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Soil erosion and risk-assessment for on- and off-farm impacts: A test case using the Midhurst area, West Sussex, UK

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ABSTRACT

Soil erosion on agricultural land is a growing problem in Western Europe and constitutes a threat to soil quality and to the ability of soils to provide environmental services. The off-site impacts of runoff and eroded soil, principally eutrophication of water bodies, sedimentation of gravel-bedded rivers, loss of reservoir capacity, muddy flooding of roads and communities, are increasingly recognised and costed. The shift of funding in the European Union (EU) from production-related to avoidance of pollution and landscape protection, raises issues of cross-compliance: public support for agriculture has to be seen to give value-for-money. In this context risk-assessment procedures have been introduced to help farmers recognise sites where either certain crops should not be grown or anti-erosion measures are required. In England, Defra [Defra, 2005a. Controlling Soil Erosion: a Manual for the Assessment and Management of Agricultural Land at Risk of Water Erosion in Lowland England. Revised September 2005. Department for Environment, Food and Rural Affairs, London] sets out a system of risk-assessment, including ranking of crops susceptible to erosion and anti-erosion measures, that may be selected. We assess this system using field data for an area of erodible soils in the Rother valley, Sussex. The Defra approach correctly identifies most at-risk fields and, taken together with land-use maps, allows non-compliance with advice to be highlighted. We suggest a simple extension to the system which would further identify at-risk fields in terms of possible damage to roads and rivers from muddy runoff. The increased risk of erosion in the study area is associated with certain crops: potatoes, winter cereals, maize and grazed turnips and seems unlikely to be the result of changes in rainfall which over the last 130 years are minimal. We have not evaluated proposed anti-erosion measures in the area because few have been put into practice. The European Water Framework Directive will increasingly focus attention on agricultural fields as a source of river pollution. Assessing the risk of erosion and the need for field testing of suggested approaches, are not simply issues for the EU, but for the management of global agricultural systems.

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1. Introduction

All agricultural systems are threatened to some degree by erosion. The threat may be over short time periods or longer; the latter are particularly difficult for farmers to take account of since other threats to their livelihoods, especially farming economics, are often more immediate. In the Developed World, although starvation or eviction may not be serious threats, the issue of economic insolvency is real. Prices change by the year and failure to respond

may lead to financial disaster. For this reason the threat of erosion may be considered to be of minor account especially as the costs of off-site damage tends to be borne by others or by society at large. Over-production in the EU has led to attempts to sustain rural livelihoods and shift production-oriented subsidies to support for environmentally-friendly farming or landscape management. In this context, many EU countries introduced support for schemes that would reduce phosphorous and nitrate pollution and control muddy flooding. In England and Wales, one aspect of this policy is the Defra (2005a) advice for controlling erosion. Farmers are now required to keep land in 'good agricultural and environmental condition' in order to receive their area-based single farm payment – part of the so-called 'cross-compliance' regime (Defra, 2006a,b). One aspect of the regime requires all farmers to have carried out a soil protection review, which assesses the risk of erosion on their

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fields and requires them to reduce that risk to acceptable levels if they are to continue to receive the single farm payment. The risk-assessment approach discussed in this paper is thus linked to environmental payments available to all British farmers (Defra, 2005b). It is therefore a major financial tool for the achievement of environmental targets.

The Defra assessment of risk of erosion procedures have to be easily understood and implementable by all farmers and useable on a field-by-field basis. Traditional approaches have involved forms of modelling which, in some circumstances, are too complex or too data-hungry to be suitable. The need to return to rather simpler approaches is argued in some quarters (Favis-Mortlock et al., 2001). The question remains as to whether such an approach can give adequate results in terms of predicting the fields on which, *in actuality*, erosion occurs.

The aims of this paper are to describe and explain erosion in an area of the Rother valley, West Sussex, and to use this field-based data to evaluate the Defra scheme for erosion risk-assessment. Modifications to the scheme will also be considered.

2. The study area

2.1. Lower Greensand soils and erosion risk

This study focuses on an area of soils developed in Lower Greensand beds of Cretaceous age forming a small but important component of the agricultural soils of southern England (Fig. 1). Their easily worked, sandy and loamy character make them attractive for a wide variety of crops and this is reflected in a long history of occupation and agriculture (e.g. Scaife and Macphail, 1983).

Several studies on these soils point to the risk of erosion when used for arable farming. In the Silsoe area of Bedfordshire, erosion was recorded on experimental plots (Morgan, 1977; Morgan et al., 1987) and the same area was used for the development of the EUROSEM model (Quinton and Catt, 2004; Morgan et al., 1998). Photographic surveys of erosion were conducted by Jackson (1986) and the area was included in a MAFF erosion monitoring project 1989–1994 (Chambers et al., 1992; Chambers and Garwood, 2000). In the Isle of Wight, Lower Greensand soils of the Arreton valley, have been the subject of two studies (Turnbull, 1985; Evans, 1993) and off-site impacts on roads in the area are discussed by Boardman (1994). At Hascombe, Surrey, and Albourne and Washington in West Sussex, serious erosion was recorded on fields of winter cereals, strawberries and post-harvest maize, respectively (Boardman, 1983a,b; Boardman, unpublished).

2.2. The Rother Valley

The area of the Lower Greensand outcrop between Petersfield and Petworth is drained by the east flowing River Rother (Fig. 2). Land adjacent to the river is mostly under arable farming; higher ground to the north is under woodland and that to the south is heathland and woodland. The main arable crops in the valley are winter cereals, potatoes, maize, turnips for winter grazing, oil seed rape, and small areas of vegetable and salad crops. The number of dairy herds and therefore grassland has declined in recent years. Sears (1996) notes the steady increase in cropped land as against pasture in the Rother valley from the 1970s to the 1990s.

Lower Greensand rocks in southern England were laid down in a variety of shallow-water, near-shore marine environments and, while dominated by sands, their textures may vary (Gallois and Edmunds, 1965). Soil associations on these rocks have been mapped on the National Soil Map (1:250,000) (Mackney et al., 1983) and

described in more detail, including their constituent soil series, in Jarvis et al. (1984).

