A comparison of management approaches to control muddy floods in central Belgium, northern France and southern England

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Abstract

Muddy floods, i.e. water flowing from agricultural fields and carrying large quantities of soil, affect routinely numerous municipalities of central Belgium, northern France and southern England. A comparison of flood frequency between different European regions is difficult, because of the lack of a uniform and official database as well as the landscape heterogeneity of administrative entities. Agri-Environmental Measures (AEMs; e.g. grass buffer strips) can contribute to the control of muddy floods but their installation is voluntary and depends therefore on farmers' willingness. Actions to increase awareness and to inform the farmers proved to increase drastically their participation rate in AEM programmes. In all the studied regions, flood prone areas are increasingly taken into account to define land approved for development. Moreover, several schemes for the control of muddy floods have also been proposed at the regional scale. However, there is a spatial mismatch between the scale at which muddy floods are triggered (small catchment scale) and the scale at which public authorities can operate (municipality, grouping of municipalities, delineated flood prone areas, river basin). In future, beside curative measures (e.g. retention ponds and dams), farming techniques preventing runoff and erosion in the field (e.g. conservation tillage) should be encouraged. This could be achieved by the creation of a new AEM. Moreover, guidelines for the location of AEMs could usefully be introduced. Existing flood control schemes should also be systematically carried out by catchment agencies including legal, environmental and financial expertise. These agencies should be set up for local groupings of municipalities and provide them technical assistance to equip the flood prone areas and carry out maintenance of the implemented control measures.

Key words
Muddy floods, stakeholders, environmental management, agri-environmental measures, soil erosion, flooding of properties

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1. Introduction

In the European loess belt, water flowing from agricultural fields and carrying large quantities of soil as suspended sediment or bedload frequently concentrates and leads to muddy floods in the downstream villages (Boardman et al., 1994; 2006). They are generally triggered on silty and loamy soils which are prone to surface sealing. Central Belgium, northern France and southern England are severely affected by these floods (see e.g. Boardman et al., 2003; Souchère et al., 2003; Evrard et al., 2007a). The main physical processes contributing to muddy floods are runoff generation on crusted soils, the detachment of soil particles and aggregates by rainfall and runoff as well as the sediment transport over long distances by runoff, particularly when the flow concentrates in linear landscape features such as thalwegs, field borders and tramlines. This increases runoff connectivity, flow velocity and peak discharge between cropland and downstream villages or rivers. The occurrence of muddy floods in the different regions of the European loess belt is related to the interaction between rainfall distribution and soil surface conditions including vegetation cover (Auzet et al., 1990; Ludwig et al., 1995; Souchère et al., 1998; Takken et al., 2001; Evrard et al., in press). In Belgium and eastern France, most floods are associated with heavy thunderstorms on fields planted with summer crops (e.g. maize, sugarbeet, potatoes) and occur between May and September (Vandaele and Poesen, 1995; Evrard et al., 2007a). The floods are even more concentrated in eastern France with a peak in May and June (Van Dijk et al., 2005). In southern England on the South Downs as well as in northwestern France (Normandy), they are mainly reported in autumn and winter, associated with fields planted with cereals (Boardman et al., 2003).

Beside on-site impacts (e.g. gullying, damage to crops), muddy floods lead to numerous off-site impacts and induce high damage costs (Boardman et al., 2003; Evrard et al., 2007a). Therefore, measures controlling erosion and runoff are needed. Alleviating muddy floods is a very complicated task because it is at the crossroads of several policies. It is a combination of hydrological and geomorphological processes leading to soil erosion on agricultural land and to damage in downstream inhabited areas. Therefore, prevention of muddy floods requires spatially-integrated initiatives related to water, agriculture and environment management as well as land use policies. The multiplicity of the stakeholders involved in muddy flood management as well as their varied expectations make the definition of an integrated policy even more complex. Moreover, muddy floods are a very local phenomenon, often triggered by local thunderstorms, but they are influenced by large-scale policies. For instance, the implementation of the European Common Agricultural Policy (CAP) partly explains the increase of flood frequency observed during the recent decades (Souchère et al., 2003). Similarly, these policies encouraged the conversion of chalk landscapes in southern England from grass and spring cereals to winter cereals and led directly to the erosion problems of the 1980s. In 1992, CAP reforms introduced agri-environmental schemes, according to which farmers can receive payments to implement environmentally-friendly farming techniques going beyond good farming practices (Ritson and Harvey, 1997). However, many of the financial incentives encourage ways of tacking the symptoms of the problems (e.g. runoff, erosion), rather than the causes themselves (i.e. intensive agriculture). The extent to which agri-environmental measures are applied in order to reduce runoff and erosion could usefully be evaluated fifteen years after their introduction.

The European Commission has also recently worked on two directives that can play a role in muddy flood mitigation. First, the Water Framework Directive (2000/60/EC) establishes a common framework for water protection and management at the scale of river basin districts. Second, the Soil Thematic Strategy sets out principles to protect the soils across the EU. The member states must define their strategy to use soils in a sustainable way on their territory within this common framework. Even though agricultural and environmental policies are mainly driven by European legislation, the individual states and regions transpose and apply them locally in different ways. Beside EU-driven actions, numerous mitigation measures are taken at the regional or even the local scale.

The objective of this paper is to identify the existing strategies to mitigate muddy floods in severely affected areas of the European loess belt (central Belgium, northern France and southern England) and to point out the most effective and efficient measures that should be promoted. Stress is laid on European-driven policies and regional mitigation schemes. After a brief comparison of data sources on muddy flood frequency in the regions, we compare the mitigation measures taken at European, national and regional scales. Then, we move on to the local scale to highlight the specific initiatives taken by the farmers and the municipal authorities. Finally, effective strategies enabling integrated management of the phenomenon using appropriate tools will be proposed with respect to the management scale.

The paper constitutes an updating and expansion of earlier views of the topic (Boardman et al., 1994; Fullen et al., 2006).

2. Studied regions and available databases on muddy floods

Central Belgium, northern France and southern England are all located in the loess belt of northwestern Europe and are characterized by soils containing at least 60% silt which are very sensitive to surface sealing (Boardman et al., 1994; Fig. 1). Major landscape changes have been observed in these regions during the last decades (Souchère et al., 2003). Urbanisation has expanded into rural areas. Numerous land consolidation programmes were carried out in Belgium and in France without taking into account the limitation of hydrological transfers at the catchment scale (Evrard et al., 2007b). A regional crop specialisation is generally observed in many regions, such as large-scale maize cultivation in Alsace (Van Dijk et al., 2005). Moreover, the area under grassland has decreased during the three last decades in all of these regions as a result of the intensification of livestock breeding and dairy farming.

2.1. Physical and demographic characteristics of the studied regions

The physical characteristics of the studied regions are similar. They have significant proportions of cropland and the areas in Belgium and northern France have gentle slopes; in southern England slopes in the range 5 to 15 degrees are frequently cultivated (Table 1). Mean annual temperature ranges from 9 to 11°C, while average precipitation reaches between 700 and 1000 mm. Rainfall is well distributed throughout the year in Belgium as well as in northeastern France. In contrast, annual rainfall as well as the contribution of autumn and winter rainfall is higher in southern England (Fig. 2).

