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

3
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18
19 **Abstract**

20
21 Muddy floods, i.e. water flowing from agricultural fields and carrying large quantities of soil, affect
22 routinely numerous municipalities of central Belgium, northern France and southern England. A
23 comparison of flood frequency between different European regions is difficult, because of the lack of a
24 uniform and official database as well as the landscape heterogeneity of administrative entities. Agri-
25 Environmental Measures (AEMs; e.g. grass buffer strips) can contribute to the control of muddy
26 floods but their installation is voluntary and depends therefore on farmers' willingness. Actions to
27 increase awareness and to inform the farmers proved to increase drastically their participation rate in
28 AEM programmes. In all the studied regions, flood prone areas are increasingly taken into account to
29 define land approved for development. Moreover, several schemes for the control of muddy floods
30 have also been proposed at the regional scale. However, there is a spatial mismatch between the scale
31 at which muddy floods are triggered (small catchment scale) and the scale at which public authorities
32 can operate (municipality, grouping of municipalities, delineated flood prone areas, river basin). In
33 future, beside curative measures (e.g. retention ponds and dams), farming techniques preventing runoff
34 and erosion in the field (e.g. conservation tillage) should be encouraged. This could be achieved by the
35 creation of a new AEM. Moreover, guidelines for the location of AEMs could usefully be introduced.
36 Existing flood control schemes should also be systematically carried out by catchment agencies
37 including legal, environmental and financial expertise. These agencies should be set up for local
38 groupings of municipalities and provide them technical assistance to equip the flood prone areas and
39 carry out maintenance of the implemented control measures.
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3 41 **Key words**

4 42 Muddy floods, stakeholders, environmental management, agri-environmental measures, soil
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6 43 erosion, flooding of properties
7

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10 45

11 46 **1. Introduction**

12 47

13 48 In the European loess belt, water flowing from agricultural fields and carrying large
14
15 49 quantities of soil as suspended sediment or bedload frequently concentrates and leads to
16
17 50 muddy floods in the downstream villages (Boardman et al., 1994; 2006). They are generally
18
19 51 triggered on silty and loamy soils which are prone to surface sealing. Central Belgium,
20
21 52 northern France and southern England are severely affected by these floods (see e.g.
22
23 53 Boardman et al., 2003; Souchère et al., 2003; Evrard et al., 2007a). The main physical
24
25 54 processes contributing to muddy floods are runoff generation on crusted soils, the detachment
26
27 55 of soil particles and aggregates by rainfall and runoff as well as the sediment transport over
28
29 56 long distances by runoff, particularly when the flow concentrates in linear landscape features
30
31 57 such as thalwegs, field borders and tramlines. This increases runoff connectivity, flow
32
33 58 velocity and peak discharge between cropland and downstream villages or rivers. The
34
35 59 occurrence of muddy floods in the different regions of the European loess belt is related to the
36
37 60 interaction between rainfall distribution and soil surface conditions including vegetation cover
38
39 61 (Auzet et al., 1990; Ludwig et al., 1995; Souchère et al., 1998; Takken et al., 2001; Evrard et
40
41 62 al., in press). In Belgium and eastern France, most floods are associated with heavy
42
43 63 thunderstorms on fields planted with summer crops (e.g. maize, sugarbeet, potatoes) and
44
45 64 occur between May and September (Vandaele and Poesen, 1995; Evrard et al., 2007a). The
46
47 65 floods are even more concentrated in eastern France with a peak in May and June (Van Dijk
48
49 66 et al., 2005). In southern England on the South Downs as well as in northwestern France
50
51 67 (Normandy), they are mainly reported in autumn and winter, associated with fields planted
52
53 68 with cereals (Boardman et al., 2003).