Soils on the Lower Greensand outcrop in the study area are grouped as Frilford, Fyfield 1, Fyfield 2, Shirrell Heath 1 and Shirrell Heath 2 associations. The Frilford association is comprised of well-drained sandy soils, while both Fyfield associations contain well-drained coarse to fine sandy loams (Jarvis et al., 1984). Fyfield association soils are dominant in the four sample sites; Shirrell Heath are mainly under wood or heathland. Within these soils there is considerable textural variability and a lack of local data, however, Guerra (1991) sampled 81 soils from Fyfield 1 sites around Rogate and obtained a mean value of 62% sand, 25% silt and 13% clay. Soils on eroded sites in the same study had organic matter contents of 2.1–3.8% and bulk densities of 1.3–1.9 g cm⁻³. Evans (1990) classifies the Fyfield 1 and 2 and the Frilford associations as high erosion risk. This assessment takes into account current dominant land-uses, landform and soil characteristics.

The propensity of sandy and loamy soils with silt and clay to crust is well documented and studies of erosion on Lower Greensand soils have often mentioned this as a contributor to erosion (e.g. Boardman, 1983b; Farres and Wood, 1990; Blamire, 2006). In addition, both surface and sub-surface compaction due to arable farming also increases the risk of erosion (Jarvis et al., 1984; Blamire, 2006). Widespread crusting was observed on bare and poorly vegetated soils in late 2006.

In the last two decades, field boundary removal has declined sharply in southern England. In the four Sample Sites (Fig. 2), a total of 21 field boundaries have been removed in comparison with those shown on the 1997 map (Explorer 133, 1:25,000 Ordnance Survey).

The annual average rainfall at Petworth Park (1881–2007) is 857 mm with highest mean monthly amounts in December (101 mm), November (99 mm), October (95 mm) and January (90 mm). The location of rain gauges is shown on Fig. 2.

3. Erosion in the Rother valley

The Rother valley is a well known locality for soil erosion. Every winter rills and gullies can be seen on fields adjacent to the A272 between Petersfield and Petworth with spreads of reddish sandy soil on the road (Fig. 2). Brown sandy soils around Rogate were noted as, 'often susceptible to quite considerable amounts of erosion ... although no quantitative evidence is available' (Nortcliff, 1978). In the early 1980s the village of Easebourne, adjacent to Midhurst, was affected by muddy floods from arable fields. Guerra's (1991) qualitative survey of eroding fields in the Rogate area covered an 18 month relatively dry period with many fields affected by wash and rilling predominantly in the autumn and winter months. In the winter of 1994/1995, Robinson (1999) carried out questionnaire surveys of farmers in two erosion-prone areas of southeast England, one of them being on the Lower Greensand between Rogate and Midhurst in the Rother valley. The erosion hazard had little impact on land-use decisions but farmers claimed to be using low-cost anti-erosion measures.

Sediment entering the River Lod, a tributary of the Rother, originated on post-harvest potato and leek fields but reached the river via wheelings, a gate, a road and a drainage ditch as a result of a rainfall event on 1 February 1995 (6.5 mm at Petworth Park). The presence of straw bales and sediment traps suggested that this was not the first occurrence of its kind (Theurer et al., 1998). Sears (1996) points out the dramatic increase in high to moderate risk erosive land within 2 km of the Rother in the period 1971–1991 and that although buffers of grass or woodland often exist along the river, there is field evidence that these are by-passed by water and sediment using field drainage systems, farm tracks, roads and ditches. Excessive fine sediment in the river channel is seen as

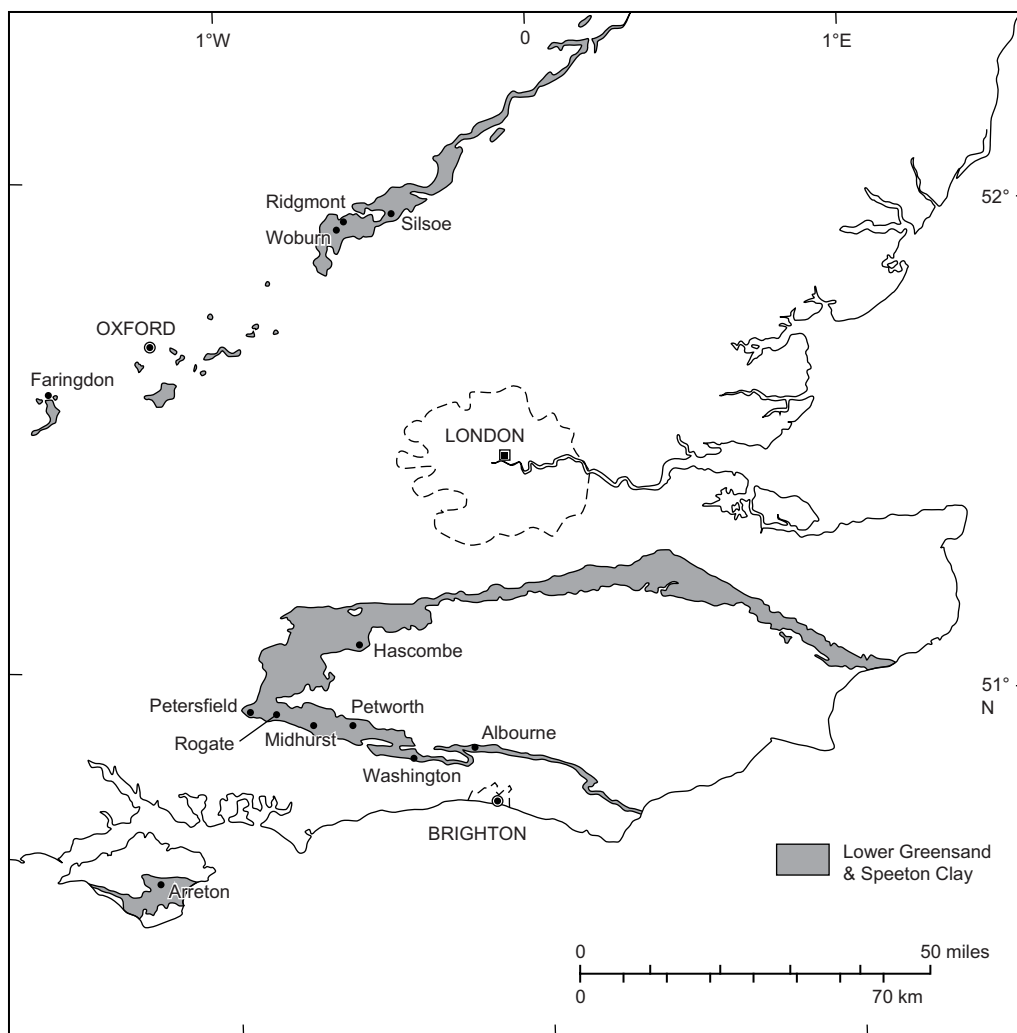


Fig. 1. The Lower Greensand outcrop in southern England.