In Belgium, muddy floods are concentrated in the central part of the country where loess-derived soils dominate. The area is managed by the administrative entities of Flanders and Wallonia (Fig. 1). The Brussels region is excluded, given cropland is virtually absent from the capital city.

An important part of the areas affected by muddy floods in France is located in the northern part of the country (Le Bissonnais et al., 2002). Two administrative units (the so-called 'départements' and referred to as 'departments' in the remainder of the text) with particularly high muddy flood densities were selected for study (Aisne and Upper Rhine; Fig.

1). The Aisne department is located in the Paris Basin. The central part of the department is characterised by intensive cropping (winter cereals, sugar beet, oil-seed rape). The Upper Rhine department is characterised by widespread monoculture of maize that provides a low vegetation cover to the soil during the heavy thunderstorms of May and June (Van Dijk et al., 2005). Hilly regions of the department are particularly affected by muddy floods (e.g. Sundgau, Fig. 1).

In southern England several areas have been affected by muddy floods but good data only exists for the South Downs in the counties of East and West Sussex. The thin, stony soils of the Downs limit the range of crops that can be grown and the area is dominated by winter cereals, with some oil-seed rape and grazing for sheep. Dry valley systems drain to the south where ephemeral flows of water encounter coastal resorts such as Brighton and Worthing. The risk of muddy flooding is largely confined to the autumn and early winter months before adequate crop cover is established. To the north of the South Downs, on loamy and sandy soils on Cretaceous sandstone outcrops, intensive farming of cereals and spring-planted crops of potatoes and maize give rise to muddy flooding especially around the town of Midhurst.

General demographic and farm characteristics of the studied regions are summarised in Table 2. For a similar natural context, the studied regions show a large variation in population densities (between 73 inh.km^{-2} in the Aisne and 499 inh.km^{-2} in Flanders). Residential expansion is currently observed in the rural peripheries of large cities (e.g. Brussels, Mulhouse; Caruso, 2002). Large farms dominate in northern France (88 ha on average in the Aisne vs. 18-45 ha in the other regions).

2.2. Data sources on muddy flood frequency

The first problem arises when we want to obtain data on the extent and frequency of muddy floods and compare them. There is no uniform and official database recording muddy floods systematically in all the regions. Moreover, administrative units do not correspond to natural regions, introducing a bias in the comparison of muddy flood frequency between the different European regions.

In Belgium, the Disaster Fund (Belgian Ministry of Home Affairs) provides a database of natural disasters. Floods are not qualified as ‘muddy’ but it is possible to restrict the search excluding floods ‘due to the overtopping of rivers’. However, the Belgian Federal Government approved on May 21, 2003 a law on compulsory insurance covering natural disasters. Consequently, only the damage due to very exceptional events (leading to more than € 280 millions damage) will still be compensated by the Belgian state in the future. In this context, the most reliable data source consists of a questionnaire sent to all municipalities of central Belgium (Evrard et al., 2007a). This survey showed that 79 % of the municipalities (n=201) were affected by at least one muddy flood over a ten year period (1991-2000 for Wallonia ; 1995-2004 for Flanders). Of these 160 flooded municipalities, 22 % experienced more than 10 floods in 10 years.

In the Aisne department, the municipalities potentially affected by muddy floods can be identified thanks to the adoption of a 'flood risk prevention scheme'(PPRI). In the past, these schemes were not explicit on the nature of flooding. Since 2000, specific schemes aim to cope with muddy floods. By 2006, 51% of the municipalities in the Aisne department (n=834) required a flood prevention scheme but it had been approved in only 39 municipalities (5%).

In the Upper Rhine department, reports of natural disaster statements provide data on the flooded municipalities. Since 1982, the French Natural Disaster law provides compensation to the victims (Auzet et al., 2006). One third of the municipalities in the department (n=377) were affected by at least one muddy flood during the period 1985-2003.

In southern England there is no official attempt to collect data on flooding or damage. Boardman et al. (2003) report 138 incidents of damage to property by muddy floods in the years 1976-2001. This relates to an area of the eastern South Downs from Worthing to Eastbourne of about 496 km^2. This estimate is based on personal observation and the use of newspaper reports. There is no systematically collected data for the Midhurst area. In other areas of England, there are anecdotal reports of muddy flooding, some newspaper reports and occasional case studies in the academic literature (e.g. Boardman, 1995; Evans, 1996; Evans, 2004).

Overall, Flanders seems to be the most affected by muddy floods (Table 2). It is also the region with the highest population density. However, a comparison of flood frequency between administrative units that do not correspond to homogeneous natural regions is not objective.

2.3. Data sources on muddy flood costs

Studies evaluating the costs induced by on- and off-site impacts of muddy floods are very rare. Costs associated with single floods are available for certain municipalities (see e.g. Verstraeten and Poesen, 1999; Evans, 1996; Evans, 2004; Boardman et al., 2006). A global estimate of off-site damages induced by muddy floods has been made for central Belgium (between € 16 and 172 millions per year; Evrard et al., 2007a).

Costs induced by muddy floods in France are roughly estimated in the reports on natural disaster statements. However, insurance companies refuse to publish damage cost data because of confidentiality issues. Cost data are only made available for very local areas or individual floods. For instance, muddy floods led to a mean damage cost of € 118 ha^{-1} yr^{-1} in the village of Soucy (Aisne department) during a 10 year-period.

There is also little data in southern England on costs of damage. Robinson and Blackman (1990) report off-site costs of serious muddy flooding in 1987 at four major sites in Brighton suburbs in excess of € 957,000 excluding police and fire service costs. Most of them were borne by local councils and insurers, but at least € 162,000 was uninsured. Two major flooding incidents at Breaky Bottom Vineyard and farmhouse in 1987 and 2000 have resulted in out-of-court settlements from the insurers of the up-valley farmer (Boardman 1988, 1994, 2000, 2001). Total cost to the insurers for the 2000-01 event alone were approximately € 1.45 million.

Overall, data available show that muddy floods induce high damage costs and that these costs remain in the same order of magnitude in the different European regions.

3. Stakeholders involved in muddy flood mitigation

Muddy flood mitigation is at the crossroads of different policies (agriculture, environment, land use planning and water management). The European Commission is in charge of the European Common Agricultural Policy and prepares numerous environment-related directives. The national governments (or the regions in Belgium) have to transpose and apply them locally.

In Belgium, the regional administration funds a large number of public or non-profit making organisations that work on different topics (rural development, river or natural park management), but without any effective coordination. Roads and watercourses are hierarchically classified and managed by different administration levels (regional, provincial, local), making any ‘hydrologically-consistent’ supervision very difficult. For instance, watercourse managers must cope with siltation of rivers without any possibility to control erosion on the cultivated land draining to the rivers.

