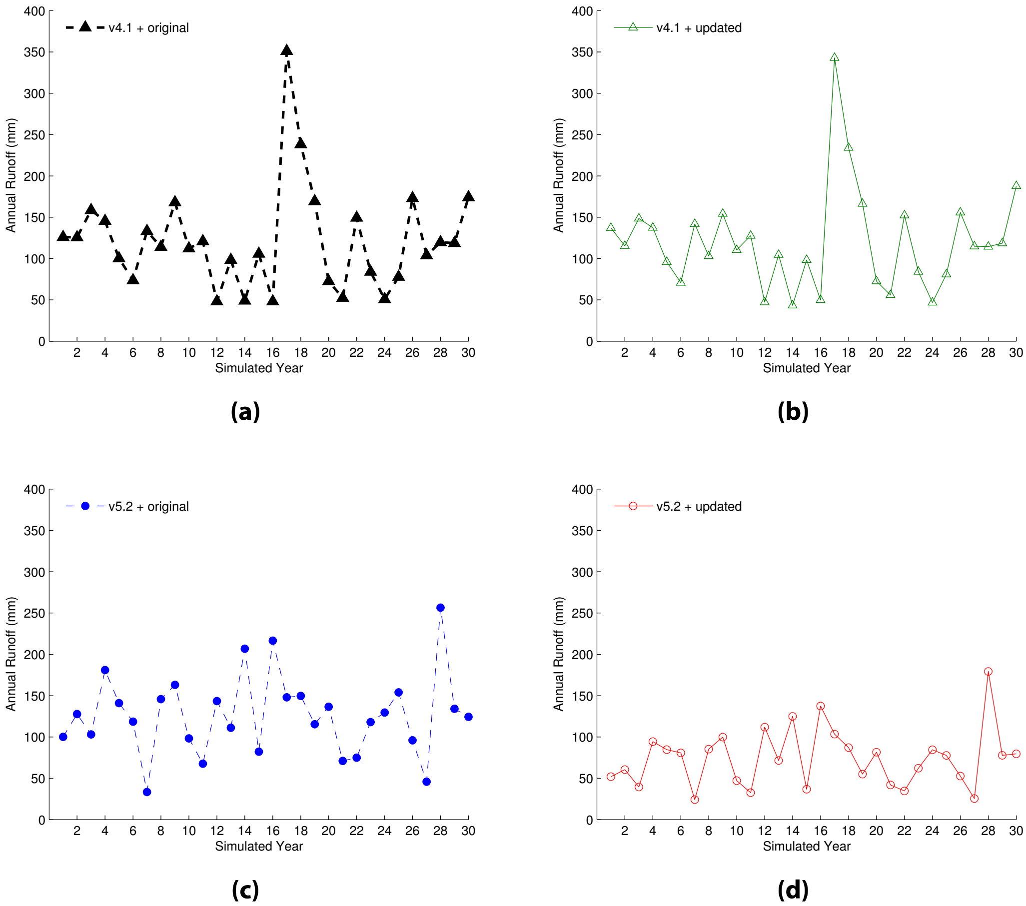


Figure 4.6 Simulated annual runoff for Ditchling Road simulated with (a) old CLIGEN with original input file; (b) old CLIGEN with updated input file; (c) new CLIGEN with original input file; (d) new CLIGEN with updated input file. Note the same Y-axis in plots.