54
55 69 Beside on-site impacts (e.g. gullyng, damage to crops), muddy floods lead to
56
57 70 numerous off-site impacts and induce high damage costs (Boardman et al., 2003; Evrard et
58
59 71 al., 2007a). Therefore, measures controlling erosion and runoff are needed. Alleviating muddy
60
61 72 floods is a very complicated task because it is at the crossroads of several policies. It is a
62
63 73 combination of hydrological and geomorphological processes leading to soil erosion on
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65 74 agricultural land and to damage in downstream inhabited areas. Therefore, prevention of
66
67 75 muddy floods requires spatially-integrated initiatives related to water, agriculture and

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3 76 environment management as well as land use policies. The multiplicity of the stakeholders
4
5 77 involved in muddy flood management as well as their varied expectations make the definition
6
7 78 of an integrated policy even more complex. Moreover, muddy floods are a very local
8
9 79 phenomenon, often triggered by local thunderstorms, but they are influenced by large-scale
10
11 80 policies. For instance, the implementation of the European Common Agricultural Policy
12
13 81 (CAP) partly explains the increase of flood frequency observed during the recent decades
14
15 82 (Souchère et al., 2003). Similarly, these policies encouraged the conversion of chalk
16
17 83 landscapes in southern England from grass and spring cereals to winter cereals and led
18
19 84 directly to the erosion problems of the 1980s. In 1992, CAP reforms introduced agri-
20
21 85 environmental schemes, according to which farmers can receive payments to implement
22
23 86 environmentally-friendly farming techniques going beyond good farming practices (Ritson
24
25 87 and Harvey, 1997). However, many of the financial incentives encourage ways of tackling the
26
27 88 symptoms of the problems (e.g. runoff, erosion), rather than the causes themselves (i.e.
28
29 89 intensive agriculture). The extent to which agri-environmental measures are applied in order
30
31 90 to reduce runoff and erosion could usefully be evaluated fifteen years after their introduction.

30 91 The European Commission has also recently worked on two directives that can play a
31
32 92 role in muddy flood mitigation. First, the Water Framework Directive (2000/60/EC)
33
34 93 establishes a common framework for water protection and management at the scale of river
35
36 94 basin districts. Second, the Soil Thematic Strategy sets out principles to protect the soils
37
38 95 across the EU. The member states must define their strategy to use soils in a sustainable way
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40 96 on their territory within this common framework. Even though agricultural and environmental
41
42 97 policies are mainly driven by European legislation, the individual states and regions transpose
43
44 98 and apply them locally in different ways. Beside EU-driven actions, numerous mitigation
45
46 99 measures are taken at the regional or even the local scale.

46 100 The objective of this paper is to identify the existing strategies to mitigate muddy
47
48 101 floods in severely affected areas of the European loess belt (central Belgium, northern France
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50 102 and southern England) and to point out the most effective and efficient measures that should
51
52 103 be promoted. Stress is laid on European-driven policies and regional mitigation schemes.
53
54 104 After a brief comparison of data sources on muddy flood frequency in the regions, we
55
56 105 compare the mitigation measures taken at European, national and regional scales. Then, we
57
58 106 move on to the local scale to highlight the specific initiatives taken by the farmers and the
59
60 107 municipal authorities. Finally, effective strategies enabling integrated management of the
108 108 phenomenon using appropriate tools will be proposed with respect to the management scale.

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3 109 The paper constitutes an updating and expansion of earlier views of the topic (Boardman et
4 al., 1994; Fullen et al., 2006).
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8 112 **2. Studied regions and available databases on muddy floods**

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12 114 Central Belgium, northern France and southern England are all located in the loess belt
13 of northwestern Europe and are characterized by soils containing at least 60% silt which are
14 115 very sensitive to surface sealing (Boardman et al., 1994; Fig. 1). Major landscape changes
15 116 have been observed in these regions during the last decades (Souchère et al., 2003).
16 117 Urbanisation has expanded into rural areas. Numerous land consolidation programmes were
17 118 carried out in Belgium and in France without taking into account the limitation of
18 119 hydrological transfers at the catchment scale (Evrard et al., 2007b). A regional crop
19 120 specialisation is generally observed in many regions, such as large-scale maize cultivation in
20 121 Alsace (Van Dijk et al., 2005). Moreover, the area under grassland has decreased during the
21 122 three last decades in all of these regions as a result of the intensification of livestock breeding
22 123 and dairy farming.
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34 126 *2.1. Physical and demographic characteristics of the studied regions*

