DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS **CSG 15**

Research and Development

Final Project Report

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Project title	Investigation of the relationship between potentially erosive storm energy, daily rainfall total and index of continentality.
DEFRA project code	**SP0408**
Contractor organisation and location	ADAS Wolverhampton Woodthorne, Wergs Rd Wolverhampton WV6 8TQ
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Executive summary (maximum 2 sides A4)

Phosphate and sediment loss to surface waters are of increasing concern because of their impacts on biological diversity, fisheries and tourism, and the risk of eutrophication. Transport of P and sediment to waters is largely mediated by erosion and surface runoff, which are themselves sensitive to the kinetic energy of rainfall. Under a given set of conditions, modelled erosion is a linear function of the total kinetic energy of rainfall falling during the study period, and the relationship can be defined for each set of conditions from multiple runs of the model. A method is therefore needed for estimating this kinetic energy from a knowledge of total rainfall, which is the form in which weather and climate data are usually available to catchment-scale models. It would be expected that the number of storms, and hence the kinetic energy per unit of rainfall volume, would vary both seasonally and with location.

The objective of this project was to define a method of estimating the spatial and temporal distribution of rainfall kinetic energy in an appropriate format for input into catchment-scale soil erosion and runoff models. This involved summarising frequency distributions for study sites chosen to be representative of the range of seasonal rainfall volume and continentality observed within England and Wales. Continentality is a measure of the ‘storminess’ or variability of rainfall intensities at a site, and is defined as the ratio of the expected 1 hour and 48 hour rainfall totals with a return period of five years. These values are calculated from long runs of detailed rainfall records.

The procedure for determining potentially erosive storm rainfall energy comprised five stages:

1. Suitable rainfall stations were selected representing the observed range of AAR and continentality across the agricultural land of England and Wales. Mean annual rainfall ranged from 599 to 1265 mm.
2. A first stage of data quality control was undertaken where tip-time data, from which kinetic energy was to be determined were summarised to daily totals and validated against a daily archive.
3. A second stage involved comparison of the number of days per year recording more than 10mm rain from the raw data and the quality controlled data. At the end of this stage 11 sites were selected with validated records of over 10 years in length.
4. The return periods of validated 15 minute rainfall totals were analysed against standard values from the Flood Studies Report
5. Kinetic energy was calculated from the 15 minute rainfall time series using standard relationships used in erosion models. The kinetic energies were summarised on a daily basis, and classified according daily rainfall totals.

The results showed a strong, highly significant correlation between rainfall totals and rainfall kinetic energy. This is not surprising, but the regressions allow estimation of total kinetic energy from a knowledge of total rainfall volume, and allow the uncertainty in this estimate to be defined both in terms of year-on-year variation and variation between sites.

The relationship varied markedly between months. Thus late summer and autumn months showed a greater kinetic energy per unit of rainfall than did the winter months. Such differences have important implications for erosion risk since soils are most commonly bare of vegetation during the autumn period, and this is also when much manure is applied. The risk of erosive events is greater during this period, once soils have rewetted, than it is in early spring.

No clear relationship was found between kinetic energy relationships and the continentality index. This was somewhat surprising given the range of sites examined, but it simplifies catchment-scale modelling.

Therefore, for input to erosion models, national regressions between daily rainfall total and mean kinetic energy were determined for each month. The prediction of total monthly kinetic energy impacting at the soil surface from daily rainfall data and information on crop cover was illustrated for 8 years of data from ADAS Rosemaund.

The data compiled in the course of this project and the interpretations carried out allow estimation of rainfall splash detachment to be calculated on a sub-annual basis. This is necessary for catchment scale erosion modelling where the impact of decisions such as crop sowing date needs to be represented. Further work will be needed to incorporate these relationships into catchment-scale models such as PSYCHIC (PE0202) and the national Phosphate Indicator.

Scientific report (maximum 20 sides A4)

Phosphate and sediment loss to surface waters are of increasing concern because of their impacts on biological diversity, fisheries and tourism, and the risk of eutrophication. Transport of P and sediment to waters is largely mediated by erosion and surface runoff, which are themselves sensitive to the kinetic energy of rainfall. Under a given set of conditions, modelled erosion is a linear function of the total kinetic energy of rainfall falling during the study period, and the relationship can be defined for each set of conditions from multiple runs of the model. A method is therefore needed for estimating this kinetic energy from a knowledge of total rainfall, which is the form in which weather and climate data are usually available to catchment-scale models. It would be expected that the number of storms, and hence the kinetic energy per unit of rainfall volume, would vary both seasonally and with location.

The objective of this project was to summarise the frequency distributions of potentially erosive storm energy for study sites representative of the range of seasonal rainfall volume and an index of continentality within England and Wales. Continentaility is a measure of the ‘storminess’ or variability of rainfall intensities at a site, and is defined as the ratio of the expected 1 hour and 48 hour rainfall totals with a return period of five years. These values are calculated from long runs of detailed rainfall records.