In France, a hierarchical structure prevails (State-Region-Department-Municipality). Several state services and agencies (Departmental Agency of Agriculture and Forest – DDAF;

Departmental Agency of Equipment – DDE; Water Agencies; Departmental Councils) are implicated in erosion management as well as local farmers' trade unions ('Chambres d'Agriculture'). Even though there is collaboration between these institutions, there is generally no specific structure to coordinate muddy flood mitigation. Therefore, an 'erosion task force' ('mission érosion') was set up in 1998 in the Aisne. It does not replace the other agencies, but aims to set up specific, individual and local actions. This initiative remains very local and highlights different management approaches between the French departments. The dynamism of local farmers' trade unions and departmental authorities has a major influence on the implementation of local actions to control erosion phenomena.

In England, Defra (Department for Environment, Food and Rural Affairs) is responsible for agricultural policy and thus for erosion and muddy flooding. Water quality issues under the Water Framework Directive are devolved by Defra to the Environment Agency. Natural England is in charge of the impacts on biodiversity and the Highways Agency and local authorities are responsible for flooded roads and adjacent property.

Who is in charge of risk mitigation at local scales depends not only on large-scale policies (e.g. CAP) but also on field realities. Large-scale policies are not always easily applicable in the local geomorphologic context. Moreover, recent investigation of risk perception in the Upper Rhine department shows that the population demands from local authorities that they implement 'visible' protection measures (Heitz et al., in press). This experience can also be reproduced in England (Evans and Boardman, 2003). Policy is hence decided at the European scale whereas the population asks for local actions.

4. Muddy flood mitigation measures resulting from the CAP

In Belgium, the regions are responsible for the implementation of agriculture, environment and land use planning policies in the framework of the EU guidelines. In France, the national ministry of agriculture is in charge of these policies. Decentralized state agencies are responsible for the implementation and the control of agricultural and environmental rules. Policy in England is characterised by centralisation with little devolution to regional or local government.

4.1. Cross-compliance

Cross compliance regarding erosion mitigation consists in a series of standards that farmers need to meet in order to receive the totality of their subsidies. It has been implemented with regional specifications (Table 3a). In Wallonia, specific rules are applied to fields having at least 50% of their area (or minimum 0.5 ha) with a slope steeper than 10%. In contrast, Flanders bases its rules on the results of an adapted version of the RUSLE equation applied for each cultivated field of the region (see e.g. Verstraeten et al., 2001). Alternative farming practices must be used or Agri-Environmental Measures (AEMs) must be installed on the fields at risk. In France, cross-compliance relies on respect for good agricultural and environmental conditions. A cover crop ('couvert environnemental') or grass buffer strips must also be sown on at least 3% of the cultivated surface for which subsidies are granted. In England, in order to receive payments (Single Payment Scheme), farmers have to maintain land in Good Agricultural and Environmental Condition (GAEC) for a payment of €43.5 ha^{-1}. Farmers can then be volunteer to enter an Entry Level Scheme of Environmental Stewardship if they wish for further payments. To enter the Higher level Scheme, farmers have to bid competitively. As part of Entry Level and Higher Level schemes, a Farm Environmental Record has to be produced and record, among other things, land suffering from erosion and runoff. Each farm has a points target related to farm size that they must attain by choosing from a range of options. Some of these options help control runoff e.g. grass buffer strips. There are also options related to management of high erosion risk cultivated land, of special concern being that under root crops such as potatoes and sugar beet, maize and outdoor pigs.

4.2. Agri-Environmental Measures

Farmers have to fulfil minimum environmental standards in order to receive their EU single payments. If the farmers want to go beyond those standards, they have the possibility to implement Agri-Environmental Measures (AEMs) during a five-year minimum period. They are hence paid by society for the environmental service they deliver. Agri-environmental schemes are flexible and implemented differently according to the state or region in Europe (European Commission, 2005). Such flexibility enables the regions or states to meet certain local environmental needs.

Belgium

In Wallonia, two AEMs contribute to runoff and erosion mitigation even if they were not designed to achieve this specific objective: (i) installation of Grass Buffer Strips (GBS) and (ii) sowing of cover crops during the dormant period. Farmers' participation rate to these measures increased from 1998 to 2006 in the Walloon loess belt and reached 17% in 2006 (Fig. 3). In the 'Hillsland natural park', agricultural advisers convinced farmers to install GBS where muddy floods have routinely damaged roads or houses. Consequently, in 2002, farmers' participation rate to AEMs was much higher in the area covered by the park (27% for GBS; 40% for sowing a cover crop during the dormant period) as compared to the mean rates for the Walloon loess belt (12% for GBS and cover crops). The extension officers stopped their advice at the end of 2002 and the farmers' participation rate in the area covered by the park subsequently decreased until it reached the mean participation level for the Walloon loess belt (Fig. 3).

In Flanders, similar AEMs (management of field edges; sowing of cover crops) have been available to farmers since 1999. The increase in the area with cover crops occurred later than in Wallonia (Fig. 4). Cover crops have not been subsidised by the Flemish government since 2007, since it is considered that it should be part of standard good environmental practices. In contrast, the area of cover crops keeps increasing in Wallonia, after a slight decrease in 2004 due to important changes to the Walloon agri-environmental scheme.

Since January, 2005, a new AEM enables the Walloon farmers to install GBS with the specific objective of erosion mitigation for which they need an agreement designed by an expert. This new rule leads to an extra subsidy (€ 1250 ha^{-1} instead of € 900 ha^{-1} for standard GBS). In Flanders, a package of five AEMs aiming at erosion control (dam and retention pond; direct drilling; grass buffer strips; grassed waterway; minimum tillage) exists since 2005. Overall, AEMs for erosion mitigation are more widespread in Wallonia than in Flanders (Fig. 5). Several explanatory factors can be put forward. First, in Wallonia, extension officers visit the fields where erosion problems are observed and propose to the farmers the most suitable solution. Second, 'word of mouth' about AEMs is probably more efficient among the Walloon farmers, their number being smaller and their capacities to invest larger, because of the much greater farm size (Table 2).

France

Numerous AEMs are available to French farmers, but two types of measures represent 60% of total grants: (i) the subsidies for least favoured areas and (ii) the subsidies for the maintenance of extensive breeding systems (PHAEs for 'Primes Herbagères Agri-Environnement'). The last measure is mostly applied where grassland dominates, which is not the case in the Upper Rhine nor in the Aisne. In France, there are no specific AEMs aimed at erosion mitigation. Several AEMs exist, but they aim to meet more general objectives (e.g. conversion to sustainable farming and integrated landscape management).

The CTEs ('Contrats Territoriaux d'Exploitation') were introduced in 1999. They were the first tool promoting the multifunctional role of agriculture in France. They focused on improving water quality (conversion of cropland into grassland, installation of grass strips, limited use of fertilisers) and soil quality (planting of hedges, no-till or reduced tillage). At the national scale, farms that adopted such AEMs are concentrated in rural and mountainous areas (Vosges, Alps, Pyrenees, Massif Central; Urbano and Vollet, 2005). CTEs were replaced in 2003 by CADs ('Contrats d'Agriculture Durable') which aim to allow the conversion to more sustainable farming. Farmers can choose to install proposed measures such as new grassland or planting of hedges. However, the number of farmers concerned remains limited (e.g. 99 contracts in 2004 in the Aisne department). The transition period between CTE and CAD regimes was rather confusing for farmers and many of them were discouraged.