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37 128 The physical characteristics of the studied regions are similar. They have significant
38 129 proportions of cropland and the areas in Belgium and northern France have gentle slopes; in
39 130 southern England slopes in the range 5 to 15 degrees are frequently cultivated (Table 1).
40 131 Mean annual temperature ranges from 9 to 11°C, while average precipitation reaches between
41 132 700 and 1000 mm. Rainfall is well distributed throughout the year in Belgium as well as in
42 133 northeastern France. In contrast, annual rainfall as well as the contribution of autumn and
43 134 winter rainfall is higher in southern England (Fig. 2).
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49 135 In Belgium, muddy floods are concentrated in the central part of the country where
50 136 loess-derived soils dominate. The area is managed by the administrative entities of Flanders
51 137 and Wallonia (Fig. 1). The Brussels region is excluded, given cropland is virtually absent
52 138 from the capital city.
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56 139 An important part of the areas affected by muddy floods in France is located in the
57 140 northern part of the country (Le Bissonnais et al., 2002). Two administrative units (the so-
58 141 called 'départements' and referred to as 'departments' in the remainder of the text) with
59 particularly high muddy flood densities were selected for study (Aisne and Upper Rhine; Fig.
60 142

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2
3 143 1). The Aisne department is located in the Paris Basin. The central part of the department is
4
5 144 characterised by intensive cropping (winter cereals, sugar beet, oil-seed rape). The Upper
6
7 145 Rhine department is characterised by widespread monoculture of maize that provides a low
8
9 146 vegetation cover to the soil during the heavy thunderstorms of May and June (Van Dijk et al.,
10
11 147 2005). Hilly regions of the department are particularly affected by muddy floods (e.g.
12
13 148 Sundgau, Fig. 1).

14 149 In southern England several areas have been affected by muddy floods but good data
15
16 150 only exists for the South Downs in the counties of East and West Sussex. The thin, stony soils
17
18 151 of the Downs limit the range of crops that can be grown and the area is dominated by winter
19
20 152 cereals, with some oil-seed rape and grazing for sheep. Dry valley systems drain to the south
21
22 153 where ephemeral flows of water encounter coastal resorts such as Brighton and Worthing.
23
24 154 The risk of muddy flooding is largely confined to the autumn and early winter months before
25
26 155 adequate crop cover is established. To the north of the South Downs, on loamy and sandy
27
28 156 soils on Cretaceous sandstone outcrops, intensive farming of cereals and spring-planted crops
29
30 157 of potatoes and maize give rise to muddy flooding especially around the town of Midhurst.

31 158 General demographic and farm characteristics of the studied regions are summarised
32
33 159 in Table 2. For a similar natural context, the studied regions show a large variation in
34
35 160 population densities (between 73 inh.km⁻² in the Aisne and 499 inh.km⁻² in Flanders).
36
37 161 Residential expansion is currently observed in the rural peripheries of large cities (e.g.
38
39 162 Brussels, Mulhouse; Caruso, 2002). Large farms dominate in northern France (88 ha on
40
41 163 average in the Aisne vs. 18-45 ha in the other regions).

42 164 43 165 *2.2. Data sources on muddy flood frequency*

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46 167 The first problem arises when we want to obtain data on the extent and frequency of
47
48 168 muddy floods and compare them. There is no uniform and official database recording muddy
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50 169 floods systematically in all the regions. Moreover, administrative units do not correspond to
51
52 170 natural regions, introducing a bias in the comparison of muddy flood frequency between the
53
54 171 different European regions.