The report comprises two sections. Firstly, the procedure for determining potentially erosive storm energy is described and the findings presented. Secondly, the potential use of the data are described in terms of characterising particle detachment and sediment transfer, which are important precursors in the prediction of phosphorus loss as identified in past and current DEFRA funded research (e.g. NT1027, PE0202).

1. Determination of potentially erosive storm energy

The following procedures were carried out

1.1. *Identification of suitable rainfall data sources in terms of length and completeness of record*

The continentality index was mapped (Figure 1) for England and Wales. The index is defined as the ratio of the expected 1 hour and 2 day rainfall totals with a return period of five years. The return period data, supplied by the Met. Office, was produced in accordance with the Flood Estimation Handbook,1999 (FEH).

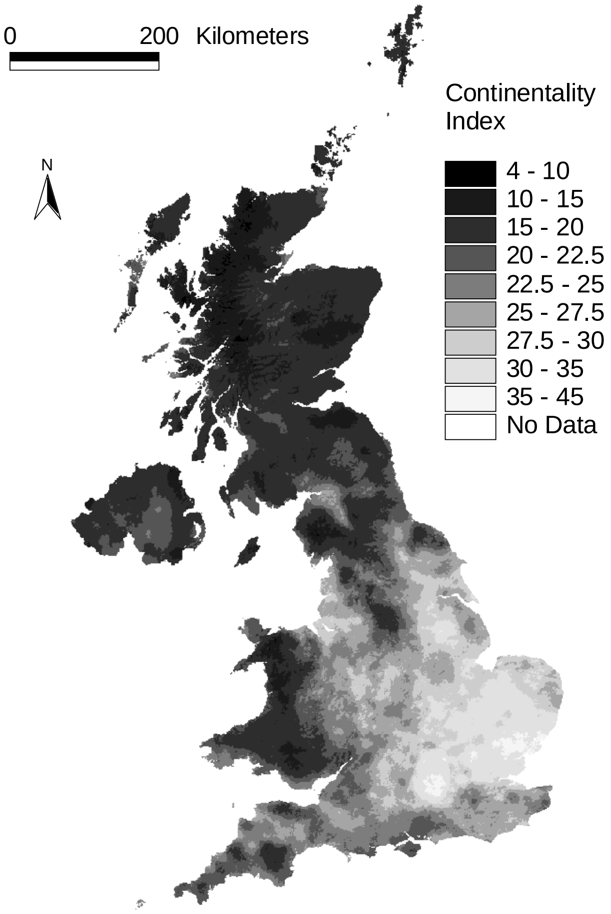


Figure 1

Figure 1 shows the continentality index has low values in high rainfall areas with relatively light short duration rainfall in Wales, northwest and southwest England, and high values in low rainfall areas with frequent thunderstorms i.e. southern and eastern England.

1.2. Validation of Tip Time Data Against the Daily Archive

The Met Office retains original recordings (tip-time data) from tipping bucket rain gauges at a range of sites, totalling 185, across the UK. The length of record varies between 1 and 15 years depending on the site. These records were examined and a subset was selected, the criteria being at least 10 years of data. The subset was further narrowed to maintain a range of continentality within England and Wales.

The raw tip-time data were transformed into daily total (24 hours running from 0900 GMT to 0900 GMT the next day). This time period is in accordance with standard Met Office observational procedures for daily total rainfall. The daily totals were then validated against quality controlled archive values for each site. Linear regressions were carried out on the data. The r^2 value of the regressions had to exceed 0.90 to pass the quality check. A number of sites failed this quality check and were therefore deleted from the analysis

Table 1 gives details of the final list of stations used in the analysis along with their continentality index and annual average rainfall.

Table1

Station	Eastings	Northings	Annual Average Rainfall	Continentality Index
1. Bala	2935	3356	1265	22
2. Boulmer	4253	6142	649	30
3. Brize Norton	4292	2067	649	39
4. Church Fenton	4528	4380	608	36
5. Heathrow	5077	1767	599	39
6. Herstmonceux	5630	1127	700	33
7. Hurn	4117	0978	791	33
8. Marham	5737	3091	621	41
9. Shawbury	3553	3221	652	37
10. St Mawgan	1872	0641	1005	29
11. Valley	2308	3758	843	28

Continentality was correlated with annual rainfall (Continentality = -0.0238 * AAR + 51; r^2 = 0.74) but there was considerable scatter about the relationship.

1.3. Calibration and validation

The number of days per year with daily rainfall total >=10mm derived from the raw data and the quality controlled data were compared for validation purposes. This is detailed in Tables 2 and 3.