There is a lack of information about the specific financial amounts granted for erosion mitigation in France. Developing a means of producing, centralising and diffusing such statistics should be a priority for the relevant agencies.

England

Under the Single Payment Scheme, farmers have to keep land in Good Agricultural and Environmental Condition in order to receive payments. As part of this, they have to fill in a Soil Protection Review. Stewardship schemes, as outlined above, can be taken up and for those a Farm Environmental Record is needed. On fields at risk of erosion, they can gain points by agreeing not keep outdoor pigs, to plant potatoes, sugar beet or maize. Specific advice on the management of maize is offered (RDS, 2005). Detailed risk assessment procedures, and advice on management of specific arable crops to avoid erosion and runoff is given in Defra (2005) and Cuttle et al. (2006). Risk assessment includes risk of runoff leaving fields and damaging surface waters and roads and thus muddy flooding.

Comparative discussion

If we focus on AEMs dealing with erosion and runoff control in the different regions (Table 3b), a comparison seems to be very difficult, given that AEMs objectives and practical requirements are completely different. Overall, adoption of AEMs by the farmers increases in Belgium and in France. However, their implementation relies on individual farmers' decisions, with the exception of GBS for erosion mitigation in Wallonia. At least, rules for the location of AEMs should be introduced, whatever the final objective. It is not only important for erosion mitigation, but also for biodiversity conservation (e.g. Berger et al., 2003). Actions to increase awareness and to inform the farmers at the local scale proved to be effective (e.g. in the Hillsland Natural Park, Wallonia). The measures should also be more targeted. Each year, c. € 2000 millions are spent on AEMs in the EU (European Commission, 2005). However, a very low proportion of this amount is dedicated to erosion mitigation. The member states should fund specific studies to make sure the measures they support serve their purpose. AEMs are generally applied to a larger extent in rural and mountainous areas, where they constitute an important part of the farmers' income. In contrast, in the very productive loess regions, most farmers still consider that a more intense agricultural use of the soil will generate higher incomes even over the long term, which explains a lower adoption of AEMs in those areas. Still most off-site impacts of agriculture are observed in the intensively farmed regions.

Even though they generally aim to facilitate their implementation, changes in AEM schemes and practical requirements can induce discouragement among farmers if they are too frequent (e.g. transition between CTEs and CADs in France; new Walloon agri-environmental programme in 2005). A certain stability is needed, as well as support from local agricultural advisors; this is beginning to happen in England through schemes such as the Catchment Sensitive Farming Initiative. The links between advisors and the scientific community could also be improved.

5. Regional mitigation schemes

5.1. Belgium

In 1997, the Flemish government recognised erosion as an environmental problem, leading among other consequences to muddy floods. It adopted an 'erosion decree' in December, 2001, allowing municipalities to receive funding to carry out a local plan against erosion (€ 12.5 ha^{-1} covered by the plan) and implement erosion control measures in the field

(75% of total amount; Verstraeten et al., 2003). By 2007, 85% of the municipalities in the Flemish loess belt had started the process leading to the drawing up of such a scheme. It does not mean that control measures are being installed in all of these municipalities. In many cases, the schemes have been drawn but they have not been applied so far. The Flemish Water Ordinance ('watertoets') also imposes the evaluation of the impact of any new construction on water issues before the deliverance of planning permission.

In Wallonia, the government decided to tackle the flooding problem designing an integrated scheme called 'Rainfall Scheme' ('Plan Pluies' in French) in 2003. In the near future, similar schemes to the ones proposed in Flanders will be funded by the Walloon regional authorities. Maps of flood prone areas (one for river flooding and another for local flooding) are also being drawn and should serve as a useful decision tool for regional land use planning.

5.2. France

In France, several tools are designed at the departmental scale. The creation of specific schemes at the departmental level was beneficial for their local implementation. Two main tools are available: risk prevention schemes (PPR- 'Plan de Prévention des Risques') and SAGE schemes ('Schéma d'Aménagement et de Gestion de l'Eau' – 'Land use and water management planning schemes').

PPR schemes have been created to cope with given risks (forest fire, earthquake, flood). Five maps must be systematically drawn (hazard location, historical evolution, vulnerability, places that are most at risk, global risk). According to these maps, specific measures can be prescribed: building of protection installations, rules for new buildings and, in extreme cases, expropriation. However, the adoption of a PPR does not necessarily lead to the installation of measures in the field. Furthermore, the latter consist most of the time of protection measures (e.g. dams) and do not prevent erosion and runoff generation in the fields.

SAGE schemes aim at water resource planning and management. This planning document is designed at the river basin scale by different regional agencies. Since it has legal power, the other decisions related to water management must take the SAGE provisions into account. This tool has several advantages compared to the flood prevention scheme. First, it works at the catchment scale. Second, it is an integrated tool that not only focuses on runoff and muddy floods but it also deals with water pollution, water protection and fish breeding.

Stakeholder meetings to increase awareness are organised in the framework of the SAGE schemes. They are therefore potential measures for a possible centralisation of competences, but they remain rather complex to implement. By 2005, 31 SAGE schemes had been created in France, and 101 more schemes are being implemented.

The Upper Rhine department also proposes a specific integrated tool called 'Gerplan' to promote landscape multifunctionality and, if relevant, to control muddy floods. It aims to define concrete management proposals for the different landscape components (cropland, orchards, riparian zones). Actions are planned for a 10 year-period and funding is provided by the departmental authorities. Planned actions (e.g. changes of farming practices, construction of retention ponds) are detailed for each field at an operational scale (1: 5000). By 2007, 22 local boards grouping several municipalities in Upper Rhine had decided to implement Gerplans, which are drawn up by consultants on behalf of farmers' trade unions and agriculture local state agencies.

The French government also adopted a law on natural risks in 2003 according to which a commission dealing with such risks has to be created in each department (Auzet et al., 2006). This law implies that during the sale of a property, potential owners are systematically informed of the risks relative to its location. This measure is not only applied to natural risks (earthquakes, floods) but also to technological risks (e.g. presence of Seveso factories).

Moreover, a decree of 2005 specifically deals with erosion mitigation. The departmental authorities have the possibility to delineate erosion prone areas and to draw up a mitigation scheme. Local stakeholders must meet the objectives prescribed by the authorities in the scheme within three years.

5.3. England

Initiatives relevant to control of muddy flooding are the Environmentally Sensitive Area scheme (established in 1987), which funds farmers to revert arable fields to grassland. On the South Downs, 5000ha have been entered into the scheme (SDMP, 2004). In partnership with other agencies, the Environment Agency has funded a Landcare scheme aimed at reducing runoff from farmers' fields into the River Rother around Midhurst (Horsey, 2006). This has now been discontinued. In 2005, Defra identified 42 catchments in England and are funding a Catchment Sensitive Farming scheme (2005-08) to address issues of diffuse pollution (Defra, 2007). None of the priority catchments are in the area under consideration;

some of the 42 have muddy flooding problems such as the Lugg in Herefordshire (Walker, 2007). Defra have also published a First Soil Action Plan for England (Defra, 2006); and most usefully a guide to controlling soil erosion (Defra, 2007). There are several over-lapping and non-coordinated schemes some of which are funded for a short time.