55 172 In Belgium, the Disaster Fund (Belgian Ministry of Home Affairs) provides a database
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57 173 of natural disasters. Floods are not qualified as 'muddy' but it is possible to restrict the search
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59 174 excluding floods 'due to the overtopping of rivers'. However, the Belgian Federal
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175 Government approved on May 21, 2003 a law on compulsory insurance covering natural
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disasters. Consequently, only the damage due to very exceptional events (leading to more

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3 177 than € 280 millions damage) will still be compensated by the Belgian state in the future. In
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5 178 this context, the most reliable data source consists of a questionnaire sent to all municipalities
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7 179 of central Belgium (Evrard et al., 2007a). This survey showed that 79 % of the municipalities
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9 180 (n=201) were affected by at least one muddy flood over a ten year period (1991-2000 for
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11 181 Wallonia ; 1995-2004 for Flanders). Of these 160 flooded municipalities, 22 % experienced
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13 182 more than 10 floods in 10 years.

14 183 In the Aisne department, the municipalities potentially affected by muddy floods can
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16 184 be identified thanks to the adoption of a 'flood risk prevention scheme'(PPRI). In the past,
17
18 185 these schemes were not explicit on the nature of flooding. Since 2000, specific schemes aim
19
20 186 to cope with muddy floods. By 2006, 51% of the municipalities in the Aisne department
21
22 187 (n=834) required a flood prevention scheme but it had been approved in only 39
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24 188 municipalities (5%).

25 189 In the Upper Rhine department, reports of natural disaster statements provide data on
26
27 190 the flooded municipalities. Since 1982, the French Natural Disaster law provides
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29 191 compensation to the victims (Auzet et al., 2006). One third of the municipalities in the
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31 192 department (n=377) were affected by at least one muddy flood during the period 1985-2003.

32 193 In southern England there is no official attempt to collect data on flooding or damage.
33
34 194 Boardman et al. (2003) report 138 incidents of damage to property by muddy floods in the
35
36 195 years 1976-2001. This relates to an area of the eastern South Downs from Worthing to
37
38 196 Eastbourne of about 496 km². This estimate is based on personal observation and the use of
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40 197 newspaper reports. There is no systematically collected data for the Midhurst area. In other
41
42 198 areas of England, there are anecdotal reports of muddy flooding, some newspaper reports and
43
44 199 occasional case studies in the academic literature (e.g. Boardman, 1995; Evans, 1996; Evans,
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46 200 2004).

47 201 Overall, Flanders seems to be the most affected by muddy floods (Table 2). It is also
48
49 202 the region with the highest population density. However, a comparison of flood frequency
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51 203 between administrative units that do not correspond to homogeneous natural regions is not
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53 204 objective.

54 205 55 206 *2.3. Data sources on muddy flood costs*

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58 208 Studies evaluating the costs induced by on- and off-site impacts of muddy floods are
59
60 209 very rare. Costs associated with single floods are available for certain municipalities (see e.g.
210 Verstraeten and Poesen, 1999; Evans, 1996; Evans, 2004; Boardman et al., 2006). A global

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3 211 estimate of off-site damages induced by muddy floods has been made for central Belgium
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5 212 (between € 16 and 172 millions per year; Evrard et al., 2007a).

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7 213 Costs induced by muddy floods in France are roughly estimated in the reports on
8
9 214 natural disaster statements. However, insurance companies refuse to publish damage cost data
10
11 215 because of confidentiality issues. Cost data are only made available for very local areas or
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13 216 individual floods. For instance, muddy floods led to a mean damage cost of € 118 ha⁻¹ yr⁻¹ in
14
15 217 the village of Soucy (Aisne department) during a 10 year-period.

16 218 There is also little data in southern England on costs of damage. Robinson and
17
18 219 Blackman (1990) report off-site costs of serious muddy flooding in 1987 at four major sites in
19
20 220 Brighton suburbs in excess of € 957,000 excluding police and fire service costs. Most of them
21
22 221 were borne by local councils and insurers, but at least € 162,000 was uninsured. Two major
23
24 222 flooding incidents at Breaky Bottom Vineyard and farmhouse in 1987 and 2000 have resulted
25
26 223 in out-of-court settlements from the insurers of the up-valley farmer (Boardman 1988, 1994,
27
28 224 2000, 2001). Total cost to the insurers for the 2000-01 event alone were approximately € 1.45
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30 225 million.