Table 2 Number of Days Annually with Daily Rainfall Total >= 10mm 1986-95 (TT = tip-time, A = archive)

Station	Source	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Bala	TT	-	-	-	-	48	**45**	**41**	**42**	**48**	**31**
	A	-	-	-	-	44	**44**	**39**	**42**	**51**	**32**
Boulmer	TT	-	-	**13**	**6**	**14**	**11**	**13**	**18**	**15**	12
	A	-	-	**11**	**6**	**16**	**11**	**13**	**20**	**15**	15
Brize Norton	TT	12	**18**	**14**	**22**	**6**	13	**21**	16	**9**	**20**
	A	17	**18**	**14**	**22**	**7**	16	**20**	23	**10**	**21**
Church Fenton	TT	-	-	**13**	**9**	**10**	**5**	**17**	**13**	**13**	**12**
	A	-	-	**15**	**10**	**9**	**5**	**16**	**14**	**13**	**12**
Heathrow	TT	-	-		14	**8**	**15**	**11**	**13**	**13**	**14**
	A	-	-		14	**7**	**15**	**12**	**14**	**13**	**14**
Herstmonceux	TT	-	26	19	17	**14**	**24**	-	**30**	**31**	**21**
	A	-	-	-	-	-	-	-	**30**	**31**	**22**
Hurn	TT	-	**26**	18	24	**21**	**21**	**29**	29	**28**	**31**
	A	-	**24**	22	28	**21**	**21**	**27**	36	**30**	**33**
Marham	TT	-	-	**8**	9	**10**	**8**	**15**	**23**	14	**9**
	A	-	-	**8**	12	**11**	**8**	**16**	**24**	18	**10**
Shawbury	TT	-	-	**14**	**16**	**7**	**11**	**18**	15	**11**	**12**
	A	-	-	**14**	**16**	**9**	**10**	**20**	20	**12**	**14**
St Mawgan	TT	-	-	**37**	**26**	**34**	20	**29**	49	**42**	26
	A	-	-	**37**	**28**	**35**	23	**32**	53	**42**	30
Valley	TT	-	-	**18**	17	**17**	**11**	**22**	**18**	**25**	**18**
	A	-	-	**21**	22	**18**	**10**	**22**	**15**	**24**	**17**

Table 3. Number of Days Annually with Daily Rainfall Total >= 10mm 1996-2001

Station	Source	1996	1997	1998	1999	2000	2001
Bala	TT	**37**	**32**	**49**	**52**	46	**34**
	A	**39**	**33**	**47**	**49**	56	**34**
Boulmer	TT	**11**	**17**	**29**	**16**	**21**	-
	A	**10**	**17**	**30**	**15**	**24**	-
Brize Norton	TT	**9**	**15**	**17**	**20**	**24**	**12**
	A	**9**	**15**	**17**	**20**	**24**	**12**
Church Fenton	TT	**7**	**11**	**17**	**16**	**27**	**13**
	A	**9**	**11**	**18**	**14**	**25**	**11**
Heathrow	TT	**10**	**4**	**14**	**14**	**19**	**22**
	A	**10**	**4**	**14**	**14**	**21**	**23**
Herstmonceux	TT	**21**	**26**	**28**	**24**	**40**	-
	A	**21**	**27**	**27**	**24**	**40**	-
Hurn	TT	**21**	**25**	24	**28**	**43**	5
	A	**25**	**29**	30	**27**	**43**	**-**
Marham	TT	**15**	**13**	**17**	**14**	**18**	22
	A	**15**	**13**	**17**	**15**	**17**	18
Shawbury	TT	**8**	**13**	**13**	**18**	**19**	**14**
	A	**10**	**13**	**14**	**18**	**20**	**15**
St Mawgan	TT	**37**	**29**	**41**	**33**	**35**	**27**
	A	**38**	**29**	**41**	**33**	**36**	**25**
Valley	TT	**13**	**17**	**24**	**23**	**34**	**16**
	A	**15**	**16**	**25**	**23**	**32**	**15**

As can be seen in Tables 2 and 3 there were differences between the totals. A criterion was set to exclude years with differences of 5 or more days. This removed a number of years from most sites but all sites had a minimum of 10 years of validated data. The years included in the final analysis are shown in bold.

1.4. Station Based Rainfall Datasets

In order to validate the site data it was decided to compare the 15 minute site data with 15 minute interval data calculated using the Flood Studies Report, 1975 (FSR). The FSR is the standard reference book of rainfall return period data. It does not contain raw data at a subhourly level and so could not be used to calculate kinetic energy directly. Return periods were calculated for twice in one year, once a year, once every two years, once every five years and once every 10 years for each site. The 15 minute data were used because they are the basis of many detailed erosion model calculations, since they provide the most detailed practicable information on rainfall energy.

The following method was used; the frequency of 15 minute totals over the time period of each site within class intervals was counted. The total number of years of data was then divided by the frequency to produce a return period. Thus, if a given class of 15 minute totals occurred 5 times in 10 years, the return period would be 2 years. A logarithmic relationship was found between the return period and the rainfall amount. A linear regression was carried out with resulting r^2 of between 0.8 and 0.9. The regression equation was applied to the standard return period time intervals and rainfall totals resulted.