5.4. Diagnosis: spatial mismatch

Multiplicity of state agencies and splitting-up of the initiatives is apparent (Table 4). Based on the stakeholders involved and the main tools available for erosion and flood mitigation, two main types of measures can be pointed out:

(i) AEMs that are directly installed by farmers, but the objective and the practical requirements of which are defined by national (France and England) or regional (Belgium) authorities;

(ii) Specific schemes at the municipal scale (flood risk prevention schemes in France; erosion mitigation scheme in Flanders) or at the river basin scale (SAGE schemes in France). The latter do not exist at present in Wallonia but specific AEMs for erosion mitigation requiring an expert's approval are proposed.

Overall, there is a spatial mismatch between, on the one hand, the scale at which muddy floods are triggered (small catchment scale) and, on the other hand, the scale at which farmers (farm-scale) and public authorities (municipality- or region scale) can operate. This is mainly true in small Belgian municipalities as well as in France. In England neither County Councils nor District Councils have any responsibility for flood protection either with regard to rivers or muddy floods from agricultural land.

In Flanders, the Melsterbeek Water Board (264 km²), a grouping of five municipalities as well as the local water agency, is the only area where erosion and flood control measures are installed in the framework of a catchment-integrated approach. Even though the EU Water Framework Directive requires that countries set up management plans at the river basin scale by December 2009, the French government has rather encouraged the creation of municipal-scale risk prevention schemes since 2000. Five years later, it has been updated with significant financial investment to 5000 schemes. In such a context, prevention schemes aimed at mitigating risk, largely dominate. The advantage is that creating one tool for all types of risks facilitates collective actions. Inverting the trend by strengthening catchment agencies which should be better known to the population and the authorities is the major challenge for the future. It presupposes that municipalities learn to work together. The municipalities of central Belgium also have to take up the challenge. In twenty hotspot municipalities of central Belgium that were studied in detail (Evrard et al., 2007a), the runoff generation area and the flooded zone were located in different municipalities in 62 cases (17% of flooded areas). Of these 62 areas, an important part of the drainage basin was located in the other Belgian region (24% of the cases), or even in another country in six cases (10%). A similar situation is observed in the Upper Rhine department where 20% of muddy floods are generated in a municipality and affect another village located downstream.

In England also, the Catchment Sensitive Farming (CSF) scheme concentrates on perceived hotspots of risk to rivers and targets catchments which have nature conservation value where sediments or nutrients are a threat. The scheme however is voluntary and farmers can opt-in or out. Grants are available for capital works and the CSF officer provides advice on prevention of erosion and runoff to the farmers. The scheme is funded for two years and is at present under review. Many bodies are putting emphasis on the Environmental Stewardship scheme since most farmers are expected to opt-in in order to receive payments. Potentially, though the options are very limited (buffer strips and land use change), the scheme may have a positive impact. Unknown factors are whether there will be rigorous policing of measures and their effectiveness, and if the monetary incentives will be sufficient to attract growers of high-value crops (e.g. maize, potatoes and sugar beet) on high erosion risk land. However, if there are muddy floods from a farmer's land he is not complying with GAEC conditions of the Single Payment Scheme, which may make it easier to enforce the regulations providing such floods are reported. This is a matter of educating the general public.

6. Local measures against muddy floods

6.1. Measures taken by the municipalities

In Flanders, the municipalities frequently affected by muddy floods or severe erosion can decide to implement a municipal mitigation scheme. This is not the case in the other regions, but similar tools will soon be available for erosion prone areas in France and Wallonia. Following a visit to frequently flooded Walloon municipalities (n=12; Evrard et al., 2007a), two main observations could be made: 1) muddy floods are considered a major problem for the population in 42% of the cases and they got worse during the last decade according to 83% of the local authorities; 2) there is no integrated flood management in 83% of the cases. Furthermore, in 83% of the municipalities, the only actions considered are modifications to the sewage system or construction of retention ponds. The construction of a retention pond is very expensive (mean cost of € 380,000 (Verstraeten and Poesen, 1999), and does not prevent runoff generation. Still the local authorities consider that rainfall intensity is the most influential natural factor and frequently quote large-scale potato and maize crops as important human factors triggering muddy floods. Certain municipalities therefore decided to tackle the problem. For instance, a Walloon municipality confronted with 37 areas affected by muddy floods grants specific subsidies to local farmers for the installation of GBS in flood prone areas. In the Walloon Brabant province, the Rural Foundation of Wallonia organises municipal commissions (‘commissions agricoles communales’) where local authorities, farmers and inhabitants can discuss specific matters such as erosion mitigation. Finally, certain river management committees (‘contrats rivières’) intend to inform and increase awareness of erosion among the population and the farmers. They can help solving problems in individual cases.

French local authorities (e.g. in the Upper Rhine) are subjected to pressure from the population to instigate control measures. They can expropriate agricultural fields to install them. Even though they are aware of the implication that floods may be triggered by inappropriate land use planning, pressure is sometimes too important. In some cases, the mayors demand a concerted implementation of measures at the catchment scale, implicating their counterparts in upstream villages (Heitz, 2005). Local urban schemes (PLUs or ‘Plans Locaux d’Urbanisme’) take risk areas into account to define land approved for development. They are the only official document of land use planning available at the local scale in France. They are drawn up on behalf of the municipal authorities but also approved by departmental and regional authorities.

In England local authorities have no statutory responsibility to protect people from muddy flooding as the first case of its kind made quite clear (Stammers and Boardman, 1984). In practice, whenever people and their properties are damaged by flooding, they appeal to their political representatives and they put pressure on local councils. Councils therefore have often acted as organisers of emergency defence measures such as ditches, dams and pipes. Councils have attempted to organise protection over longer time periods but have been less successful and have been reluctant to commit resources to this process. Evans and Boardman (2003) describe repeated flooding of houses in the Sompting catchment on the South Downs and the political process in achieving success. In fact, limited land use change driven by Set Aside regulations led to control of flooding. Highway authorities also have power under the Highways Act (1980) to control runoff from fields that reaches roads. This has only been used in the Isle of Wight (Boardman, 1994). In exceptional cases, where local councils own agricultural land, they have instituted either land use change or the building of dams in order to protect communities from flooding (Boardman et al., 2003). In areas such as the South Downs where flooding does not occur every year or in the same place perhaps for many years, there is a problem of lack of institutional memory within local councils in that they deal with muddy flood problems occasionally. No councils have specialists to deal with erosion and runoff problems but generally rely on all-purpose engineers. There is also the temptation to believe that measures put in place at one time will solve the problem without constant maintenance (e.g. ditch clearance). Finally, there is no co-ordinating body to bring together the experience of local councils.