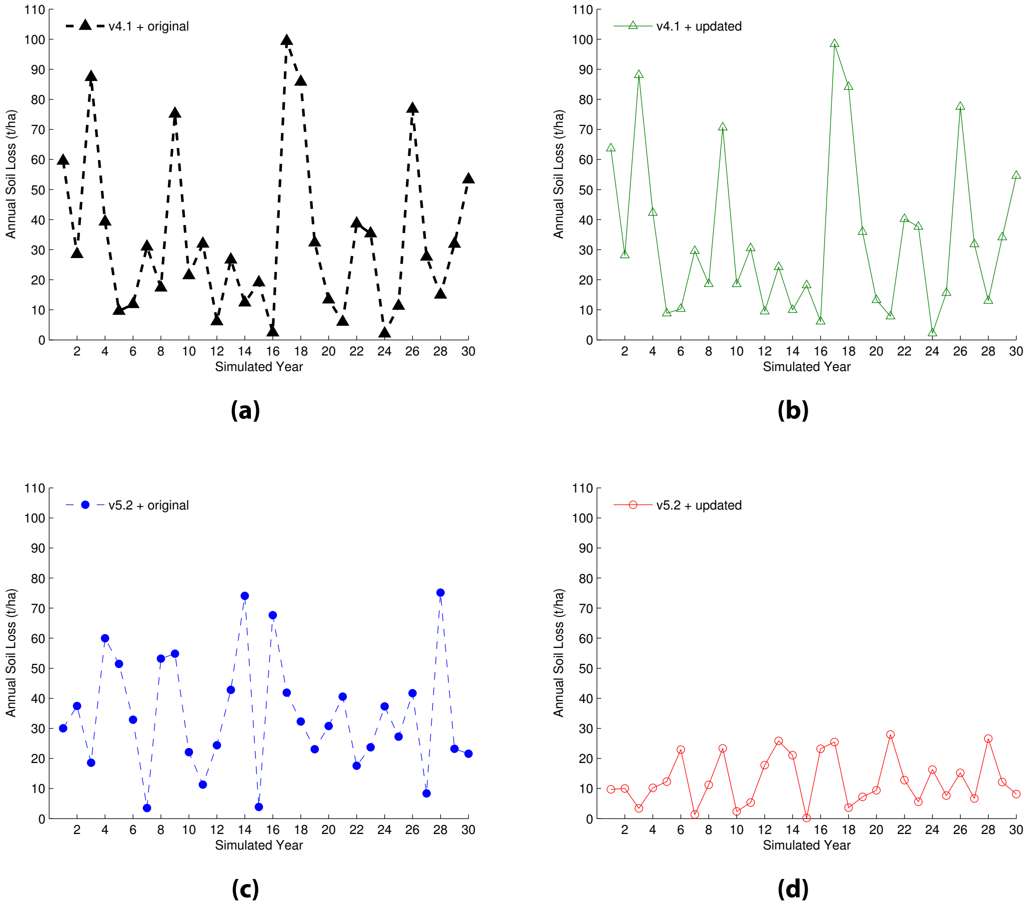


Figure 4.7 Simulated annual soil loss for Ditchling Road simulated with (a) old CLIGEN with original input file; (b) old CLIGEN with updated input file; (c) new CLIGEN with original input file; (d) new CLIGEN with updated input file. Note the same Y-axis in plots.

weather data generated by v4.1 + updated were slightly decreased by 1.4% and increased by 1.5% respectively in comparison to the estimation done by the use of weather data generated with v4.1 + original (Table 4.6).

Table 4.6 WEPP simulated average annual runoff (mm) and soil loss (t/ha) with CLIGEN generated weather with four different configurations.

	CLIGEN v4.1		CLIGEN v5.2	
	original input	updated input	original input	updated input
Runoff	122.1	120.4 (−1.4)	126.5 (+3.6)	74.2 (−39.2)
Soil Loss	33.6	34.1 (+1.5)	34.4 (+2.4)	12.8 (−61.9)

Figures in ( ) represent % differences from CLIGEN v4.1+original input file.
+/− sign indicates an increase/decrease.

When both CLIGENs (v4.1 and v5.2) were run with original input file to generate weather data, subsequent WEPP estimations of average annual runoff and soil loss were not much different between the two versions of CLIGEN. Average annual runoff and soil loss were only increased by 3.6% and 2.4%, respectively. (Table 4.6).

WEPP estimated considerably decreased runoff and soil loss rates when rainfall data generated by new CLIGEN with updated input file were used (Figure 4.6d and Figure 4.7d) in comparison to the other three configurations (Figures 4.6a–c and Figures 4.7a–c). This result is consistent with the result from rainfall simulations. In comparison to mean runoff and soil loss rates estimated using rainfall data generated by old CLIGEN with original input file, the runoff and soil loss rates decreased by about 39% and about 62% respectively when rainfall data generated by new CLIGEN with updated input file were used for WEPP simulations (Table 4.6). The importance of these results are discussed in the following section.