Table 4 details the comparison of return period data calculated from the site data and using the ITED system for the site at Brize Norton (NGR 4292 2067).
(The ITED is the Met Office system to calculate rainfall return period data using Flood Studies Report methodologies.)

Table 4

Return Periods of 15 minute events at Brize Norton

Interval	ITED value	Data Derived value
Twice in 1 year	5.5	4.5
Once a year	7.6	5.8
Once every 2 years	9.8	7.1
Once every 5 years	12.3	8.8
Once every 10 years	14.5	10.0

Table 4 shows that the derived values were consistently lower than the FSR calculated values. These discrepancies were discussed in a personal communication with Dan Hollis of The Met Office, who is the Met Office authority on the system. His view was that since the FSR does not actually quote a factor for quarter-hour/15-minute amounts, a direct comparison is not possible. However, the factor for both 1 day and 1 hour rainfall totals is 1.16, leading to an expectation of a similar value for 15 minute totals. Complete agreement should not be expected because a) the gridded data used by models such as ITED is probably smoothed to some degree, tending to reduce the apparent intensity of rainfall; b) the amount of raw 15-minute data that underpins ITED is quite small; c) the stations used here may differ from those used in the original FSR/ITED analysis. He considered that the differences were within accepted limits.

1.5. Linkage with Rainfall Erosivity

Kinetic energy for hourly rainfall totals was calculated using 15 minute rainfall data and Equation 1 (from Morgan, 2001)

Eq. 1

$$KE = 8.95 + 8.441 \log_{10} I$$

KE= Kinetic Energy ($Jm^{-2}mm^{-1}$)
I = rainfall rate per hour (mm/h)

Therefore for a 15 minute event

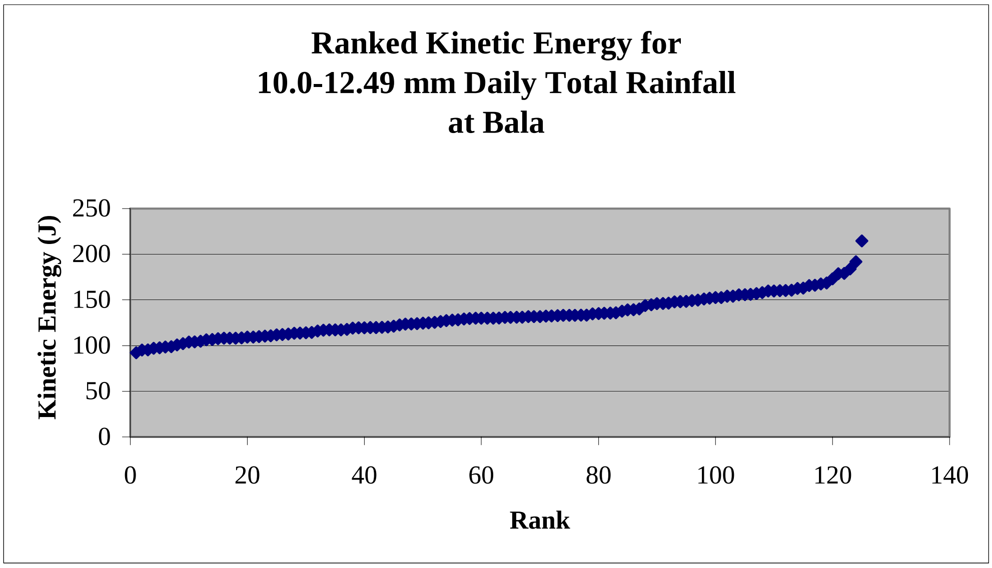
$$KE = (8.95 + 8.441 * \log_{10} (4 * 15 \text{ minute total rainfall})) * 15 \text{ minute total rainfall}$$

KE = Kinetic Energy (Jm^{-2})

The hourly kinetic energy values were totalled to give daily totals and a relationship between them and daily total rainfall were tested.

Firstly the frequency of kinetic energy with class intervals of 10.0-12.4, 12.5-14.9, 15.0-17.4, 17.5-19.9, 20.0-24.9, 25.0-29.9, 30.0-34.9, 35.0-39.9, 40.0-44.9, 45.0-49.9, 50.0-54.9, 55.0-59.9, 60.0-64.9, 65.0-69.9mm was counted. A graph showing data for the site at Bala is detailed in Figure 2. A X^2 test was carried out to test for a normal distribution. The data failed the test indicating that the kinetic energy did not follow a normal distribution.

Figure 2



Secondly, for each daily rainfall class, median, mean, lower and upper quartile kinetic energy values for all months were plotted against the continentality index for each site. Linear regressions were carried out on these data with r^2 values of below 0.06 showing that there is no relationship between kinetic energy values for the whole year and continentality indices.

