Flooding of properties and sedimentation in retention ponds in central Belgium

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Abstract An inquiry set up in central Belgium shows that 43% of the municipalities (n = 121) suffer every 2–5 years from muddy floods generated from direct runoff from agricultural land and 36% with flooding of permanent streams. In order to control floods, more than 100 retention ponds have been constructed over the last 20 years with 50 more due to be built in the near future. These retention ponds store large volumes of sediment from runoff events and are thus dredged regularly resulting in annual costs of the order of 1.5 million ECU. These sediment volumes can be used for assessing and predicting sediment yield values for drainage basins. Values for sediment yield vary between 0.19 and 9.32 m^3 ha^{-1} $year^{-1}$ for drainage basins ranging from 25 to 5000 ha.

INTRODUCTION

For the last few decades more and more off-site problems of soil erosion have arisen in many parts of northwestern Europe (Boardman *et al.*, 1994). This is certainly true in central Belgium. Storm runoff is often too high compared to the capacity of drainage ditches or the sewage system. This leads to flooding of lowlands such as meadows, and in properties of densely populated areas. If there is significant soil erosion in the drainage basin these floods can take the form of "muddy floods", covering the streets and floors inside houses with a blanket of mud. This not only results in financial costs to the government and private households for cleaning up, but also psychological damage to those who are frequently confronted with it.

Therefore, at different government levels measures have been taken to reduce or even avoid the damage caused by these floods. The most common way to do so is by constructing retention ponds. These ponds hold up the storm runoff for a certain time and thus limit the peak discharge to a level that is acceptable for the drainage system. However, after a few years these ponds can be completely filled with sediment which reduces their retention capacity. Therefore, the sediment has to be removed resulting in higher costs than expected when the ponds were built.

The objective of this study is to present an overall picture of the extent of the problem of flooding in central Belgium and the use of retention ponds as a control measure. This study also focuses on the problem of siltation of the ponds and on their potential for predicting sediment yield.

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FLOODING OF PROPERTIES IN CENTRAL BELGIUM

The study area

In central Belgium, the problem area was defined based on two important erosion factors, i.e. topography and soil. We selected those municipalities that are characterized by the presence of silt loam and sandy loam soils and that are situated at the transition from the coastal plains in the north and the lowland plateaux in the south. This transition is highly incised by different rivers creating a hilly topography. This area also appears as a zone affected by water erosion on the "Soil erosion map of western Europe" (De Ploey, 1989). In this zone we selected a continuous area (the hatched area on Fig. 1) consisting of 137 municipalities covering a total of 5516 km^2 (mean surface area per municipality is 4026 ha).

Data collection

An inquiry was set up in order to establish how many municipalities have to deal from time to time with muddy floods. This inquiry was sent to all 137 municipalities selected. The most important questions which address these problems can be generalized as follows with the possible answers in parenthesis:
(a) Are or have their been problems of flooding or muddy floods? (yes/no)
(b) What is their nature? (flooding of roads and/or houses—muddy floods covering roads and/or entering houses)
(c) What is their frequency and when do they appear?
(d) What is the most logical explanation for their presence? (runoff from agricultural

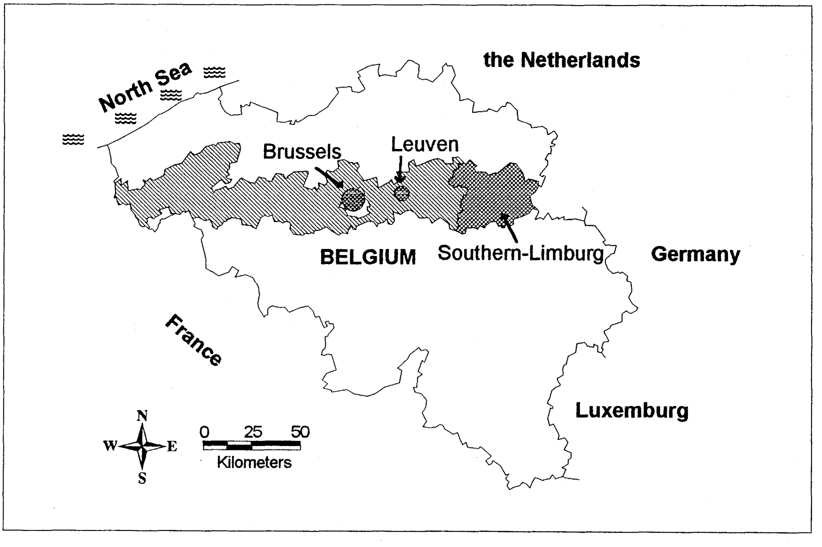

Fig. 1 Map with the location of the 137 municipalities studied in central Belgium (hatched area) including the detailed study area of southern Limburg (cross-hatched area).