a threat to fish breeding in sand and gravel-bedded rivers. A significant increase in the sediment load entering the Rother due to the change from grazing (mainly dairy farming) to arable land-use is identified as ‘the foremost issue that currently threatens the viability and sustainability of fisheries within the Western Rother’ (EA, 2002). The recent update of the Fisheries Action Plan for the Rother speaks of the ‘serious threat posed to the catchment by the input of silt ... impacting upon the ecology and fish stocks of the river’ (EA, undated). Pollution from pesticides and phosphates is also associated with siltation.

In 2002 as a response to concerns about water quality in the river, The Rother Valley Landcare Project, a partnership between the Sussex Downs Conservation Board, English Nature and the Environment Agency (EA), was set up to work with farmers to reduce the impact of sediment and other pollutants on the river. The project ceased in 2005 due to loss of funding from the EA.

In late 2002 serious sediment pollution took place as a result of the development of a large gully which discharged into Costers Brook, a tributary of the Rother.

In the winter of 2000–2001, there was extensive erosion in the Rother valley. Air photographs taken in March 2001 were analysed with respect to erosion features (rills, gullies and fans) formed on arable fields. Four Sample Sites were selected for detailed analysis covering an area of 16.2 km² (Shepherd, 2003) (Fig. 2). The analysis was carried out in 2003 and therefore field checking was not

possible. The high quality coloured photographs show clearly rill networks. Erosion features on a small number of arable fields had been ploughed-out by the time the photographs were taken. It seems likely that all arable fields with incomplete crop cover suffered erosion during that winter (John Blamire, personal communication). The numbers of eroded fields as seen on the air photographs will therefore slightly underestimate actual numbers (Table 1).

In the autumn of 2006 serious erosion began in September and the four previously identified Sample Sites were visited throughout the following year: there were 26 day-visits from 22 October 2006 to 25 October 2007. Field mapping of erosion features was carried out in these areas. Rills, gullies and fans were recorded on base maps of about 1:15,000 scale and notes of land-use, crop cover and farming practices were made. Maps and notes were updated at every visit. Work was concentrated on Sample Site 2 where the most serious erosion occurred. Mapping was not confined to the boundaries of the site because fields outside the area were contributing runoff and sediment to those within the area (Fig. 3). On selected fields, measurements were made of length, cross-sectional area and the number of rills and gullies in order to estimate erosion rates (Table 2).

Comparison between erosion in the 2 years 2000 and 2006 cannot be exact because of the different methodologies used. However, it seems extremely likely that in both years all arable

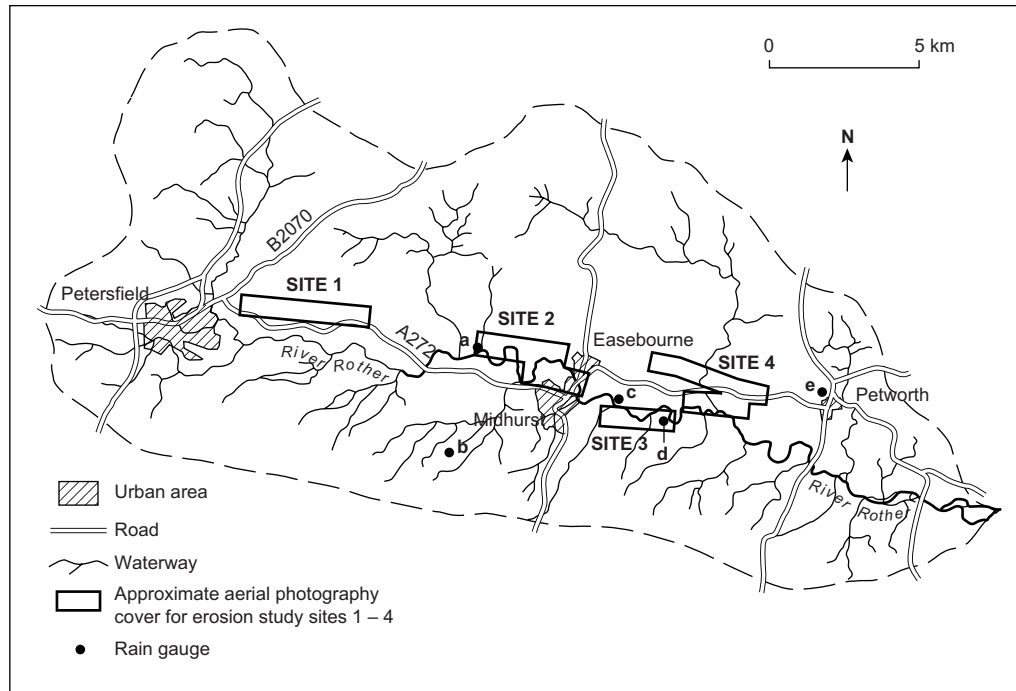


Fig. 2. Location of Sample Sites in the Rother Valley. Rain gauges: a. Iping Mill, b. Didling, c. Cowdray Park, d. Midhurst, e. Petworth Park.

fields with growing crops in the winter suffered erosion. The exception, noted below, is that eight fields of ungrazed turnips in 2006 did not erode or suffered small losses (Table 2). Erosion in 2000 was not quantified in terms of amounts. Rainfall was considerably greater in the critical months of early winter 2000 and land-use was different so that erosion was not present on all of the same fields in the 2 years. Erosion was not on the same fields in the 2 years because the rotation of wheat, fodder turnips, potatoes and oil seed rape is typical in the area. However, of 37 ephemeral gullies in the four Sample Sites in 2000, 15 occurred in the same dry valleys or depressions in 2006. The importance of 'landscape memory' is also emphasised by Griffin (2007).