Thirdly the data was separated into seasons as it was anticipated that sites of higher continentality, which are more susceptible to thunderstorms (FSR, 1975), may show higher kinetic energies for a given daily rainfall total than other sites. The median, mean, lower and upper quartile kinetic energy values of each rainfall class were again plotted against the continentality index for each site for the summer (summer being defined as July to September as the majority of thunderstorms occur during this period). Linear regressions were also carried out on these data. The resulting r^2 values were below 0.05 again showing no relationship exists between kinetic energy values and continentality indices.

There is a close relationship between AAR and kinetic energy; and between AAR and continentality. However, when considering daily rainfall data within specific class intervals (i.e. once the rainfall quantity component has been removed from the analysis) neither AAR nor continentality can explain variability between sites. Therefore it was decided to calculate monthly kinetic energy using data from all sites. Mean values and the distribution (median and lower/upper quartiles) are shown in Tables 5 and 6 respectively. Distribution is also illustrated in Figure 3. The absence of deterministic geographic-driven factors such as continentality and AAR in explaining variation in rainfall erosivity between sites contrasts with findings from the eastern USA (Richardson *et al*., 1983), where admittedly climatic variability may be considerably greater. A similar study in Denmark (Leek and Olsen, 2000) revealed that any spatial differences in erosivity within the country were highly transient, varying markedly between individual years. Hence the absence of apparent influence of continentality and AAR for England and Wales on mean erosivity values calculated both annually and seasonally using data from a number of years is not altogether surprising.

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Table 5

Mean monthly Kinetic Energy classified by daily rainfall total for all sites

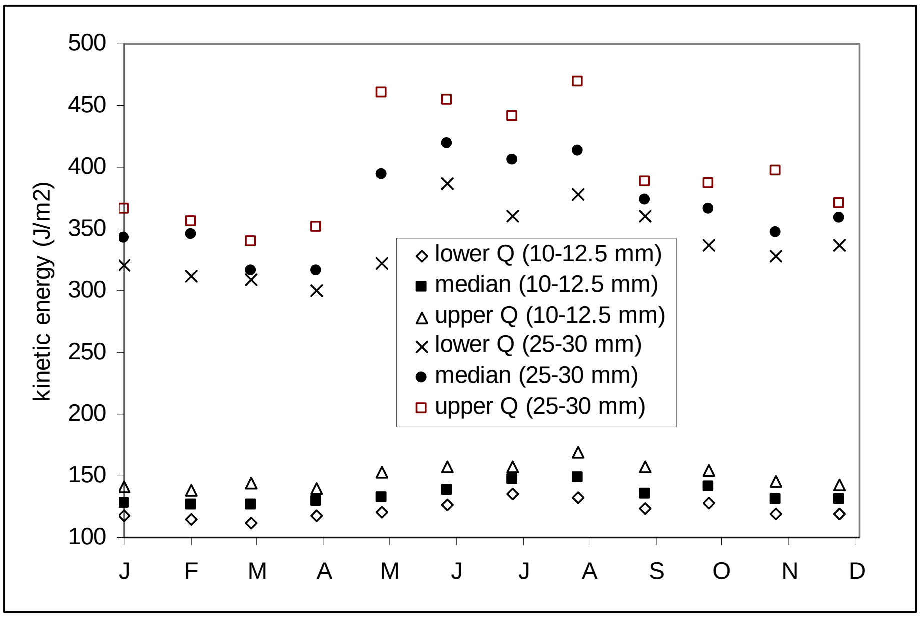
Daily Rainfall Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10.0-12.4	129.8	126.6	131.2	129.8	137.8	145.0	149.7	153.8	139.5	144.0	133.2	131.3
12.5-14.9	160.5	162.0	156.6	159.2	174.8	172.1	187.4	192.7	177.6	179.9	169.4	165.4
15.0-17.4	200.2	197.6	185.3	196.0	219.5	212.8	231.2	237.2	225.2	218.4	199.2	202.8
17.5-19.9	231.9	232.7	206.4	224.3	259.9	272.7	282.4	269.4	257.9	242.6	241.3	221.8
20.0-24.9	275.4	269.9	267.8	271.4	287.4	320.4	314.7	332.5	319.7	306.1	282.6	279.2
25.0-29.9	343.2	335.6	331.1	324.7	402.0	419.1	400.2	428.8	371.1	362.7	363.8	360.1
30.0-34.9	427.0	382.3	472.2	386.1	500.6	495.7	504.6	503.1	440.5	459.7	437.5	421.1
35.0-39.9	491.7	498.6	486.1	492.8	633.4	609.0	605.1	686.5	484.6	495.2	530.6	452.3
40.0-44.9	-	696.9	-	-	-	697.7	779.3	706.6	637.6	622.8	581.3	555.2
45.0-49.9	-	-	641.8	-	-	-	-	-	721.8	662.3	691.9	-
50.0-54.9	-	-	-	652.8	-	-	-	948.0	-	837.9	-	776.7
55.0-59.9	-	804.6	-	-	1129.7	1048.1	-	1117.3	923.0	916.1	-	727.6
60.0-64.9	-	-	-	-	-	-	-	-	-	-	-	-
65.0-69.9	-	903.5	-	-	-	-	-	-	-	-	-	-