land—inundation by rivers or brooks—runoff from built-up areas—insufficient capacity of sewage system)

A further investigation of the nature and extent of the problems was carried out in 21 municipalities in the eastern part of the study area (southern Limburg, see Fig. 1) covering 1088 km^2. Here almost every location that had or still has to deal with problems of flooding or muddy floods was recorded.

Results

For 121 out of the 137 municipalities contacted we received an answer to the first two questions: 25 (21%) have no problems, 44 (36%) have only problems associated with flooding and 52 (43%) also have to deal with muddy floods. For the 104 municipalities responding to more questions these figures become respectively 25 (24%), 35 (34%) and 44 (42%). More detailed results are shown in Table 1. From this table it can be deduced that the main sources of flooding and muddy floods are thought to be the inundation by rivers or brooks and the runoff from agricultural land respectively. As a general rule the municipalities that are situated in the larger river valleys like those of the Scheldt and the Leie rivers, are confronted mainly with flooding by rivers as their capacity is not sufficient to carry runoff from larger drainage basins whereas, for the municipalities that are situated further upstream, direct runoff from small agricultural drainage basins taking the form of muddy floods is the major cause of their problems.

Southern Limburg, the area that was investigated in more detail, has no less then 117 locations where flooding or muddy floods occur regularly. This means that for every 1000 ha there is one point experiencing these problems. The problem becomes even worse if one takes into account the frequency of these events: for 20% of the locations the return period is equal to or less than one year and for 90% of them the return period is equal to or less than five years. Three main sources were detected here: 41% of the locations have problems related to the runoff from agricultural land, 45% of the locations suffer from inundation by rivers or brooks and 14% of the locations have to deal with the overburdening of the sewage system (Mermans,

Table 1 Nature and source of the flooding and muddy floods.

Type of problem	Source of the problem:				Total number of municipalities
	Runoff from agricultural land	Runoff from built-up areas	Insufficient sewage capacity	Inundation by rivers/brooks	
Flooding	3* (9)‡	7 (20)‡	16 (46)‡	28 (80)‡	35
Muddy floods	37 (84)§	26 (59)§	22 (50)§	26 (59)§	44
None	†	†	†	†	25
Total	40	33	38	54	104

* Number of municipalities.

† Not relevant.

‡ Percentage of municipalities with problems of flooding that recognize this as a source of the problems (35 = 100%).

§ Percentage of municipalities with problems of muddy floods that recognize this as a source of the problems (44 = 100%).

1997). The 11 municipalities in the south of this area are experiencing problems of muddy floods from direct runoff originating in small agricultural drainage basins and flooding by rivers or brooks with high suspended sediment discharges. However, the 10 municipalities in the north have only problems with flooding by rivers with large drainage basins (Mermans, 1997), a conclusion that was also found for the whole study area.

RETENTION PONDS AS A FLOOD CONTROL MEASURE

Because of the extent of the problem and the economic and emotional costs to society, more and more efforts are being made to diminish the problems for the future. Retention ponds are the easiest way to do so although they are only limiting the negative off-site effects of soil erosion, not the process itself. In the same inquiry, the municipalities were asked whether there was already a retention pond on their property or if there were plans to build them. This resulted in a list of retention ponds, both existing or planned, for central Belgium. The most important figures are listed in Table 2. It is striking that only 15% of the retention ponds already built, whose main purpose is for the storage of muddy floods, are situated in six municipalities whereas there are 44 municipalities (see Table 1) that are confronted with this kind of problem. The reason for this is very simple: muddy floods occur over a very diffuse landscape so it is very difficult to solve the problems for more than one location with a single retention pond whereas, the problems of flooding by rivers or brooks are very localized namely near these rivers or brooks. A retention pond on or near a river or brook thus can provide protection for many locations (and properties) downstream in the valley. These ponds are therefore economically more acceptable.