31 226 Overall, data available show that muddy floods induce high damage costs and that
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33 227 these costs remain in the same order of magnitude in the different European regions.
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36 229 **3. Stakeholders involved in muddy flood mitigation**

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39 231 Muddy flood mitigation is at the crossroads of different policies (agriculture,
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41 232 environment, land use planning and water management). The European Commission is in
42
43 233 charge of the European Common Agricultural Policy and prepares numerous environment-
44
45 234 related directives. The national governments (or the regions in Belgium) have to transpose
46
47 235 and apply them locally.

48 236 In Belgium, the regional administration funds a large number of public or non-profit
49
50 237 making organisations that work on different topics (rural development, river or natural park
51
52 238 management), but without any effective coordination. Roads and watercourses are
53
54 239 hierarchically classified and managed by different administration levels (regional, provincial,
55
56 240 local), making any 'hydrologically-consistent' supervision very difficult. For instance,
57
58 241 watercourse managers must cope with siltation of rivers without any possibility to control
59
60 242 erosion on the cultivated land draining to the rivers.

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

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3 245 Departmental Agency of Equipment – DDE; Water Agencies; Departmental Councils) are
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5 246 implicated in erosion management as well as local farmers’ trade unions (‘Chambres
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7 247 d’Agriculture’). Even though there is collaboration between these institutions, there is
8
9 248 generally no specific structure to coordinate muddy flood mitigation. Therefore, an ‘erosion
10
11 249 task force’ (‘mission érosion’) was set up in 1998 in the Aisne. It does not replace the other
12
13 250 agencies, but aims to set up specific, individual and local actions. This initiative remains very
14
15 251 local and highlights different management approaches between the French departments. The
16
17 252 dynamism of local farmers’ trade unions and departmental authorities has a major influence
18
19 253 on the implementation of local actions to control erosion phenomena.

20 254 In England, Defra (Department for Environment, Food and Rural Affairs) is
21
22 255 responsible for agricultural policy and thus for erosion and muddy flooding. Water quality
23
24 256 issues under the Water Framework Directive are devolved by Defra to the Environment
25
26 257 Agency. Natural England is in charge of the impacts on biodiversity and the Highways
27
28 258 Agency and local authorities are responsible for flooded roads and adjacent property.

29 259 Who is in charge of risk mitigation at local scales depends not only on large-scale
30
31 260 policies (e.g. CAP) but also on field realities. Large-scale policies are not always easily
32
33 261 applicable in the local geomorphologic context. Moreover, recent investigation of risk
34
35 262 perception in the Upper Rhine department shows that the population demands from local
36
37 263 authorities that they implement ‘visible’ protection measures (Heitz et al., in press). This
38
39 264 experience can also be reproduced in England (Evans and Boardman, 2003). Policy is hence
40
41 265 decided at the European scale whereas the population asks for local actions.

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42 267 **4. Muddy flood mitigation measures resulting from the CAP**

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45 269 In Belgium, the regions are responsible for the implementation of agriculture,
46
47 270 environment and land use planning policies in the framework of the EU guidelines. In France,
48
49 271 the national ministry of agriculture is in charge of these policies. Decentralized state agencies
50
51 272 are responsible for the implementation and the control of agricultural and environmental
52
53 273 rules. Policy in England is characterised by centralisation with little devolution to regional or
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55 274 local government.