Table 6

Lower quartile, median and upper quartile kinetic energy for all sites (daily rainfall 10-30 mm only)

Daily Rainfall Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10.0-12.4	117.3	114.1	112.5	117.2	121.2	127.1	135.0	133.0	123.4	128.3	119.2	119.2
	127.4	126.6	125.9	129.5	131.9	137.5	146.8	149.0	135.8	141.2	130.9	130.8
	141.7	137.6	144.5	140.3	153.2	156.9	157.1	168.6	157.0	154.9	144.9	142.2
12.5-14.9	147.7	143.6	147.6	140.3	154.9	146.7	166.8	169.8	151.6	162.3	156.3	149.7
	159.5	159.4	155.8	153.4	177.2	165.5	176.3	191.1	171.4	176.5	166.7	165.5
	172.2	180.6	161.4	171.4	192.5	198.0	207.0	207.7	194.4	194.8	181.3	177.7
15.0-17.4	186.4	182.0	165.4	173.6	190.6	182.7	200.2	205.5	198.0	197.5	184.5	185.6
	195.9	202.8	188.6	191.8	218.0	200.2	220.9	223.4	222.5	214.8	196.5	202.2
	209.3	215.0	198.5	218.6	236.3	235.5	258.6	260.7	245.4	231.4	214.0	213.2
17.5-19.9	218.6	209.7	191.3	197.0	225.9	229.4	236.8	238.2	229.7	221.9	223.9	206.8
	231.8	236.7	214.1	218.9	238.8	265.1	279.4	256.4	254.8	235.4	237.0	223.2
	244.7	249.4	224.4	240.2	273.9	291.9	316.9	297.9	274.3	260.0	264.1	240.5
20.0-24.9	256.3	242.4	248.8	239.6	242.9	283.5	269.1	310.0	282.9	284.5	264.9	252.7
	269.9	263.7	267.1	273.3	292.3	315.5	296.5	334.3	304.1	304.0	282.6	270.4
	292.1	302.5	285.3	303.6	296.8	341.8	368.4	353.1	345.1	334.7	304.5	300.7
25.0-29.9	321.1	311.7	308.1	300.1	322.6	387.1	359.8	377.5	359.8	337.0	327.6	336.9
	342.7	345.7	316.1	316.1	393.7	419.0	405.4	413.3	373.4	365.7	347.7	358.4
	366.8	355.2	339.1	351.1	459.6	454.1	441.8	468.4	388.8	386.2	396.4	370.9

Figure 3



2. Linking potentially erosive rainfall energy and prediction of sediment loss

The sediment and P loss models which have been developed and applied under recently completed DEFRA funded research can be broadly divided into two categories:

1) field/farm scale approaches which maintain a relatively high level of process representation. These are typically used to predict the dynamics of response from individual storm events (e.g. use of EUROSEM (Morgan et al., 1998) linked to P transfer functions (Sharpley *et al*., 1995) as developed under NT1027),

2) catchment scale approaches which focus on prediction at an annual time step (e.g. PE0105 indicator tool).

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The ongoing PE0202 catchment mitigation project will involve developing strong linkages between the models developed for use at contrasting spatial and temporal scales of resolution. To date a framework for high risk area assessment has been developed; and this will be used as a foundation for the model (PSYCHIC) to be incorporated into the demonstration decision support system at the end of the project. This "prototype" PSYCHIC model has in a considerable part been founded on the P Indicator tool. However, it is being further developed to embody more explicit representation of sediment and P movement processes (detachment, adsorption and desorption) at notional plot-scale. These estimates are then modified by estimation of landscape delivery and results are spatially integrated to a single prediction of loss to watercourse for a catchment. For the plot-scale component the approach of Sharpley *et al*. (1995) has been adapted to work with the Morgan Morgan Finney model (MMF) of erosion loss (Morgan, 2001). To date, the "prototype" PSYCHIC model has been used on an annual time step.

For prediction of plot-scale losses at a yearly temporal resolution, MMF uses AAR together with an assessment of the intensity of erosive rain (11 mm/hr is quoted as a representative figure for temperate climates). Estimation of the erosivity as a function of AAR requires relationships such as those developed above for England and Wales. In PE0202 it is our ambition also to move towards development of a model at finer temporal resolution at which it can be expected to have available the spatial distribution of rainfall at daily resolution. To achieve this, data of the type collated in Tables 4 and 5 are of crucial importance because when modelling at the national scale, or the scale of very large catchments, it will not be feasible to call upon rainfall at half hourly resolution. Given the absence of any location-dependent factors other than AAR in determining the nature of the probability distributions of kinetic energy for a specific site, as demonstrated in Section 1 above, seasonal variation and rainfall totals alone therefore should be used to drive the procedure for defining the kinetic energy of the rainfall input. Figure 4 shows the range of variability in the relationship between daily rainfall total and mean kinetic energy on a monthly basis.