The impact of runoff and eroded soils from fields in all Sample Sites was clearly seen with spreads of sand on roads regularly cleared by local councils in the winter of 2006–2007. The minor road network plays an important role as a routeway for muddy runoff from fields particularly in Sample Site 2, where many roads are eroded several metres below the level of surrounding fields ('sunken lanes': Barton, 1987), with north to south gradients toward the River Rother (Fig. 3). In one case, runoff travelled over 1500 m along roads to reach the Rother at Stedham Bridge. This flow, as well as causing severe sedimentation in the river, also resulted in the flooding of a row of cottages at the bridge. Potatoes and wheat seed from upslope fields was transported to gardens of the cottages (BBC TV, 2007). Observations during rainfall and runoff events identified a number of points at which muddy runoff enters the river (Fig. 3). Previous studies also noted by-passing of grassed flood plains by sediment and various points of sediment entry into the river (Sears, 1996; Shephard, 2003).

4. Assessment of risk

4.1. The (Defra, 2005a) scheme: context and approach

Assessment of risk of erosion has traditionally been carried out by application of one of the many available models. The assessment may refer to actual or hypothetical conditions, e.g. with climate or

land-use change as a variable. The scale may be a single slope, regional, country or global and the approach can be used to predict the impact of long-term average conditions (e.g. Universal Soil Loss Equation) or a single event (e.g. EUROSEM). However, the trend to use complex, computer-based models has led to issues of data availability, expert inclusion in running the models, and validation of model results (Favis-Mortlock et al., 2001; Jetten and Favis-Mortlock, 2006; Boardman, 2006).

The targeting of scarce public monies on sites that can be identified as at-risk of erosion has long been advocated (Boardman, 1988a), but financial support for production on a tonnage or headage basis has, in the European Union, been preferred. Recent introduction of agri-environmental measures, and the principle of cross-compliance, has returned the debate to how best to support production, protect the environment, and ensure a measure of value-for-money in terms of agricultural subsidies.

In this context, new agri-environmental measures in England and Wales propose a system of identification of high-risk erosion sites, leading to the selection of measures to prevent erosion on those sites, in return for financial support. Each field is assessed, by the farmer, on the basis of soil texture and slope and a map of ranking from very high to low risk is produced for the farm (Defra, 2005a). Because farmers are asked to carry out the assessment a simple, easy-to-use system was introduced (Table 3).

Erosion risk is also associated with crop cover and Defra (2005a) provides a ranking of susceptible land-uses which includes

Table 1
Erosion in the Sample Sites.

Sample Site	Area (km ²)	Number eroding fields 2000	Number eroding fields 2006
1	3.95	17	13
2	4.90	19	21
3	2.58	7	3
4	4.77	12	17
Total	16.20	55	54

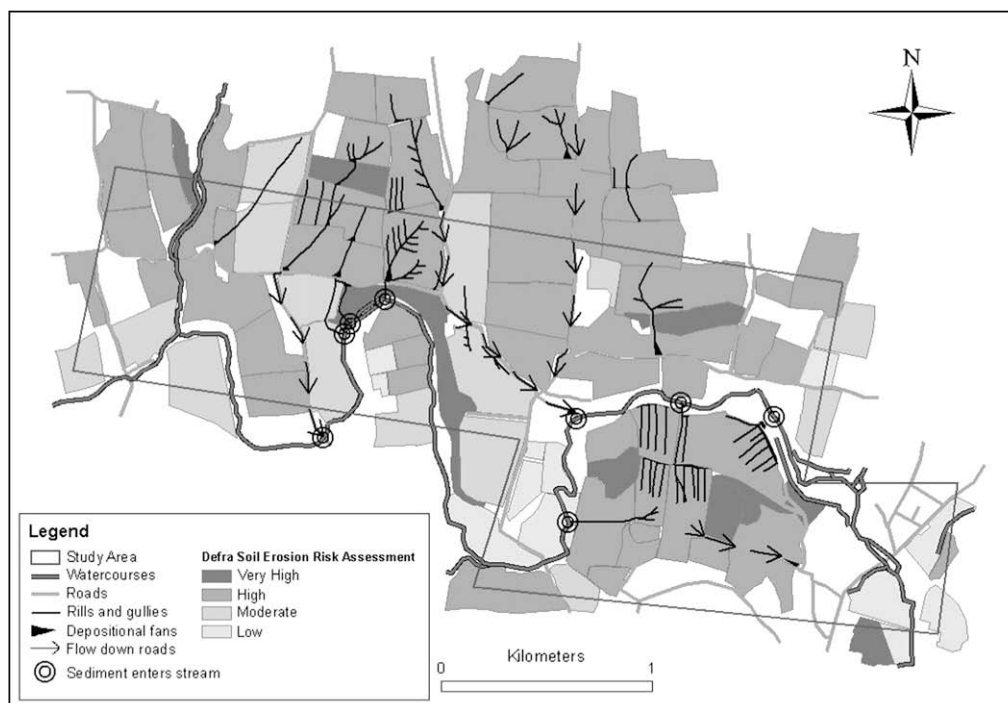


Fig. 3. Risk of erosion in Sample Site 2 based on soil texture and slope.

potatoes, sugar beet, maize and grazed fodder crops in the highest risk category. A note is added that on high and very high-risk sites (Table 3), the highly susceptible land-uses should be avoided unless measures are taken to control erosion. Thus, there is a clear warning that certain combinations of soil texture, slope and crop type will lead to high-risks of erosion. Farmers are required to identify high-risk sites and either put in place anti-erosion measures or avoid high-risk crops on these sites in order to meet cross-compliance rules and so be eligible to receive their Single Farm Payment.

In order to test the efficacy of the Defra (2005a) system of risk-assessment all fields in Sample Site 2 were assessed according to soil texture and slope (Fig. 3). Texture was assessed with reference to Table 3 and slope was estimated using the contour interval on OS 1:25,500 scale maps. Land-use in the autumn and winter of 2006–2007 was mapped (Fig. 4). Fields where land-use that was highly susceptible to erosion coincided with sites classified as at high or very high-risk on the basis of soil texture and slope were recorded as non-compliant with Defra (2005a) advice (Fig. 5). On these figures sites of erosion are also represented. In the year 2006–2007 measures to reduce the risk of erosion appeared to be absent.