6.2. Measures taken by farmers

Numerous farmers feel responsible for erosion processes (e.g. Bielders et al., 2003). A couple of them have decided on their own initiatives to alleviate muddy floods. In the Aisne department, the ‘erosion task force’ can propose the installation of several measures (e.g. GBS, dams and buffer ditches) in their fields. Moreover, in the Aisne, several farmers sow alternate strips of maize and wheat to limit runoff generation and concentration. In the Belgian Melsterbeek catchment, farmers similarly decided to implement double sowing in the thalweg of their fields (Gyssels et al., 2002). On the South Downs, southern England, several farmers have built retention dams to protect their own or others property from muddy floods. These have usually been built as an emergency response to flooding. In some cases they have failed. Changes in land use or farming practice directly attributable to the risk of muddy flooding are difficult to confirm (but see Evans and Boardman, 2003). Direct drilling (minimal cultivation) is rare but is being used by one farmer to reduce the risk of flooding his neighbour. Another example of a farmer’s individual actions to mitigate erosion in England is described by Evans (2006).

Consultation between several farmers of the same municipality is also possible. They can decide to coordinate the location of the different crops to limit runoff generation at the catchment scale (Joannon et al., 2006). Certain municipalities in the Upper Rhine department (e.g. Morschwiller-le-Bas) have organised such consultation. However, these initiatives remain very local (Christen and Wintz, 2006). The importance of this consultation phenomenon is impossible to quantify, but it seems to be more widespread in France than in Belgium, given the much larger mean size of the French farms (Table 2). Furthermore, in

Belgium, many farmers are reluctant to discuss it. Many of them have commitments with agro-food companies to produce crops (e.g. carrots, peas). It becomes difficult to combine their different commitments with the consultation about crop location at the catchment scale.

In France, the Supreme Court of Appeal has perhaps set a precedent for conflicts between farmers due to erosion. A fish breeder whose basins were damaged by runoff loaded with sediments instituted proceedings against the farmer cultivating the upstream slope. The Supreme Court quashed a sentence stipulating that runoff and erosion were due to heavy rainfall. The Supreme Court argued that the farmer cultivating the upstream fields was responsible for the damage induced to the downstream fish breeding basins.

In England, there is some history of legal attempts to protect properties from runoff from agricultural land and to sue those responsible for the damage for negligence. Legal advice in several cases suggests that to be successful, it must be shown that the farmer was aware of the risk to his neighbour e.g by previous flooding; that the rainfall event was not ‘exceptional’; that farming practices including land use decisions were the cause of the flooding; that no measures were taken to protect the neighbour (Boardman, 2003). Out-of-court settlements in the Breaky Bottom flooding incidents show that these criteria can be met in some cases. In future the threat of legal action may act as a deterrent at sites with a history of previous flooding.

7. Conclusions

Muddy floods are a frequent and widespread phenomenon in the European loess belt. However, there is no standard database recording these events and data on damage costs remain rare or limited to certain municipalities. A comparison of flood frequency between different European regions is not easy, since administrative units do not correspond to homogeneous natural regions. Over the last decade, there has been a raising of consciousness among all the stakeholders involved in muddy flood management. Huge costs induced by the floods in numerous villages help justify the rapid installation of control measures. However, people and farmers remain insufficiently informed of the processes involved and the mitigation tools available. French investigations showed that the affected populations particularly appreciate the construction of retention ponds, considering that they protect them efficiently. Consultation between stakeholders at the local scale should be encouraged, e.g. in the framework of municipal agricultural commissions. Farmers are often overwhelmed with administrative tasks. Thanks to local coordinators’ help, the adoption of AEMs aiming at erosion mitigation is more successful. The creation of an integrated scheme to mitigate erosion and muddy floods is now considered in all the studied regions. Furthermore, concerted actions between municipalities must be a priority, given that the limits of municipalities do not coincide with hydrological units. A solution to the observed 'spatial mismatch' would be to enhance existing structures that are efficient (Belgian water agencies and natural parks, French SAGE schemes, English Catchment Sensitive Farming schemes) or to widen the application field of existing tools (e.g. flood prevention schemes at the catchment scale). Catchment agencies concentrating legal, environmental and financial competences (like the water boards in the Netherlands) could also help control floods and erosion. Individual measures (AEMs) installed by farmers after an expert's approval could also be stimulated. Alternatively, rules for an optimal location of AEMs should be imposed. Furthermore, the effectiveness of the current AEMs should be assessed. A comparison of the tools available in different countries to combat erosion and muddy floods should be carried out to see whether they serve their purpose. Muddy flood management can either focus on soil and water conservation or on property protection. Conflicts of viewpoints can arise and influence the type of measures that will finally be implemented. Farmers' conversion to alternative farming practices limiting runoff and erosion production in the fields must also be progressively encouraged to complete the 'palliative' approach currently pursued and assessed in pilot areas. This could be achieved through the creation of new specific AEMs.

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Fig. 1. Location of the studied regions in England, France and Belgium.

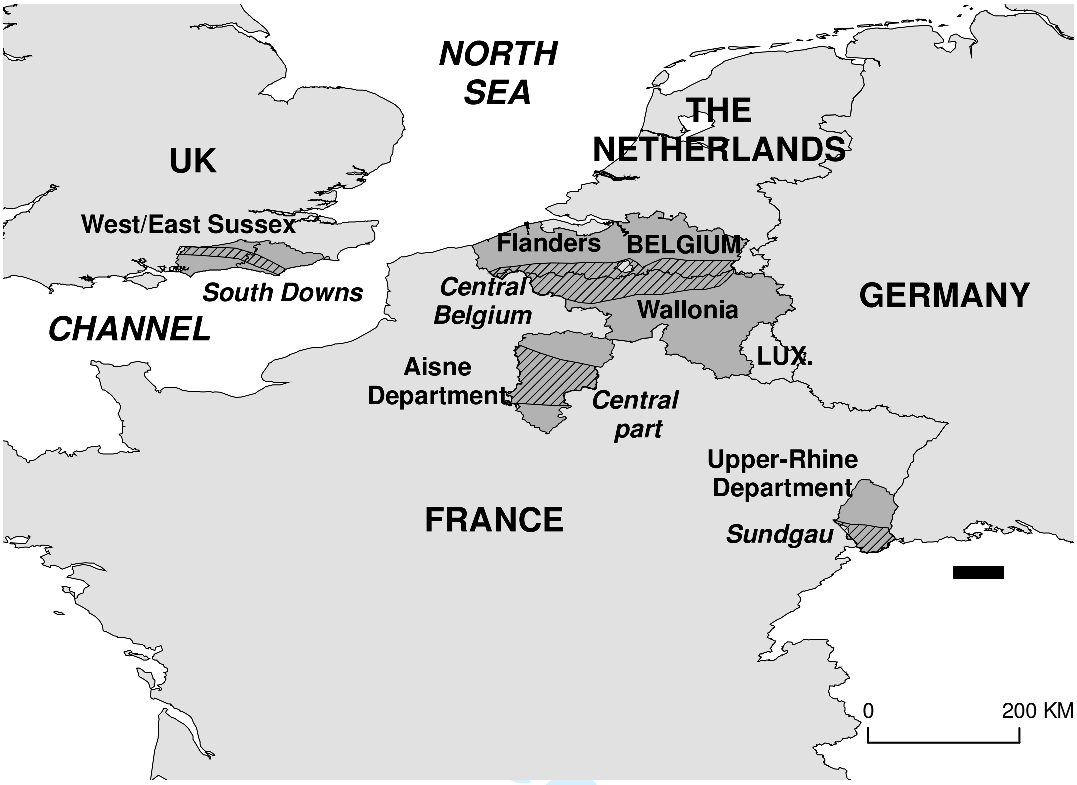

Fig. 2. Mean monthly rainfall distribution in central Belgium, northern France and southern England.