56 275

58 276 *4.1. Cross-compliance*

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3 278 Cross compliance regarding erosion mitigation consists in a series of standards that
4
5 279 farmers need to meet in order to receive the totality of their subsidies. It has been
6
7 280 implemented with regional specifications (Table 3a). In Wallonia, specific rules are applied to
8
9 281 fields having at least 50% of their area (or minimum 0.5 ha) with a slope steeper than 10%. In
10
11 282 contrast, Flanders bases its rules on the results of an adapted version of the RUSLE equation
12
13 283 applied for each cultivated field of the region (see e.g. Verstraeten et al., 2001). Alternative
14
15 284 farming practices must be used or Agri-Environmental Measures (AEMs) must be installed on
16
17 285 the fields at risk. In France, cross-compliance relies on respect for good agricultural and
18
19 286 environmental conditions. A cover crop ('couvert environnemental') or grass buffer strips
20
21 287 must also be sown on at least 3% of the cultivated surface for which subsidies are granted. In
22
23 288 England, in order to receive payments (Single Payment Scheme), farmers have to maintain
24
25 289 land in Good Agricultural and Environmental Condition (GAEC) for a payment of €43.5 ha⁻¹.
26
27 290 Farmers can then be volunteer to enter an Entry Level Scheme of Environmental Stewardship
28
29 291 if they wish for further payments. To enter the Higher level Scheme, farmers have to bid
30
31 292 competitively. As part of Entry Level and Higher Level schemes, a Farm Environmental
32
33 293 Record has to be produced and record, among other things, land suffering from erosion and
34
35 294 runoff. Each farm has a points target related to farm size that they must attain by choosing
36
37 295 from a range of options. Some of these options help control runoff e.g. grass buffer strips.
38
39 296 There are also options related to management of high erosion risk cultivated land, of special
40
41 297 concern being that under root crops such as potatoes and sugar beet, maize and outdoor pigs.
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43 298

42 299 *4.2. Agri-Environmental Measures*

43 300
44 301 Farmers have to fulfil minimum environmental standards in order to receive their EU
45
46 302 single payments. If the farmers want to go beyond those standards, they have the possibility to
47
48 303 implement Agri-Environmental Measures (AEMs) during a five-year minimum period. They
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50 304 are hence paid by society for the environmental service they deliver. Agri-environmental
51
52 305 schemes are flexible and implemented differently according to the state or region in Europe
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54 306 (European Commission, 2005). Such flexibility enables the regions or states to meet certain
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56 307 local environmental needs.
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58 308

58 309 *Belgium*

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3 311 In Wallonia, two AEMs contribute to runoff and erosion mitigation even if they were
4
5 312 not designed to achieve this specific objective: (i) installation of Grass Buffer Strips (GBS)
6
7 313 and (ii) sowing of cover crops during the dormant period. Farmers' participation rate to these
8
9 314 measures increased from 1998 to 2006 in the Walloon loess belt and reached 17% in 2006
10
11 315 (Fig. 3). In the 'Hillsland natural park', agricultural advisers convinced farmers to install
12
13 316 GBS where muddy floods have routinely damaged roads or houses. Consequently, in 2002,
14
15 317 farmers' participation rate to AEMs was much higher in the area covered by the park (27%
16
17 318 for GBS; 40% for sowing a cover crop during the dormant period) as compared to the mean
18
19 319 rates for the Walloon loess belt (12% for GBS and cover crops). The extension officers
20
21 320 stopped their advice at the end of 2002 and the farmers' participation rate in the area covered
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23 321 by the park subsequently decreased until it reached the mean participation level for the
24
25 322 Walloon loess belt (Fig. 3).

26
27 323 In Flanders, similar AEMs (management of field edges; sowing of cover crops) have
28
29 324 been available to farmers since 1999. The increase in the area with cover crops occurred later
30
31 325 than in Wallonia (Fig. 4). Cover crops have not been subsidised by the Flemish government
32
33 326 since 2007, since it is considered that it should be part of standard good environmental
34
35 327 practices. In contrast, the area of cover crops keeps increasing in Wallonia, after a slight
36
37 328 decrease in 2004 due to important changes to the Walloon agri-environmental scheme.