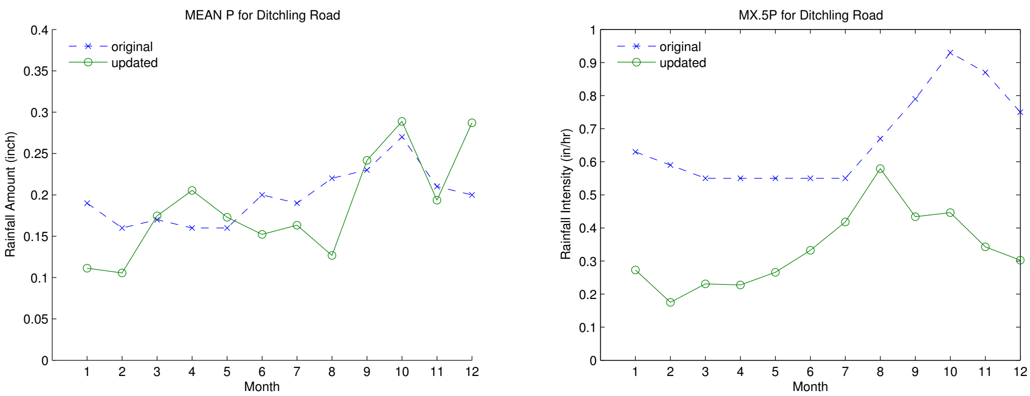
Relative vs Absolute Model Output In this research, both relative (% change) and absolute (t/ha) values were used for model outputs. It may seem more meaningful to use only relative representations (% change) of model outputs than to use absolute values (t/ha) together with % changes because what this research is interested in is how model estimates change as a result of rainfall intensity changes. However, in order to make a right judgement and to assess estimated values correctly, we need both expressions: relative and absolute. For instance, if a model estimates soil loss of 1000 t/ha from a 1 m×1 m plot after 10 mm/hr rainfall, it would hardly be considered realistic, and the model and its inputs may need to be checked to find a reason for the error. On the other hand, when a model estimates soil loss that changes from, say, 0.00001 t/ha to 0.00002 t/ha, the % change would be 100% despite the fact that this value can be seen as very trivial in the real world. Thus, presenting the model result either only in relative (% change) or absolute (t/ha) value is probably misleading. Therefore, both expressions are used in this research when simulation results are presented. Also, calibrations carried out previously provide robust realistic absolute values.

4.5 Discussion

4.5.1 Impact on Rainfall Intensity Generation

Yu (2000) suggests that CLIGEN became sensitive to the change of the rainfall intensity parameter because of the improvement. This investigation confirms this improvement. Rainfall duration generated by new CLIGEN (v5.2) showed a clear signs of the sensitivity to the change of rainfall intensities which is shown in Figures 4.2 and 4.4.

Updated CLIGEN input file has lower MX.5P values than original input file. This difference led to longer rainfall durations generated by new CLIGEN (v5.2) as shown in Figure 4.2. This was expected because of the lower MX.5P values and the similar MEAN P values in updated input file in comparison to the same parameters in original input file (Figure 4.8). With rainfall amount being almost unchanged—only slightly changed, but statistically the same ($p < 0.05$), rainfall duration has to be increased to satisfy low intensity parameters (Figure 4.8). This, in turn, decreases rainfall intensities generated by new CLIGEN (Figure 4.4, v5.2 + updated).



(a) MEAN P **(b)** MX .5P

Figure 4.8 Mean daily precipitation depth (inch) and mean maximum daily 30-minute rainfall intensity (in/hr) for each month. Note that the units are in inches, not in millimetres, as CLIGEN requires these values in inches.

Old CLIGEN (v4.1) did not show much changes in rainfall intensity even though the rainfall intensity parameter (MX.5P) were updated to the lower values when the input file was prepared. This insensitivity of old CLIGEN (v4.1) is clearly the result of the unit conversion error previously found by Yu (2000). Correcting the errors in the previous version of CLIGEN resulted in the decreased rainfall intensity (Figure 4.4).

One interesting finding is that when original CLIGEN input file was used for both climate simulations with old and new CLIGEN, rainfall durations generated by two CLIGENs were not significantly different so thus resulting intensities. This finding may be explained by the differences in two versions of CLIGEN. New CLIGEN (v5.2), as shown earlier, is much more sensitive to changes in rainfall intensity than old CLIGEN (v4.1), so that, with the CLIGEN input file that has low rainfall intensity (i.e. Updated CLIGEN input), new CLIGEN (v5.2) will simulate rainfall data with much lower rainfall intensity, hence longer rainfall durations. This has been shown previously. What is more interesting is that, in contrast, with CLIGEN input file that has high rainfall intensity (i.e.

