Sediment deposition and delivery for a small agricultural catchment during a major rainfall event in Belgium

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SUMMARY: Erosion and deposition patterns within an agricultural catchment in the Belgian Loam Belt were mapped and measured after an extreme rainfall event. From these data, the erosion and deposition budget was calculated. The survey clearly indicated that the deposits could be differentiated according to the type of process that caused deposition. For most deposits the topography was the controlling factor. However, important deposits were also found at field borders, where a vegetation barrier caused deposition. If a vegetation barrier is present, deposition starts at a significantly higher slope angle. The collected data show that sediment delivery to rivers could significantly be reduced by a well-considered choice of agricultural land-use within the catchment, even in the absence of specific structures to control sedimentation. The aggregate-size distribution of the sediment deposits in front of vegetative barriers is finer than the sediment deposited under topographically controlled conditions. However the dispersed size distribution of both types of sediment are almost similar and only slightly coarser than the dispersed size-distribution of the source material. Considerable quantities of fine material and associated pollutants, which could be expected to be exported to the river system are thus trapped within the catchment.

- Full-grown wheat fields are efficient in trapping sediment
- Vegetative barriers trap more fine sediment than topographically controlled deposits
- The selectivity of the deposition process is compensated for by the presence of aggregates in the deposits

1. INTRODUCTION

It is well known that not all sediment that is eroded within a catchment is delivered to the stream. Deposition may occur within the catchment area reducing the sediment yield at the outlet of the catchment. However, during major rainfall events flow competence is higher, compared to less extreme events (Slattery and Burt, 1995). Control measures should be especially effective for these events.

Both the total quantity (i.e. the total amount) and the quality of sediment exported from hillslopes or catchments are important parameters towards a better understanding of non-point pollution of our river systems. The quality of the exported sediment is strongly dependent on the sediment size distribution. The dispersed particle size analysis of the deposited and transported sediment is of particular importance since most nutrients and contaminants are bound to clay particles. On the other hand the undispersed size distribution of the sediment gives information on the erosion mechanisms, on the transportability of the sediment and on the size selectivity of the deposition process (Slattery and Burt, 1997).

Control measures that reduce significantly the export of sediment and sediment sorbed pollutants to streams have extensively been studied. During the last decades experimental studies have been conducted to evaluate the sediment-trapping efficiency of control measures such as grass strips (e.g. Van Dijk *et al.*, 1996), stiff-grass hedges (e.g. Meyer *et al.*, 1995) and near natural riparian forest (e.g. Hairsine, 1996) .

The sediment delivery of an agricultural catchment is also determined by the spatial organization of land-use within the catchment. The end of spring is a high-risk period for soil erosion in the Belgian Loam Belt because of the occurrence of high intensity rains falling on fields with summer crops (sugar-beets, maize, chicory, ...) having a low vegetation cover at that time (Vandaele and Poesen, 1995). If a field with a summer crop is located above a winter wheat field, the wheat will often act as a vegetative barrier to water and sediment movement because the wheat is almost full-grown at this time of the year.

This paper discusses the results of a detailed field survey, carried out after an extreme rainfall event in spring time. The objectives are (i) to investigate to what extent the sediment delivery ratio of a catchment

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is reduced by the standard agricultural land-use, i.e. in the absence of special control measures, and (ii) to compare the size characteristics of the deposited sediment with the size characteristics of the source soil material. Such information may be used to optimize the spatial distribution of land-use in order to reduce sediment and pollutant delivery to streams.

2. MATERIALS AND METHODS

The field work was carried out in an agricultural catchment which can be considered as typical for the Belgian loam belt. The catchment area is about 290 ha consisting of a rolling topography with slopes up to 17%. Soils in the catchment are mainly loess derived luvisols, truncated by erosion, with a clay content of 7-14%, a silt content of 77-81% and a sand content of 9-14%. Figure 1 shows the spatial distribution of the parcels within the catchment. The average field size is about 3.2 ha. Over 90 % of the land is used for agricultural crops.

A major rainfall event took place in this catchment on 6 June 1996 (49 mm in 30 min.). The recurrence interval of this event exceeds 200 years (Demarée, 1985). At the time the event took place, the dominant crops were winter-wheat, sugar-beets, chicory and maize. Approximately 55% of the total catchment area was under wheat-cultivation.