Figure 4

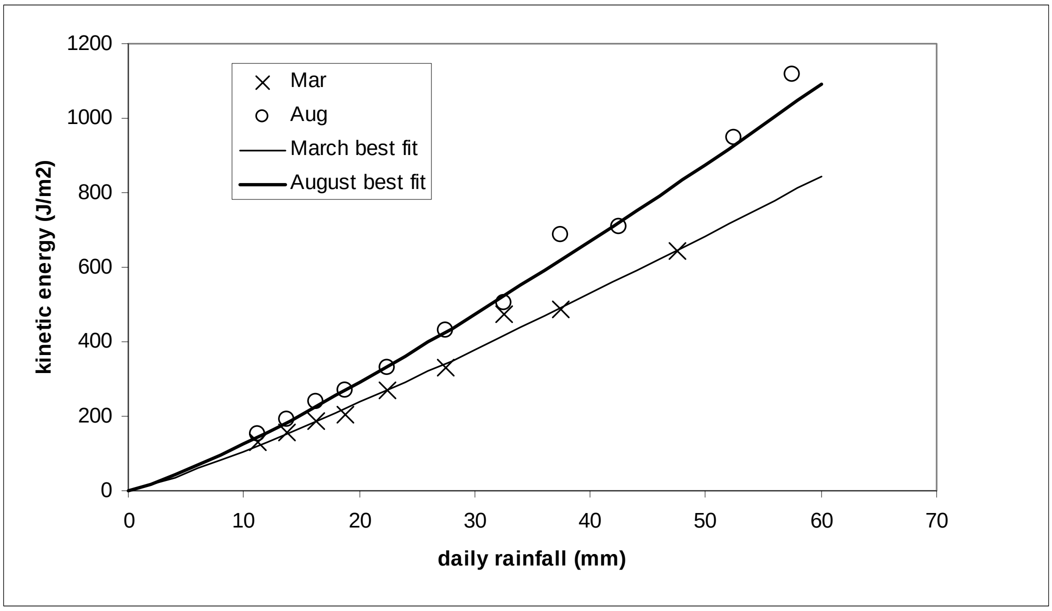


Figure 4: The relationship between daily rainfall and kinetic energy. As an example the figure uses the values displayed in Table 5 for March and August. Regressions are of the form y = ax^b

2.1. Prediction of total kinetic energy

The data from Table 5, expressed as J/m^2/mm rainfall, have been used to predict monthly estimates of rainfall kinetic energy (J/m^2) using functions employed in the MMF model. The proportion of rainfall reaching the ground as direct throughfall is calculated using functions employed in the MMF model. This also requires information on cropping. The kinetic energy of the direct throughfall was calculated on a daily basis using regression equations to determine a value per mm. Examples of these regressions for March and August are given on Figure 4. Splash detachment is a key driver for sediment transfer both in overland flow and through drains. With knowledge of soil erodibility, splash detachment is derived from kinetic energy using a direct linear relationship. Figure 5 shows predictions of total kinetic energy summarised on a monthly basis using rainfall data from ADAS Rosemaund between 1990 and 1998. Figure 6 shows more clearly how the relationship between daily rainfall and kinetic energy, which itself varies seasonally, is manifested in actual seasonal differences in total monthly input kinetic energy, including the effects of changing crop cover. For these predictions IRRIGUIDE (Bailey and Spackman, 1996) together with the MMF model were used with the following assumptions:

- Effective rainfall: The percentage of rainfall contributing to permanent interception and stemflow was taken from Morgan (1995).
- Cropping: a continuous succession of winter wheat crops. Crop parameters (plant height and percent cover) taken from IRRIGUIDE output. These parameters were used to partition rainfall into leaf drainage and direct throughfall.

Whilst the kinetic energy of incident rainfall governs the magnitude of rainsplash detachment, sediment transfer at field and farm scale is also controlled by surface runoff detachment and the transport capacity of the surface runoff.