Original CLIGEN input), new CLIGEN (v5.2) still simulate climate data with responding rainfall intensity, that is high rainfall intensity, hence short rainfall durations. This is more evident as new CLIGEN (v5.2) generated shorter annual rainfall durations with original input file (Figure 4.2) than old CLIGEN (v4.1) with original (or updated) input file. However, when mean monthly maxima of daily peak intensity were compared as shown in Figure 4.4, new CLIGEN (v5.2) generated lower values for mean monthly maxima of daily peak intensity than old CLIGEN with both input files. Overall, this finding means that the improvement of CLIGEN has less impacts on weather generations for regions where high intensity rainfall events are dominant.

Moreover, new CLIGEN with the updated input file simulated a peak monthly intensity in August (Figure 4.4) that can also be seen in the input file (Figure 4.8b). This means that new CLIGEN generates monthly rainfall intensity that are similar to MX.5P values which are calculated from observed weather data. Old CLIGEN, on the other hand, generated the similar monthly rainfall intensity for both CLIGEN input files. This implies that old CLIGEN does not recognize the intensity differences introduced by the different MX.5P parameters in the input files.

Therefore, it is strongly suggested to use new CLIGEN (v5.2) hereafter. It is also advisable to review previous CLIGEN input files when possible.

4.5.2 Impact on Subsequent WEPP Simulation

Runoff and soil erosion rates estimated by WEPP showed the similar responses as those from the analysis of rainfall generations. This implies that WEPP is sensitive to the changes of climate data which have been used for the simulation.

The two identical climate datasets generated by old CLIGEN (v4.1) with two input files (original and updated) did not affect WEPP estimated annual runoff (Figures 4.6a and 4.6b) and soil erosion rates (Figures 4.7a and 4.7b). There were slight differences between two settings in terms of average annual runoff and soil loss rates (Table 4.6). The differences were however unrealistic as average annual soil loss rate was increased even though average annual runoff was decreased. This suggests that WEPP may have some issues in estimating runoff and soil loss rates.

The use of two climate datasets generated by new CLIGEN (v5.2) with original and updated input files resulted in significantly different runoff and soil loss rates. WEPP simulated considerably lower annual runoff and soil loss rates when climate data generated by new CLIGEN (v5.2) with updated input file were used than when climate data generated by new CLIGEN (v5.2) with original input file were used. This is because of the increased rainfall duration which have been caused by the decreases in rainfall intensity (Figure 4.2). Considering that simulated rainfall amounts were not much different in both input files of CLIGEN, it is evident that low rainfall intensity is the reason for the low annual runoff and annual soil loss rates estimated by WEPP.

Therefore, the implication of the improvement in CLIGEN is relatively small when CLIGEN was used to simulate climate data for a place where rainfall events with high intensity are dominant. On the other hand, when CLIGEN was used to generate climate data for a place where rainfall events with low intensity are dominant (e.g. South Downs, UK), differences of climate data simulated by old and new CLIGEN would be so great that subsequent WEPP estimations will be greatly affected and erroneous estimations are inevitable.

In the next section, some examples of previously published studies that may have been affected by these CLIGEN improvements are subjectively selected and discussed to highlight the implication of the CLIGEN improvement.

4.5.3 Implication for Previously Published Studies with Old CLIGEN

Published papers that used old CLIGEN, prior to Yu (2000), to generate weather data are theoretically affected by the improvement. The magnitude of effects can vary depending on characteristics of typical rainfall storms in study area as shown in the present research.

Baffaut *et al.* (1996) used old CLIGEN to generate 200 years of climate data for WEPP simulations in order to investigate impacts of CLIGEN parameters on WEPP-predicted average annual soil loss. The study found that only five parameters, that are mean precipitation per event, standard deviation of the precipitation per event, skewness of the precipitation per event, probability of a wet day following a wet day and probability of a wet day following a dry day, influenced the estimated average annual soil loss. However, they found that half hour largest intensity (i.e. MX.5P) and the statistical distribution of the time to peak had less influence on the output. Insensitivity to MX.5P parameter, which Baffaut *et al.* (1996) found, could be the result of the error found in old CLIGEN as Yu (2000) pointed out.