4.2. How successful is the Defra risk-assessment scheme?

In Sample Site 2, in the autumn of 2006, there were 25 fields with crops which are classified as highly susceptible to erosion by (Defra, 2005a): winter cereals, post-harvest potatoes and grazed fodder crops (turnips); that is all of the arable fields in the site – as listed in Table 2 (Fig. 4). Of these, 20 were on sites that are classified as at high or very high-risk of erosion (Fig. 3) and thus are non-compliant with Defra advice (Fig. 5). Of the 20, field mapping recorded erosion on 18. Two without erosion were under turnips for grazing by sheep. This crop protected the fields from erosion in the wetter early winter period although grazed turnips are known in this area as a high-risk crop. The ranking of fields in Table 2 shows that the most serious erosion (the top seven cases) is on high

Table 2

Soil loss and erosion risk (Defra) on arable fields in Sample Site 2, winter 2006–2007.

Field no. and area (ha)	Land-use	Erosion forms	Soil loss ($\text{m}^3 \text{ha}^{-1}$)	Defra erosion risk
10 (7.2)	Post-harvest potatoes	Rills, gullies, fans	180*	High
21 (7.5)	Winter cereal	Rills, fans	91* (383**)	High (very high)
16 (4.1)	Winter cereal	Rills, gullies, fans	56* (231**)	High (very high)
26 (9.4)	Winter cereal	Rills, gullies, fans	50*	High
8 (9.9)	Winter cereal	Rills, gullies, fans	49*	High
11 (4.3)	Winter cereal	Rills, gullies, fans	31*	Very high
9 (8.9)	Post-harvest potatoes	Rills, gullies, fans	24*	High
24 (9.2)	Post-harvest potatoes	Small gully, +few rills	nm	Moderate
22 (13.8)	Winter cereal	Rills, fans a small gully+	nm	High
39 (10.8)	Winter cereal	Rills & small gully	nm	High
4 (12.2)	Winter wheat	Rills and small gully	nm	High
59 & 36 (17.6)	Winter cereal	Small gullies and rills	nm	High
20 (4.1)	Winter cereal	Rills and fans+	nm	High
33 (6.3)	Winter cereal	Small gullies	nm	High
38 (5.4)	Winter cereal	Gully and fan	nm	High
32 (7.4)	Forage turnips	Small gully+	nm	Moderate
12 (6.0)	Forage turnips	Small gully+	nm	Moderate
13 (6.4)	Forage turnips	Small gully+	nm	Moderate
7 (11.8)	Forage turnips	Small gully+	nm	Moderate
27 (8.9)	Forage turnips	Small gully	nm	High
2 (8.3)	Forage turnips	Small gully	nm	High
34 (4.6)	Winter cereal	Small gully and fan	nm	High
31 (15.9)	Forage turnips	No erosion	/	High
1 (2.8)	forage turnips	No erosion	/	High

Fields are ranked semi-quantitatively based on soil loss from top (most serious) to bottom of the table. (Field numbering as on Fig. 4). *Average rate for whole field; **average for worst affected part of field; nm not measured; +mainly due to runoff from higher fields.

Table 3
Water erosion risk-assessment.

Soils	Steep slopes >7°	Moderate slopes 3°–7°	Gentle slopes 2°–3°	Level ground <2°
Sandy and light silty soils	Very high	High	Moderate	Lower
Medium and calcareous soils	High	Moderate	Lower	Lower
Heavy soils	Lower	Lower	Lower	Lower

From Defra (2005a): Controlling soil erosion.

or very high-risk sites. The Defra scheme was therefore 90% successful (18/20 cases) at identifying the high-risk sites given the land-use at the time. This analysis highlights the level of non-compliance with advice to control erosion. It is noteworthy that all cases (5) of small amounts of erosion on sites classified at moderate risk were caused, at least in part, by runoff from upslope fields. The Defra scheme identifies six areas of high or very high-risk of erosion on steep slopes which are kept under woodland.

4.3. Can the Defra risk-assessment scheme be improved?

In view of concern about off-site impacts of muddy runoff, including reference to the problem in Defra (2005a), it is surprising that the assessment scheme merely considers risk on a field-by-field basis and not the cumulative impact of runoff from a series of connected fields. In this area it is clear that movement of runoff and soil from field to field and from field to river is a major problem (Fig. 3). Many field maps of erosion show the importance of the movement of water from field to field, especially in situations where large blocks of land are under the same crop (Boardman, 2001; Evans and Boardman, 2003). Risk-assessment should therefore take into account the issue of connectivity. This, however, is difficult because of the lack of information about field boundary permeability. However, farmers are capable of assessing the passage of water and soils through gates and field boundaries and

onto roads and into rivers. Risk in such cases, can also be evaluated after field evidence has been collected and therefore, after the event.

As a compromise, we suggest that the Defra scheme could be adapted simply by taking into account if a high or very high-risk field has: (a) a road downslope; and (b) a river within 200 m downslope (Walker, 2007). This will change the at-risk category of some fields and highlight those where crops susceptible to erosion should be grown with care (Fig. 6). On the risk of erosion map (Fig. 3), nine fields fall into the very high-risk category but eight of these are under permanent grass or woodland. On the risk of damage to road and river map (Fig. 6), 19 fields are now in the very high-risk category, 12 of which are currently under permanent grassland or woodland and therefore unlikely to generate runoff.

4.4. What is the role of rainfall?

A previous Defra scheme for erosion risk-assessment divided the country into areas above and below a mean annual rainfall threshold of 800 mm, presumably on the grounds of simplicity (Defra, 1999). This ignored the problem of rainfall variability (both spatially and temporally) and failed to consider 'at-risk' periods where high daily/monthly totals, for example, may have coincided with the most vulnerable periods for erosion (sowing and post-harvesting): areas that normally fall below 800 mm could be at serious risk in wetter years. This is illustrated in Fig. 7a.