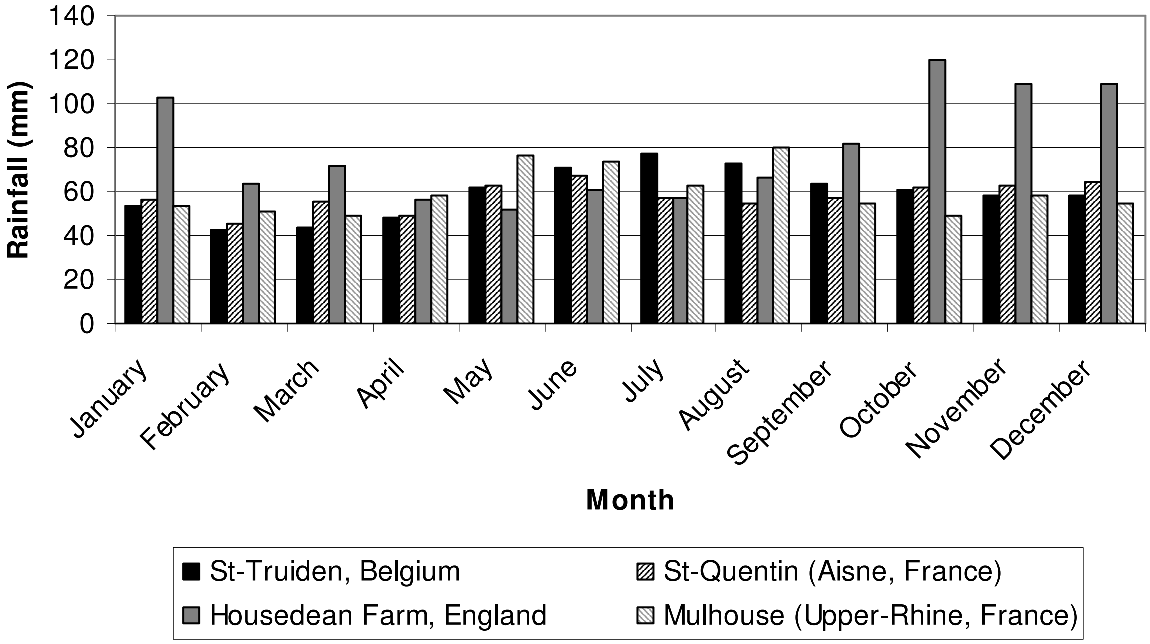

Figure 3. Evolution (1998-2006) of farmers' participation rate to two AEMs (GBS – Grassed Buffer Strips; cover crops during the dormant period) in the Walloon loess belt (WLB) and the Hillsland natural park (HNP), Belgium. Data available from the MRW-DGA and the GIREA (2006).

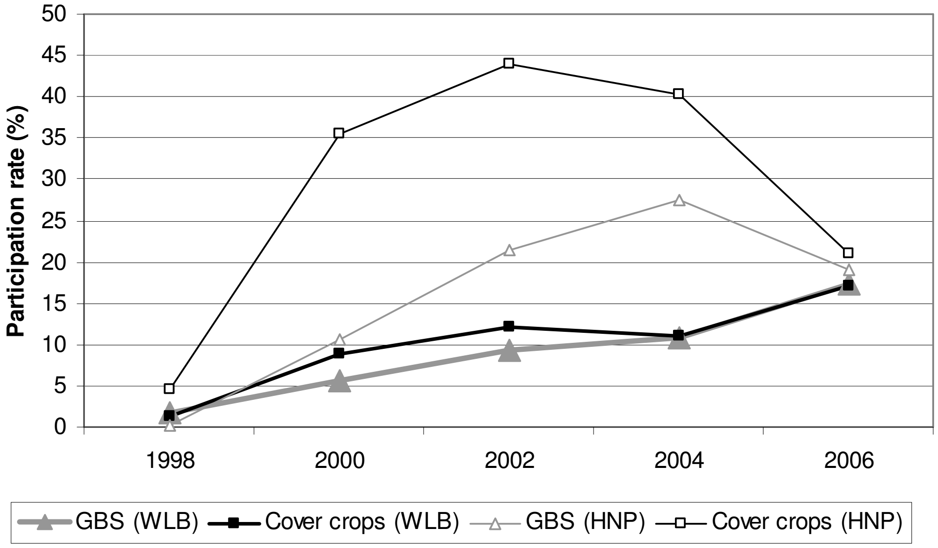

Fig. 4. Evolution of AEM adoption between 1998 and 2006 in Belgium (Flemish data from the VLM; Walloon data from the MRW-DGA and the GIREA).

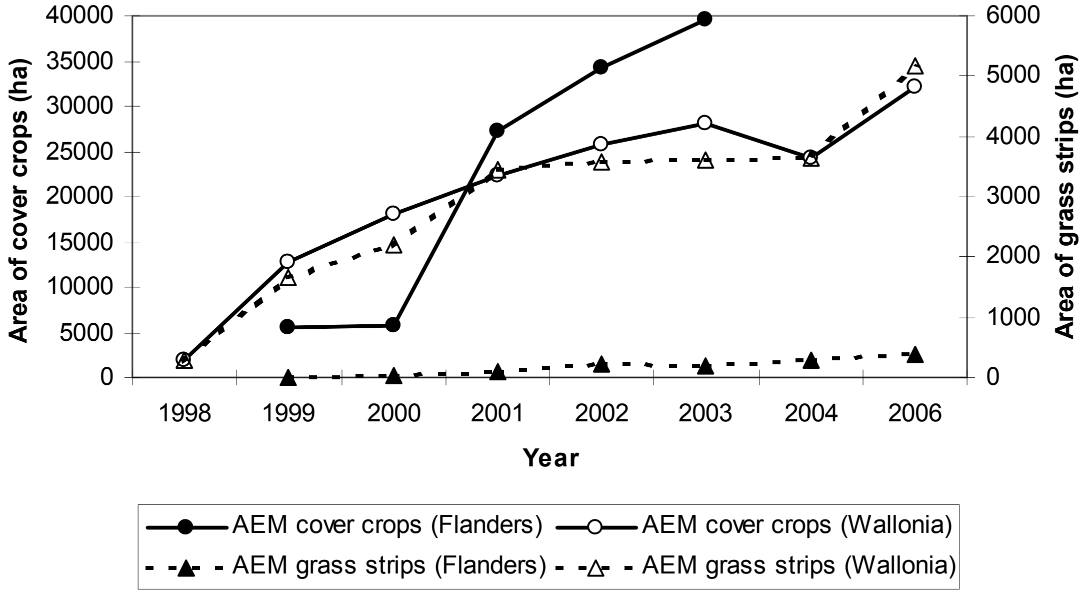

Fig. 5. Area covered by specific AEMs for erosion mitigation by the end of 2006 in the municipalities of central Belgium (m² AEM per ha of cropland). Flemish data from the Vlaamse Land Maatschappij (VLM); Walloon data from the Ministère de la Région Wallonne – Direction Générale de l'Agriculture (MRW-DGA) and the Groupe Interuniversitaire de Recherche en Écologie Appliquée (GIREA) .