After the event, the location of rills and gullies was mapped and their volumes were measured. Total soil loss by gully erosion was calculated by combining gully width and depth between measured sections. Total soil loss by rill erosion for the catchment was calculated by extrapolating data from measured transects to the whole field or to that part of the field the transect was taken representative for. Volumes of interrill erosion were estimated, using data of Govers (1991), collected during comparable rainfall intensities. For the calculation of the total soil loss a bulk density of 1300 kg.m^{-3} was used (Govers and Poesen, 1985). The location of the sediment deposits was also mapped. The volume of each deposit was calculated using the measured surface area and an average depth of the deposited sediment mass. Measured bulk densities of the deposited material ranged from 1380 to 1450 kg.m^{-3}. A more detailed overview of the method of field investigation is given by Takken *et al.* (in press).

In the catchment about 30 sediment samples of the different types of deposits and of the source material were collected. Their undispersed and dispersed grain size distributions were determined using laser diffractometry (Beuselinck *et al.*, 1998a).

Figure 1: Land-use within the catchment and deposition pattern mapped after the extreme rainfall event of June 1996, classified by the dominant deposition control (2.5 m interval between contour lines (min. 80m, max. 135m))

Table 1. Measured totals of erosion and deposition differenciated by type of erosion or deposition

	(tonnes)	(%)
Erosion		
Interrill	375	9
Rill	9818	87
Gully	1066	3
Total	**11259**	**100**
Deposition		
Topographical	3224	72
Vegetative barrier	1287	28
Total	**4511**	**100**
Sediment delivery		***60***

3. RESULTS AND DISCUSSION

3.1 Quantitative study of deposited sediment

In Table 1 the overall sediment budget is presented. In total, ca. 4500 tonnes of sediment is deposited by overland flow within the catchment. This is 40% of the total mass of eroded material, resulting in a sediment delivery ratio, defined as the ratio of sediment delivered at the catchment outlet to gross erosion within the basin, of 60%.

The results of the survey clearly indicate that the deposits can be differentiated according to the type of control that caused deposition (Table 1). The main group of deposits (72%) are controlled by topography, e.g. sediment deposited in thalwegs, colluvial fans at the end of gullies and rills. A second group of deposits are found at field borders. Here the downslope vegetation acted as a stiff grass hedge (Photo 1), trapping sediment in the ponded backwater upstream of the vegetative barrier (Dabney *et al.*, 1995). This type of deposits is found on steeper slopes than the first type (Figure 2). Topographical sedimentation was found on slopes up to 4.5%. On the contrary, sedimentation upstream of a vegetative barrier occurred on slopes up to 13%.

Figure 1 shows the spatial distribution of the sediment deposits, classified by the dominant deposition control. It can be seen that topography is by far the most important factor causing deposition. However, deposition in front of a vegetative barrier is considerable.

3.2 Qualitative study of the deposited sediment

The aggregate size distribution of the deposits in front of vegetative barriers is finer than the size distribution of the topographically controlled deposits (Figure 3). This is explained by retardation of runoff in the ponded water backslope of the vegetative barrier, which allows finer particles to settle (Meyer *et al.*, 1995). There is very little variation in the content of the <2 µm size fraction between various deposits. The variation in texture within one sediment aggregate class is mainly found in the coarser size fractions.

The aggregate size distribution of the vegetation-controlled deposits is very similar to the one of the source material. This suggest that deposition under these circumstances is non-selective. If deposition is topographically controlled it appears to be selective, with a preferential export of fine material (4-32 µm). This finding is in qualitative agreement with experimental observations on topographically controlled deposition. Experimental results clearly show that the deposition process of loamy material is strongly selective: particles > 32 µm are easily deposited while 4-32 µm particles remain in