However, a more general question remains: is there a trend towards more rain, or more intense rainfall events that could explain the increasing amounts of erosion and which should be taken into account in any risk-assessment scheme? With this in mind we have analysed the nearest long-term rainfall record to Midhurst, that of Petworth Park, using monthly data from 1881 to 2007 and daily data from 1907 to 2007 (Fig. 7a). Four short gaps were filled with data from Midhurst which, of local gauges, has the highest correlation with that of Petworth. We analysed changes in

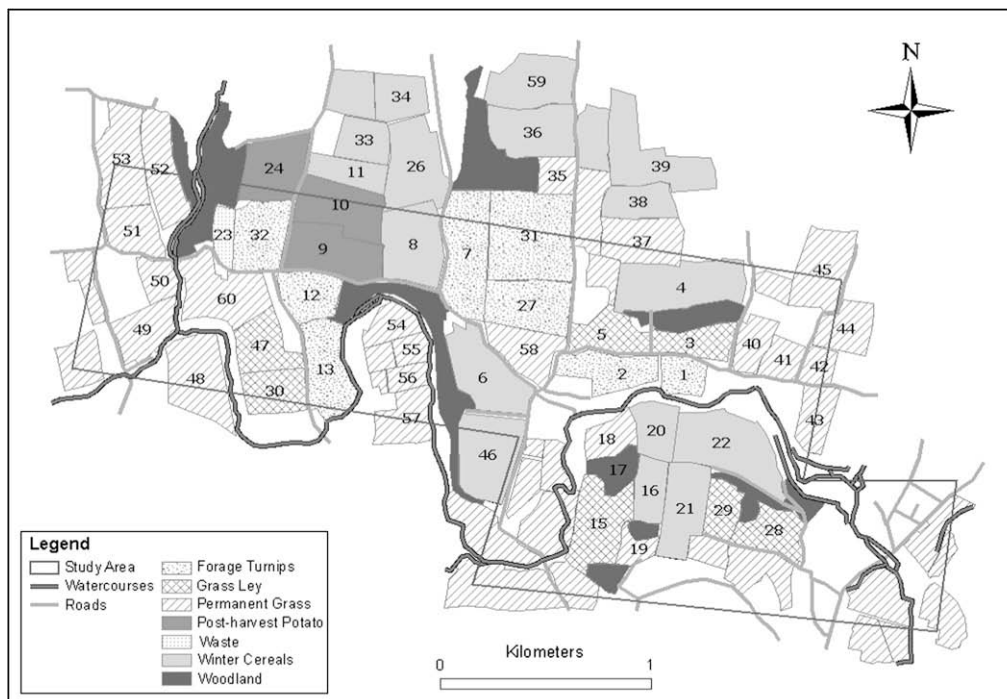


Fig. 4. Land use in Sample Site 2 autumn and winter 2006–2007.

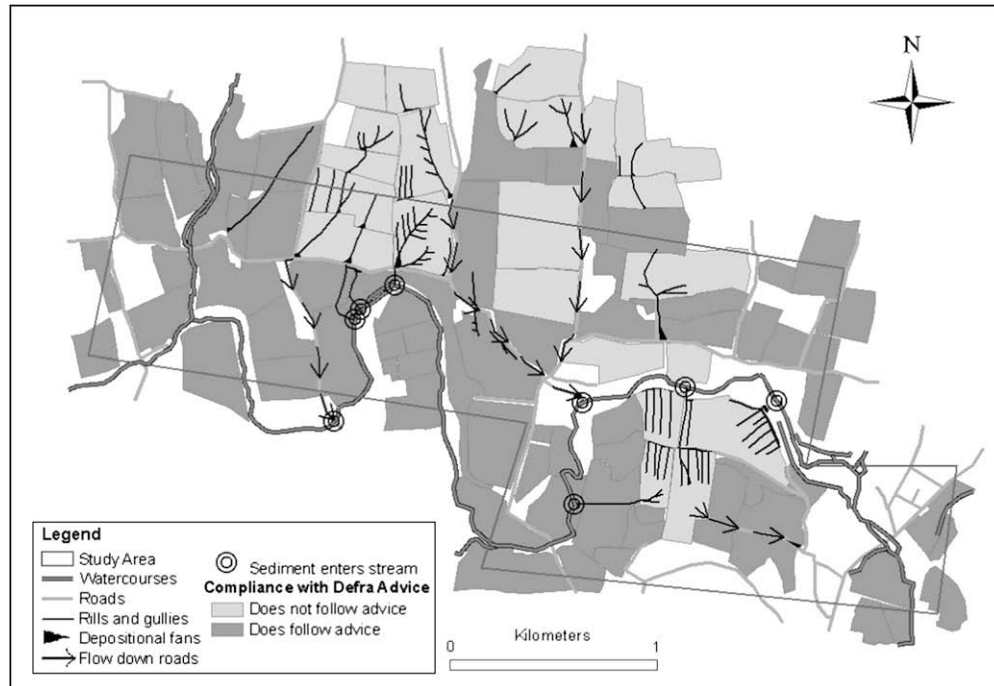


Fig. 5. Compliance with (Defra, 2005a) advice based on soil texture, slope and land-use, autumn and winter 2006–2007 in Sample Site 2.

spring (March–June) and autumn (September–December) rainfall because of the risk of erosion on spring-sown crops (cereals, maize and potatoes) and autumn-sown crops (cereals, grazed turnips and post-harvest fields of maize and potatoes).

The number of raindays with >10 mm, >20 mm, >30 mm and >50 mm of rain was also analysed in view of the importance of rainfall intensity in generating runoff and erosion, especially on highly erodible soils.

There are few statistically significant trends in the data. There is a slight decrease in the number of >10 mm raindays in spring, post-1960, and for the same period there is an increase in the number of >20 mm raindays both annually and in the autumn (Fig. 7b). There is a concentration of extreme events post-1960, with 3 years recording more than two >50 mm daily rain falls. Two years, 2000 and 2006, were especially wet with annual totals of 1429 mm (the wettest on record) and 947 mm respectively. Serious erosion



Fig. 6. Risk of damage to road or river downslope of field in Sample Site 2.