However, it is also possible that the insensitivity to MX.5P was from the characteristic of rainfall storms in the study area. Baffaut *et al.* (1996) considered Indiana, Alabama, Kansas, Colorado, Washington and Virginia, USA. It is suggested that storms with high rainfall intensity is common in the central and eastern United States Ashley *et al.* (2003). This means that the magnitude of effects from CLIGEN improvements could be smaller because the studied area are mostly in the central or eastern US except Washington. As shown in Table 4.6, areas with high rainfall intensity are less influenced by the improvement of CLIGEN.

Therefore, the information and analysis from Baffaut *et al.* (1996) do not provide any conclusive evidence to determine the effect of improved CLIGEN.

Zhang *et al.* (1996) conducted a study to evaluate the overall performance of WEPP in predicting runoff and soil loss under cropped conditions. They also used old CLIGEN to generate the weather parameters in the WEPP climate input files. Although they used CLIGEN, not all weather parameters were generated by CLIGEN. Values for amounts of rainfall, rainfall duration, time to peak intensity and ratio of mean to peak intensity were directly calculated from measured rainfall data for each storm at all the sites they considered. This means that their study may not have been affected by the change of CLIGEN. As this chapter suggested, rainfall duration and intensity are the most affected parameters in WEPP climate inputs.

Baffaut *et al.* (1998) also used old CLIGEN to generate synthetic weather series to analyse frequency distributions of measured daily soil loss values and to determine if the WEPP accurately reproduced statistical distributions of the measured daily erosion series. The sites that they selected for their study were in the eastern USA. They selected the study sites based on length of records, the number of events recorded, and the uniformity of the management practices. This means that the series of weather data generated by old CLIGEN may not have been different statistically compared to measured values because of the high rainfall intensity for their study sites Ashley *et al.* (2003). The paper did not include the result of weather simulations. However, it was indicated that CLIGEN generated data were not statistically different from monitored weather data. Thus, this paper also elaborates that the implication of the change of CLIGEN is small when old CLIGEN was used to generated weather data for areas with high rainfall intensity.

Favis-Mortlock and Guerra (1999) conducted a case study from Brazil to suggest an approach to quantifying the change in risk of serious erosion for venerable areas. Favis-Mortlock and Guerra (1999) used old CLIGEN to generate 100 years of weather data based on current-climate and, then, used three GCMs to perturb 100 years of CLIGEN generated daily weather data. The area which Favis-Mortlock and Guerra (1999) studied has several monsoon characteristics in addition to the distinct wet and dry seasons (Gan *et al.*, 2004). This means that the area have a large variability in rainfall intensity, which implies that impacts of the change of CLIGEN could be small on the overall result of the paper. However, it could still be possible that rainfall duration and number of extreme events could have been overestimated slightly.

The previously published paper that were discussed here used old CLIGEN for generating weather data. This implies that articles may have been affected by the previous errors of CLIGEN to a certain extend. However, the information included in these articles does not have enough details to determine the extend and the effect of improvements of CLIGEN. Yet, the magnitude of impacts varies depending on how CLIGEN was used and where CLIGEN was used for. In summary, it is evident that previously published papers that uses old CLIGEN to generate weather data for the area, like the central and eastern US or central South America, where high intensity storm is common are not greatly affected, at least, not as much as other places like the southern England where low intensity rainfall is common.

4.6 Conclusion

The improvement of CLIGEN have important implications on generating synthetic climate data and subsequent WEPP simulations of runoff and soil loss rates. Old CLIGEN is not sensitive to changes of rainfall intensity. The previous version generates the similar climate series with original and updated CLIGEN input files that have high and low intensity parameters, respectively. However, new CLIGEN is now sensitive to changes of rainfall intensity which is parametrized as MX.5P. The effect of the improvement of CLIGEN is more (less) significant for the regions where low (high) intensity rainfall events are dominant. All previous articles that used old version of

CLIGEN may have been affected by the errors of old CLIGEN to a certain extend. However, the magnitude of impacts varies depending on how CLIGEN was used and where CLIGEN was used for. It could have been catastrophic to find out the errors of CLIGEN at the later stage of this research because the site where this research is based on is South Downs, UK where impacts of the improvement of CLIGEN are great.