Over the last 15–20 years, there has been a steady increase of retention ponds as shown in Fig. 2 for south Limburg. Furthermore, it can be seen that the number of retention ponds built especially for storing muddy floods have recently become more attractive. From Table 2 it can be deduced that already 26–29% of the planned retention ponds are constructed in order to store direct runoff from agricultural land. However, one must point out that this is only limited to three municipalities: one of them has a plan for 10 retention ponds (the city of Aarschot, northeast of Leuven) for the protection of a whole village. This project can be seen as a pilot project for a new generation of control measures against muddy floods.

Table 2 Existing and planned retention ponds in central Belgium.

	For all situations:*		For runoff from agricultural land only (muddy floods):	
	Number of municipalities	Number of retention ponds	Number of municipalities	Number of retention ponds
Existing retention ponds	51	100	6	15
Planned retention ponds	24	45–50	3	13

Note: The number of retention ponds is a good estimate but the real number will probably be higher (not all information is currently available).

* Includes both flooding by rivers or brooks as well as by muddy floods.

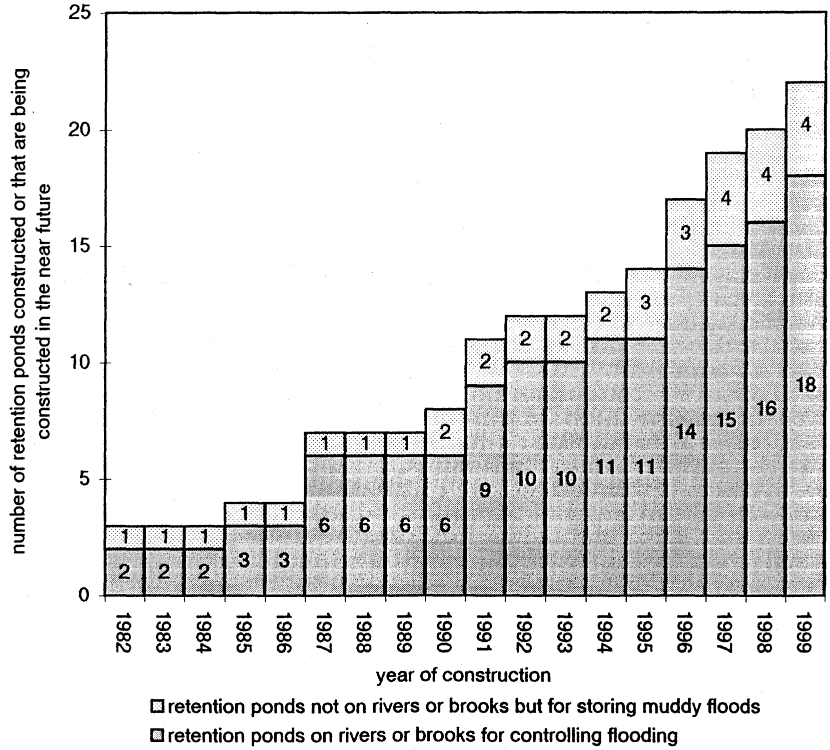

Fig. 2 The evolution of existing and planned retention ponds in the southern Limburg study area (Source: Mermans, 1997).

SEDIMENTATION IN RETENTION PONDS

Retention ponds should store the runoff from extreme events and it is well known that this runoff transports high loads of suspended sediment. In the pond, the water velocity decreases and as a result suspended particles settle. The proportion of the incoming sediment that is captured by the retention pond and which will not leave with the outflowing water is called the trap efficiency (Vanoni, 1977). As a result of the process of capturing sediment, retention ponds gradually become filled with sediment and thus their retention capacity diminishes. Hence, the pond is unable to store the runoff during the events it was constructed for and the problem of flooding re-emerges. Sedimentation is usually not accounted for when planning the ponds, except some greatly under-sized silt- or sandtraps upstream from the pond. This means that they should be dredged regularly. The result is higher costs since the removal of sediment costs around 8–10 ECU per m^3 sediment (1 ECU = 40.5 BEF, August 1997). Table 3 gives an overview of the sediment removal figures for nine retention ponds. These figures where used for a rough estimate of total values for the whole study area with approximately 100 retention ponds. Transport and dumping of the dredged sediment alone is likely to be costing more than 1.5 million ECU for central Belgium each year. This figure does not include the working hours and the use of equipment. Sometimes costs are even higher. Where sewage water from

Table 3 Sediment removal costs for some retention ponds.