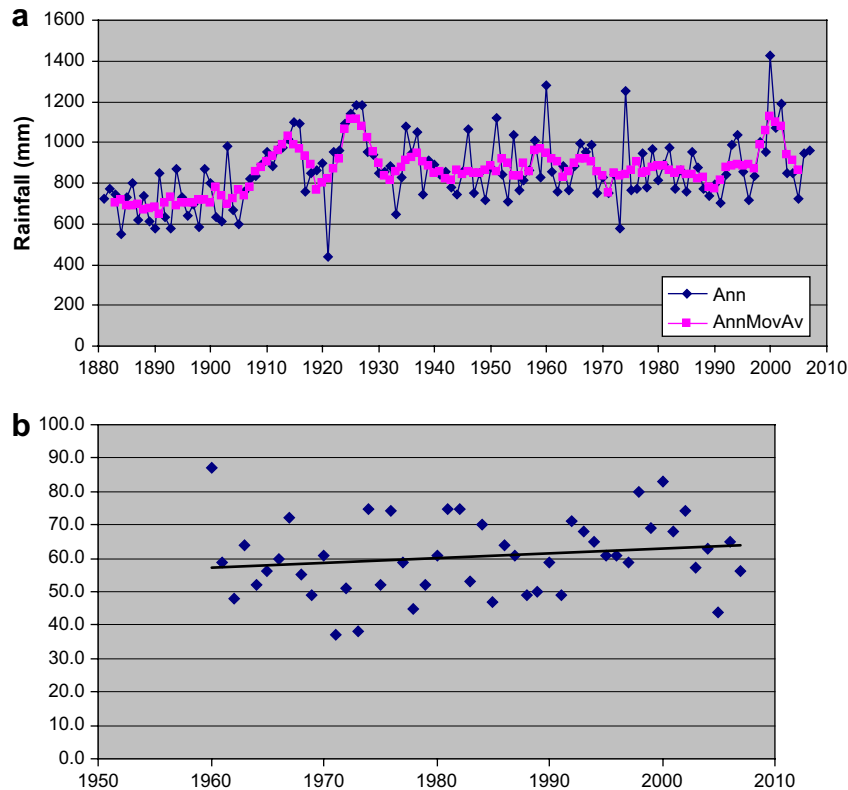


Fig. 7. a. Annual rainfall Petworth Park 1881–2007. b. The number of >20 mm raindays in autumn–winter at Petworth Park post-1960.

occurred in both years in the autumn–winter period with high monthly totals.

There is considerable local variability in rainfall amounts even though the rain gauges in the Rother valley are all at altitudes of between ca. 20 and 55 m above sea level. This is illustrated by an analysis of the magnitude of the rainfall event that initiated erosion in the autumn of 2006, on 28 September. For the 2 days, 28 and 29 September local gauges record: 26 mm (Midhurst); 33 mm (Cowdray Park); 52 mm (Iping Mill) and 25 mm (Didling); these are all within 5 km of Sample Site 2, whereas at Petworth Park, 11 km distant, the total was only 15 mm.

5. Control of runoff and erosion

Erosion is extensive in the Midhurst area on arable land in years such as 2000 and 2006 when rainfall is above average. It could be argued that all land should be taken out of arable production but this is unnecessary and unrealistic. In the four Sample Sites many fields were affected by what could be defined as ‘minor erosion’. Of 54 eroding fields in 2006, only 17 contained ephemeral gullies and rill systems. The most serious erosion was on fields in Sample Site 2 which are on high-risk sites under crops susceptible to erosion (Table 2). Thus a limited number of fields which are not compliant with Defra advice need be taken out of arable use or measures introduced to control erosion. Future movement of erosion-susceptible crops onto high-risk fields would have to be avoided. Large-scale reversion to grass in the area is unrealistic because farmers are growing high-value crops and payments under the Environmental Stewardship scheme would not compensate them for this change. However, there is no certainty that the menus of erosion control measures listed in Defra (2005a, 2006a) will be effective on high-risk sites, with erosion-susceptible crops, in

wetter years. To eliminate risk on such sites reversion to grass is necessary.

Measures to control muddy runoff, which affects other fields, roads, watercourses and residential properties are relevant in this area. One approach consists of detaining water within fields – the engineering solution. Small dams or retention ponds have been used widely for this purpose (e.g. Boardman et al., 2003, 2006). In 2002, the National Trust, owners of Woolbeding Farm, at the centre of Sample Site 2, commissioned a consultant to design a series of retention ponds that would contain muddy runoff. This approach was adopted because the then tenant would not consider any other measures and wished to continue farming potatoes, maize and grazed turnips at sites that regularly eroded (Dr N. Haycock, personal communication). The proposed dam-site map shows 25 retention ponds. Mapping in the autumn of 2006 found two dams and three low, ineffective banks and no signs of the others. However, there is no certainty that retention ponds alone would be effective. There is considerable evidence that they can be breached, bypassed, filled and overflow, and often are not maintained (Boardman et al., 2003). Successful soil conservation and flood prevention schemes require a multi-method approach combining land-use change, anti-erosion management measures and detention structures (e.g. Stammers and Boardman, 1984; Evans and Boardman, 2003; Evrard et al., 2007a,b). These measures are needed in a context of risk-assessment for specific sites.

6. Discussion

The rates of erosion in Table 2 are exceptionally high in comparison with published British records (e.g. Evans and Nortcliff, 1978; Boardman, 1988b; Boardman et al., 1996). However there is considerable anecdotal evidence that gullying is frequent in this area, particularly where potatoes, maize and cereals are grown and

therefore the rates estimated for 2006 are not unusual. [Shepherd's \(2003\)](#) mapping of the 2000–2001 events bears this out. The current paper shows clearly that the coincidence of soil texture, slope and crop type explains the location of eroding fields. Within the fields erosion is often localised along depressions and wheelings caused by farm vehicles ([Griffin, 2007](#)). Transfer of runoff from field-to-field is facilitated by gaps in field boundaries, loss of field boundaries, the positioning of gates and the fact that in autumn many adjacent fields are lacking sufficient crop cover to inhibit runoff and erosion.