Figure 5

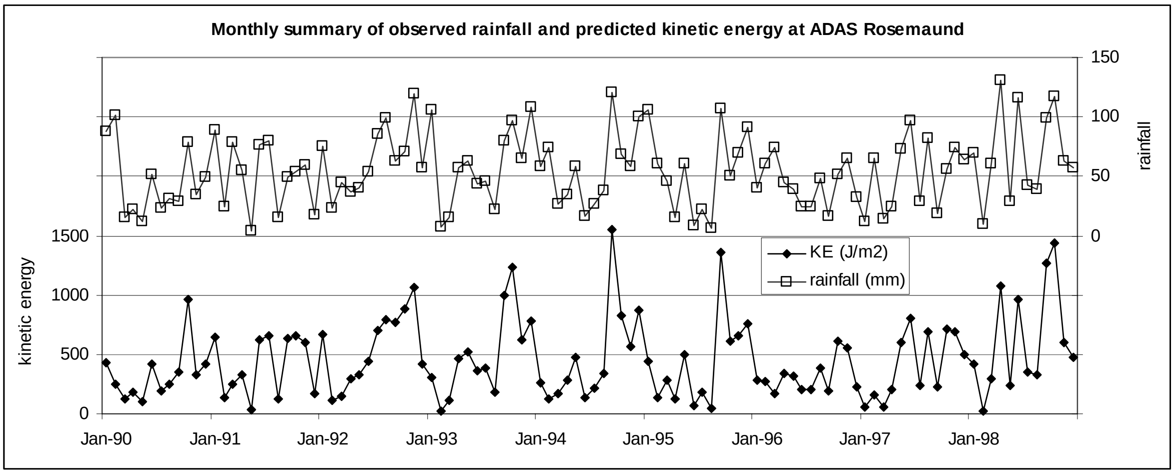
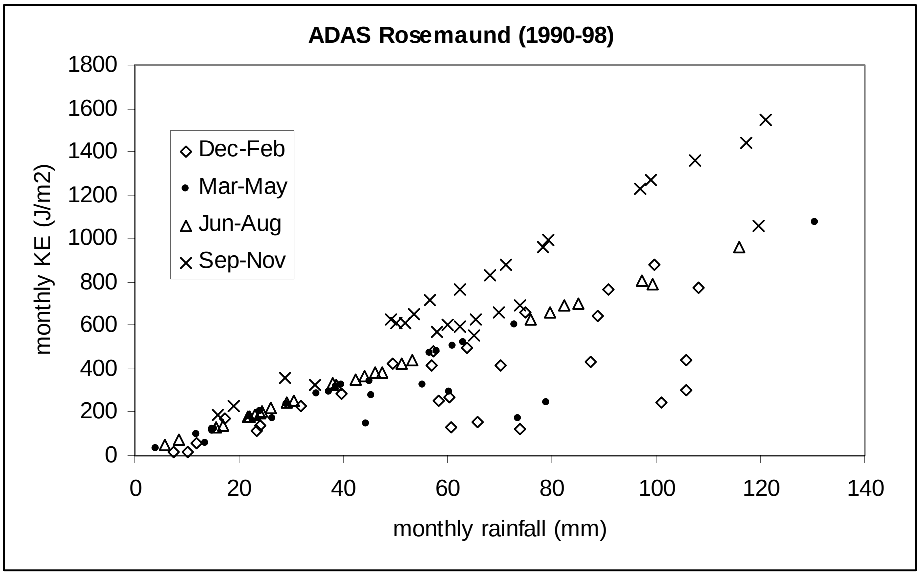


Figure 6



3. Conclusions and recommendations

1) The compilation and validation of 15-minute temporal resolution datasets has been completed. Data are available from 11 sites, reflecting the range of continentality and annual average rainfall observed across the agricultural land of England and Wales. In each case at least 10 years of data have been compiled.

The datasets represent a valuable resource for future research.

2) For all sites, daily rainfall totals above 10 mm were classified into one of 14 classes and were also indexed by month for calculation of total daily rainfall kinetic energy. Statistics of the distribution of kinetic energy revealed a complete absence of significant relationships between kinetic energy and continentality and/or annual average rainfall on an annual or seasonal basis across the range of daily rainfall totals. Differences in the continentality index across England and Wales are predominantly driven by differences in the magnitude of continuous rainfall across periods of longer than a day. These findings simplify the prediction of the spatial variability of rainfall kinetic energy for the purposes of providing inputs to catchment scale models. It is sufficient to consider seasonal factors alone (as demonstrated by Table 5).
3) The information provided on seasonal differences in expected kinetic energy totals for specific daily rainfall totals will prove invaluable in the development of catchment-scale sediment and P loss models on a sub-annual time-step. These models, which currently use an annual time-step, need to operate at finer temporal resolution in order to represent the consequences of decisions regarding such issues as the timing of manure and fertiliser applications and variation in crop sowing date.
4) Robust regressions have been derived linking rainfall total and kinetic energy on a daily basis. Mechanistically, daily kinetic energy totals provide a valuable input to models predicting rainsplash detachment. This is a key process in determining the extent of surface and subsurface transport of sediment and P. In future it may also be desirable to rederive the regressions between rainfall total and kinetic energy on a monthly basis to allow catchment-scale models to operate when the use of daily rainfall data is not feasible.

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