Location of retention ponds	Time interval between two removals (years)	Sediment removed (m^3)	Sediment removed (m^3 $year^{-1}$)	Costs of removal per year (ECU)*	Drainage area (ha)	Sediment removed (m^3 ha^{-1} $year^{-1}$)	Costs of removal per ha per year (ECU)*
Vleterbeek	4	13 000	3 250	29 250	3 260	1.00	9.00
Douvebeek	3	8 500	2 833	25 497	2 640	1.07	9.61
St Jansbeek	5	4 600	920	8 280	4 912	0.19	1.71
Broenbeek	4	4 200	1 050	9 450	2 428	0.43	3.87
Munkbosbeek	4	2 500	625	5 625	1 104	0.57	5.13
Rooigembeek	2	8 000	4 000	36 000	1 407	2.84	25.56
Zouwbeek	2	3 000	1 500	13 500	1 357	1.10	9.90
Holsbeek	7	2 000	286	2 574	260	1.10	
Hammeveld	9†	2 100	233	2 097	25	9.32	
Mean values					1 900‡	0.85§	
Estimated total values for 100 ponds			161 500	1 453 500	190 000	0.85	

* An average cost of 9 ECU m^{-3} has been used (real values range between 8 and 10 ECU m^{-3}).

† This pond has been cleared several times during the last nine years; the figures are mean values over nine years.

‡ This is the mean value of the nine listed drainage areas.

§ This figure is a weighted average for the nine listed ponds with the drainage area as the weighting factor.

households or industry joins the runoff before entering the retention pond, the sediment becomes polluted with heavy metals, phosphates, fluorides and chlorides. Such sediment has to be deposited at a special dumping ground resulting in higher costs: e.g. one municipality (Zaventem) has to spend 50 000 ECU every two years for evacuating 400 m^3 of polluted sediment.

POTENTIAL OF RETENTION PONDS FOR SEDIMENT YIELD ASSESSMENT

Sediment yield can be measured in different ways, e.g. by sediment rating curves or using empirical models like MUSLE (Williams, 1975). The use of lake and reservoir sediments, and thus sediments in retention ponds, for estimating sediment yield is another technique (e.g. Butcher *et al.*, 1993). The sediment input in a retention pond in a given period represents a minimum sediment yield for the drainage basin (given that the trap efficiency is usually less than 100%). Only simple conversions have to be made as equation (1) points out:

$$SY = \frac{SV \cdot dBD}{TE \cdot A} \tag{1}$$

where *SY*, *SV*, *dBD*, *TE* and *A* represents sediment yield (t ha^{-1} $year^{-1}$), measured sediment volume in a retention pond for a given time interval (m^3 $year^{-1}$), dry bulk density of the sediment (t m^{-3}), trap efficiency of the retention pond (%) and drainage area (ha) respectively. The sediment removal values (m^3 ha^{-1} $year^{-1}$) listed in Table 3 are indicators of the sediment yield but these figures need to be corrected for *TE* and *dBD*. These values can vary significantly as the first results of *dBD* measurements indicate. Forty samples were taken in the Hammeveld retention pond, every sample being subdivided into two or more subsamples and oven-dry weighted for the determination of *dBD* at various depths. The *dBD* varies between 1 and 1.64 g cm^{-3} with a mean of 1.23 g cm^{-3}. There seems to be more variation vertically than laterally.

In the near future further *dBD* measurements will be made and *TE* will also be measured during runoff events for different ponds. A database of sedimentation values in retention ponds and drainage basin characteristics will be set up and used to establish an empirical model predicting the sediment yield for rural areas in the northwestern European loess belt.

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