The few significant upward trends in the long-term rainfall data suggest that erosion is unlikely to be increasing as a result of changes in the pattern of rainfall, with the caveat that wet autumns such as 2000 and 2006, undoubtedly have a significant effect. However, climate scenarios for the period to 2080 suggest winter precipitation increases of up to 30% in southern England ([Hulme et al., 2002](#)) and increases in the probability of very wet winters by a factor of 5 over the next 50–100 years ([Palmer and Raisanen, 2002](#)). Therefore, in the long-term, risk-assessment procedures will have to take into account these predicted changes.

It has already been noted that transfer of eroded soil from fields to rivers is facilitated by the historic sunken lane network. Runoff from fields into sunken lanes frequently results in the cutting of bank gullies – a process recognised in the landscape model of [Farres et al. \(1993\)](#), which is applicable to this area ([Fig. 8](#)). Runoff from fields and onto roads is frequent especially after establishment of rills and gullies on the fields. It occurs during low magnitude events, e.g. 11 December 2006 after about 26 mm on the previous 2 days; 21 February 2007 after about 19 mm on the previous 3 days.

([Defra's, 2005a](#)) risk-assessment procedure has to be seen in context. It is a field-scale approach wherein a simple question is being asked: what is the risk of erosion on a particular field? What is *not* being asked, is how much erosion will occur, when it will occur and in what parts of the field. These latter questions would require application of erosion models. Expert evaluation would be another possible approach. [Evans' \(1990\)](#) classification of 296 soil

associations in England and Wales, can be regarded as a coarse-scale scoping exercise which identifies parts of the landscape at risk of erosion. It is supported by considerable empirical evidence of erosion rates, e.g. [Evans \(2005\)](#). The soil associations in this area are clearly identified as at-risk of erosion.

A further question not posed by ([Defra, 2005a](#)) is, what is the risk of an eroding field impacting on roads and rivers? We suggest a simple extension of the system to take this into account.

The Defra scheme also ignores rainfall variability. Erosion on bare fields varies from year to year depending on rainfall amount, intensity and timing. The years 2000–2001 and 2006–2007 were clearly exceptional and serious erosion was widespread. However, we have already noted several other years when erosion had a noticeable impact on roads and rivers. The increase in the arable area in the last 30 years is likely to have increased erosion amounts and frequency.

The approach taken in this paper illustrates the use of simple field mapping in order to test the validity of a risk-assessment scheme. It also highlights the various routes by which muddy runoff from agricultural fields reaches the river. Points of entry into the river are identified ([Fig. 3](#)). In this area, the provenance of polluted runoff is easily established by mapping of rills, gullies and runoff during and after rainfall events. However, water quality is also affected by the movement of fine sediment from fields to rivers by routes which, in the absence of rills and gullies, are more difficult to detect. These high-frequency, low-magnitude flows may help explain both pollution and rising sediment yields in southern English rivers (e.g. [Harrod, 1994](#); [Foster et al., 2003](#); [Evans, 2006](#)).

The threat to the ecology, and in particular to the fisheries, of the Rother is clearly acknowledged by all parties ([EA, 2002](#), undated). The European Water Framework Directive places responsibility, and vests powers with the Environment Agency to return the river to 'good ecological status'. It is not clear that the EA's plans for monitoring the condition of the river will be adequate nor that actions will be taken against land managers for allowing sediment into the river.

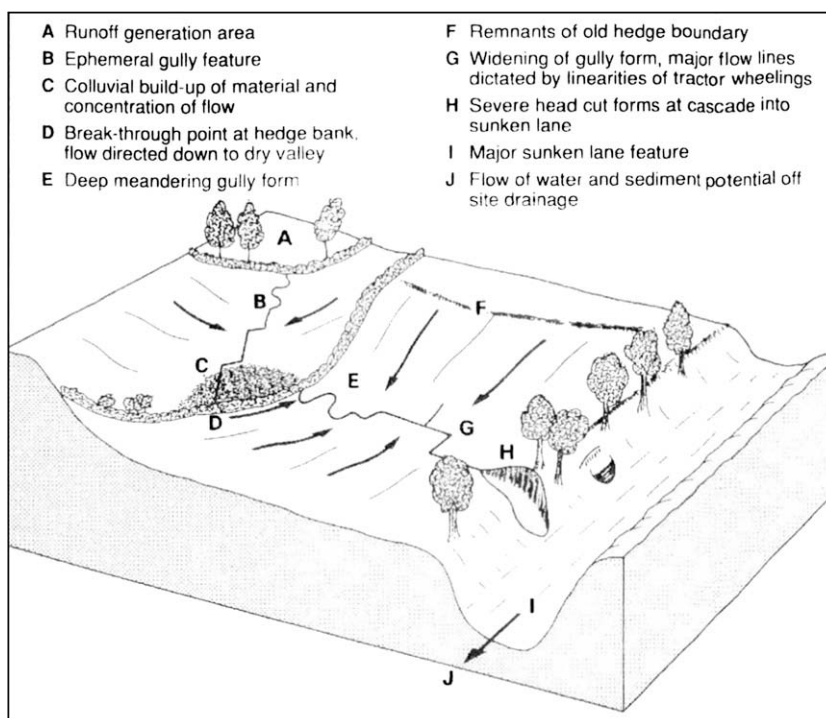


Fig. 8. Erosion on agricultural landscapes in Northwest Europe ([Farres et al., 1993](#)).

Modifications to the Defra risk-assessment scheme could be made. For example: (1) more accurate assessments of slope; (2) acknowledgement of areas of steeper slopes within fields that increase the average risk of erosion; (3) inclusion of the risk of impact of runoff on roads and rivers; (4) more sophisticated assessment of runoff origin by use of a GIS flow accumulation approach; and (5) some consideration of the risk of rainfall. However, all of these modifications would mean a loss of 'user friendliness' and would therefore need careful consideration.

7. Conclusion

The success of the Defra (2005a) risk-assessment scheme will depend on several factors. Firstly, that the scheme is recognised as an efficient means of identification of at-risk sites; secondly, that it leads to land-use change on vulnerable sites or the introduction of effective anti-erosion measures; thirdly, that farmer compliance with recommendations is regularly checked in return for agri-environmental payments; fourthly, that the scheme is not rendered obsolete by the recent rise in crop prices particularly wheat; and fifthly, that it be extended to cover off-site impacts since this would aid in the achievement of 'good ecological status' for rivers.

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