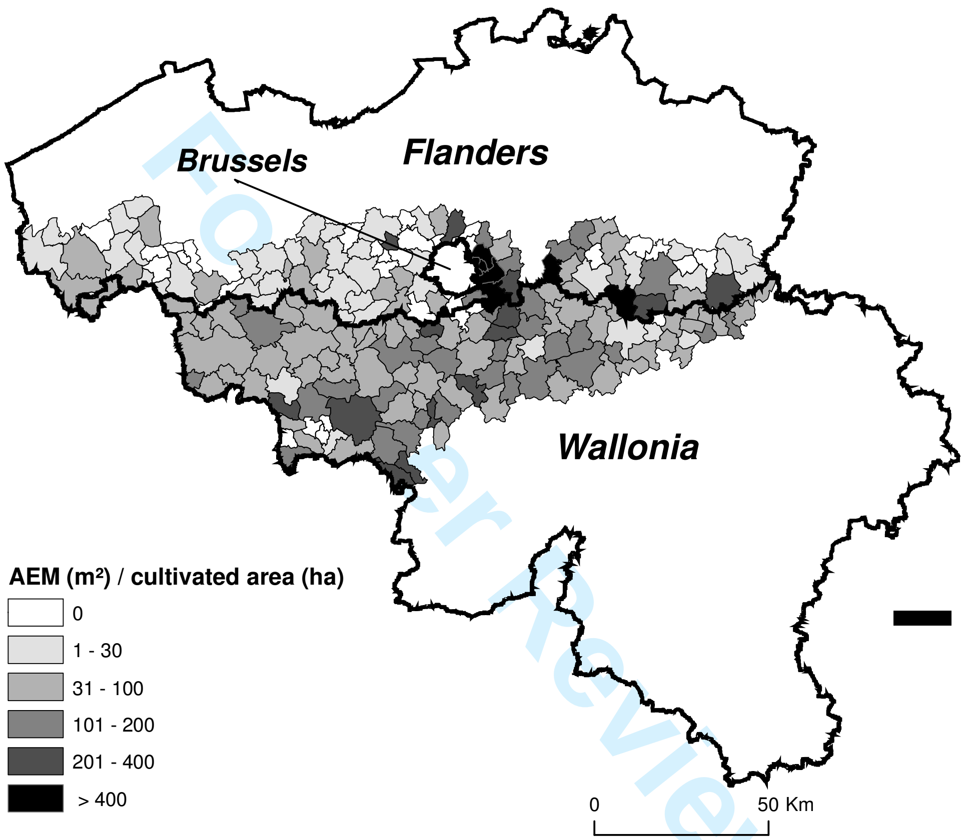

Table 1. Physical characteristics of the studied regions.

Characteristic	Flanders	Wallonia	Aisne	Upper Rhine	South Downs
Total area (km²)	4017	4850	7420	3525	1641 (*)
Altitude range (m)	5 - 150	20 - 200	35 - 280	240 - 500	0 - 200
Mean temperature (°C)	9 – 10	9 – 10	9 – 10	c. 10	10-11
Precipitation range (mm)	750 - 850	750 – 850	c. 700	c. 720	750-1000
Soil type	Luvisols	Luvisols	Luvisols	Luvisols	Luvisols and Rendzinas
% of cropland	18	24	60	29	50
% of grassland	11	14	12	9	30

(*)Area of proposed South Downs National Park, which includes area around Midhurst, West Sussex.

Table 2. Demographic characteristics of the studied regions.

Characteristics	Flanders [a]	Wallonia [b]	Aisne	Upper Rhine	South Downs
Number of municipalities	100	104	816	377	15[e]
Mean municipal area (km²)	40	47	9	9.3	n/a
% of municipalities affected by muddy floods	90	67	At least 51	41	n/a
Population density (2005)	499	368	73	201	70
Evolution of population density (1996-2005)	+ 3%	+5.20%	-0.04%	+0.59%	n/a
Mean farm size (ha)	19 [c]	38 [d]	88	50	45[f]

[a] Flemish municipalities located in the Belgian loess belt (n=100).
[b] Walloon municipalities located in the Belgian loess belt (n=104).
[c] Mean farm size of the 'sandy loam' region (SPF Economy, 2005).
[d] Mean farm size of the 'loamy' region (SPF Economy, 2005).
[e] 3 County Councils, 1 Unitary Authority, 11 Borough and District Councils.
[f] East Sussex: 40ha, West Sussex 50 ha in 2003.

n/a: not available.

Table 3. Comparison of CAP-derived measures to control muddy floods in Belgium, England and France.

	(a) Cross-compliance – Obligatory measures	
Country	Location of measures	Examples
Belgium	Fields with slope higher than 10% (Wallonia)	GBS / no row crop planting
	High erosion score according to a RUSLE-derived model (Flanders)	AEMs / alternative farming techniques
England	Points target related to farm size (Single Payment and Environmental Stewardship schemes)	Range of options (e.g. GBS)
France	Min. 3% of total surface of the farm	Cover crops / GBS
	(b) AEMs – Voluntary measures	
Country	AEM types	Remarks
Belgium	GBS / cover crops (Wallonia)	
	GBS for erosion mitigation (Wallonia)	Needs an expert's approval
	GBS / dams / alternatives farming techniques (Flanders)	
England	Environmental Stewardship Scheme – Higher Level	Environmental record map Measures associated with points
France	Contrat d'Agriculture Durable (CAD)	e.g. grassland, planting of hedges

Table 4. Comparison of available regional measures (a) to control muddy floods and (b) to take muddy flood problems into account in land use planning.

Country	(a) Measures to control muddy floods	Associated scale
Belgium	Erosion mitigation scheme (Flanders, 2001)	Municipality
	Plan Pluies (Wallonia, 2007)	Delineated area within a municipality
England	Catchment Sentitive Farming Scheme (2005)	Catchment
France	SAGE – Water Management Planning Scheme (1992)	River basin
	PPR – Flood Risk Prevention Scheme (1995)	Municipality
	Gerplan (2000)	Groups of municipalities
	(b) Land-use planning tools	**Associated scale**
Belgium	Water Ordinance (Flanders, 2003)	Municipality
	Plan Pluies (Wallonia, 2007)	Walloon Region
England	Highways Act (1980)	Fields draining to highways
France	PLU – Local Urban Schemes	Municipality
	Law on natural risks (2003)	Delineated erosion risk areas