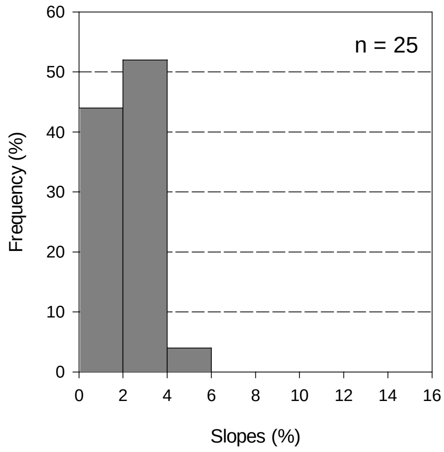

Figure 2a: Histogram of slopes below which topographical sedimentation occurs

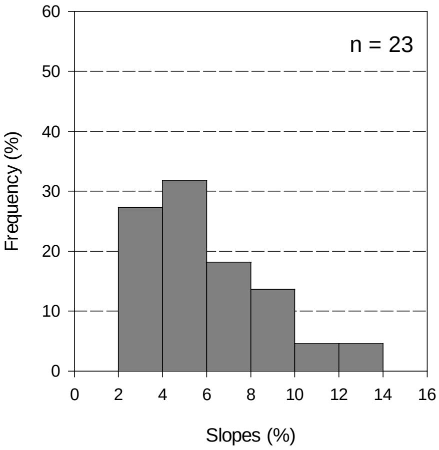

Figure 2b: Histogram of slopes below which sedimentation upstream of a vegetative barrier occurs

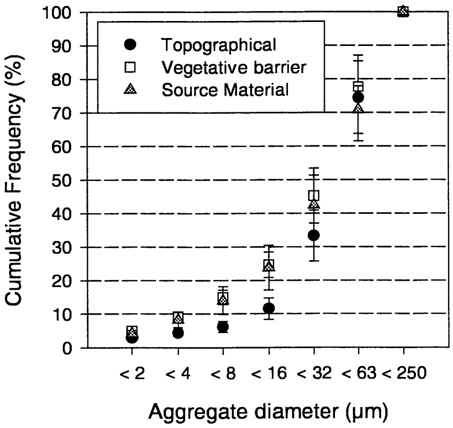

Figure 3: Undispersed cumulative grain size distribution of deposited sediment and of the source material

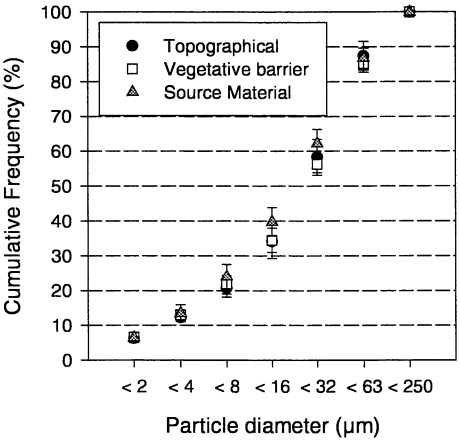

Figure 4: Dispersed cumulative grain size distribution of deposited sediment and of the source material

suspension. The presence of very fine particles (<2 µm) in deposits may be explained by sediment trapping by coarser particles (Beuselinck *et al.*, 1998b).

Contrary to the aggregated size distributions, the dispersed size distribution of both types of sediment is similar and only slightly coarser than that of the source material (Figure 4). This implies that the selectivity of the deposition process is compensated for by the presence of aggregates in the deposits. Grain size analyses of these aggregates show that they have almost the same dispersed size distribution as the dispersed source soil material. Therefore, the dispersed size distribution of the deposited material is almost totally independent of the aggregate size distribution of the material and of the hydraulic conditions during the deposition process. It is clear that this is not necessarily the case for all soils under all circumstances. If a difference between dispersed

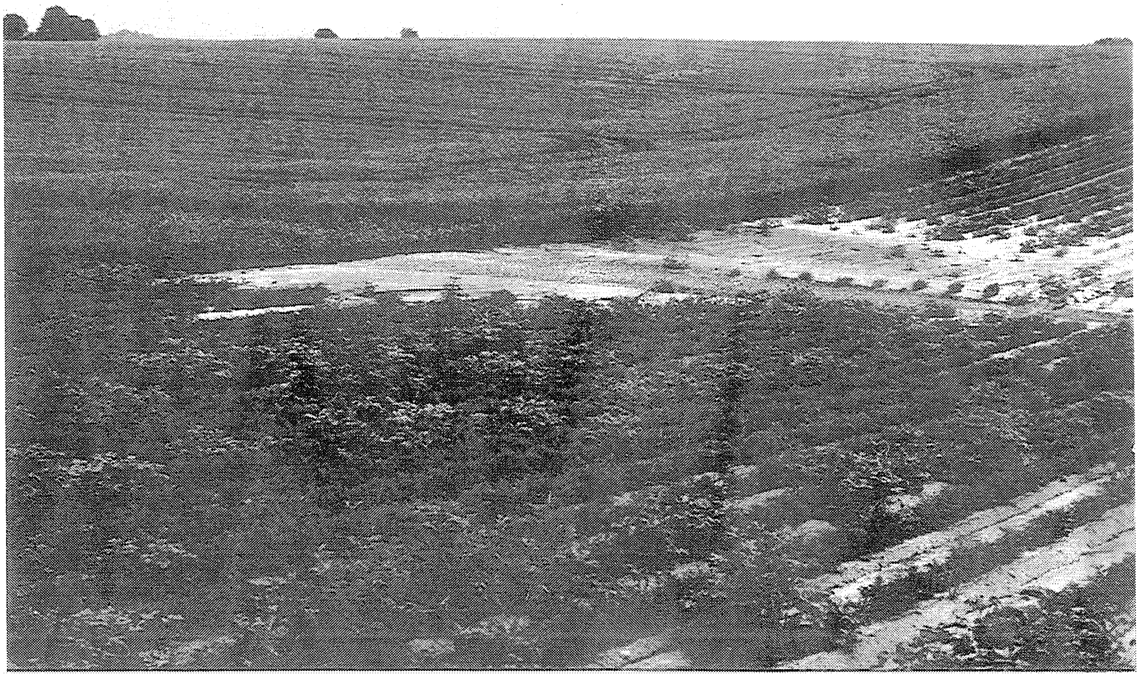

Photo 1: Example of sediment trapped by a full-grown wheat field acting as a vegetative barrier

size distribution of the aggregates and the dispersed size distribution of the overall source material exists (e.g. Slattery and Burt, 1995), size selectivity and therefore nutrient enrichment may occur even when sediment transport dominantly takes places in the form of (macro)-aggregates. Meyer *et al.* (1992) determined dispersed and undispersed size distribution of sediment eroded from 22 different soil types under intensive simulated rainstorms. The results showed that many of the soils contained large proportions of stable aggregates. For most soil types the sediment aggregates consists of almost the same primary particle size distribution as the soil itself. In some soils the coarser aggregates were enriched in clay compared to the source material. Trapping of these coarse aggregates thus greatly reduces the delivery of the fine soil particles and their associated pollutants to the river system.

4. CONCLUSIONS

The survey shows that high cover vegetation, e.g. a wheat field in late spring and early summer, is quite effective in trapping sediment on relative steep slopes: ca. 30 % of the deposition occurring during an extreme event in the catchment studied was controlled by vegetation. Full-grown wheat fields trap sediment at slopes at which no topographically controlled deposition would occur. These results indicate that sediment delivery at the outlet of the catchments could be significantly reduced even in the absence of specific structures to control sedimentation by a well-considered choice of agricultural land-use. Existing erosion-deposition models do not always take into account the effect of vegetation on deposition (Takken *et al*, in press).

Size selectivity of deposited and delivered sediment is important since it determines the quality of the sediment reaching the outlet of a catchment. The observation that the dispersed size distribution of the deposits is almost similar to the size distribution of the source material implies, that due to the presence of aggregates in the deposits, the net selectivity of the deposition process during extreme rainfall events is rather limited. Consequently, considerable quantities of fine material and their associated pollutants are trapped within the catchment.

This research clearly shows that data on the undispersed size distribution of the eroded, transported and deposited sediment is as important as the data on the dispersed grain size analysis to get a better understanding of the sediment quality of the deposited and exported sediment. Furthermore, it is clear that sedimentation models need to be based upon the aggregate size distribution of the transported material if the grain size distribution of the deposited sediment is to be predicted correctly.

5. ACKNOWLEDGMENTS

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