38
39 329 Since January, 2005, a new AEM enables the Walloon farmers to install GBS with the
40
41 330 specific objective of erosion mitigation for which they need an agreement designed by an
42
43 331 expert. This new rule leads to an extra subsidy (€1250 ha⁻¹ instead of € 900 ha⁻¹ for standard
44
45 332 GBS). In Flanders, a package of five AEMs aiming at erosion control (dam and retention
46
47 333 pond; direct drilling; grass buffer strips; grassed waterway; minimum tillage) exists since
48
49 334 2005. Overall, AEMs for erosion mitigation are more widespread in Wallonia than in
50
51 335 Flanders (Fig. 5). Several explanatory factors can be put forward. First, in Wallonia, extension
52
53 336 officers visit the fields where erosion problems are observed and propose to the farmers the
54
55 337 most suitable solution. Second, 'word of mouth' about AEMs is probably more efficient
56
57 338 among the Walloon farmers, their number being smaller and their capacities to invest larger,
58
59 339 because of the much greater farm size (Table 2).

340

341 *France*

342

343 Numerous AEMs are available to French farmers, but two types of measures represent
344 60% of total grants: (i) the subsidies for least favoured areas and (ii) the subsidies for the

1
2
3 345 maintenance of extensive breeding systems (PHAEs for 'Primes Herbagères Agri-
4 346 Environnement'). The last measure is mostly applied where grassland dominates, which is not
5 347 the case in the Upper Rhine nor in the Aisne. In France, there are no specific AEMs aimed at
6 348 erosion mitigation. Several AEMs exist, but they aim to meet more general objectives (e.g.
7 349 conversion to sustainable farming and integrated landscape management).

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9
10 350 The CTEs ('Contrats Territoriaux d'Exploitation') were introduced in 1999. They
11 351 were the first tool promoting the multifunctional role of agriculture in France. They focused
12 352 on improving water quality (conversion of cropland into grassland, installation of grass strips,
13 353 limited use of fertilisers) and soil quality (planting of hedges, no-till or reduced tillage). At the
14 354 national scale, farms that adopted such AEMs are concentrated in rural and mountainous areas
15 355 (Vosges, Alps, Pyrenees, Massif Central; Urbano and Vollet, 2005). CTEs were replaced in
16 356 2003 by CADs ('Contrats d'Agriculture Durable') which aim to allow the conversion to more
17 357 sustainable farming. Farmers can choose to install proposed measures such as new grassland
18 358 or planting of hedges. However, the number of farmers concerned remains limited (e.g. 99
19 359 contracts in 2004 in the Aisne department). The transition period between CTE and CAD
20 360 regimes was rather confusing for farmers and many of them were discouraged.

21 361 There is a lack of information about the specific financial amounts granted for erosion
22 362 mitigation in France. Developing a means of producing, centralising and diffusing such
23 363 statistics should be a priority for the relevant agencies.

24 364

25 365 *England*

26 366

27 367 Under the Single Payment Scheme, farmers have to keep land in Good Agricultural
28 368 and Environmental Condition in order to receive payments. As part of this, they have to fill
29 369 in a Soil Protection Review. Stewardship schemes, as outlined above, can be taken up and for
30 370 those a Farm Environmental Record is needed. On fields at risk of erosion, they can gain
31 371 points by agreeing not keep outdoor pigs, to plant potatoes, sugar beet or maize. Specific
32 372 advice on the management of maize is offered (RDS, 2005). Detailed risk assessment
33 373 procedures, and advice on management of specific arable crops to avoid erosion and runoff is
34 374 given in Defra (2005) and Cuttle et al. (2006). Risk assessment includes risk of runoff leaving
35 375 fields and damaging surface waters and roads and thus muddy flooding.

36 376

37 377 *Comparative discussion*

38 378

1
2
3 379 If we focus on AEMs dealing with erosion and runoff control in the different regions
4
5 380 (Table 3b), a comparison seems to be very difficult, given that AEMs objectives and practical
6
7 381 requirements are completely different. Overall, adoption of AEMs by the farmers increases in
8
9 382 Belgium and in France. However, their implementation relies on individual farmers'
10
11 383 decisions, with the exception of GBS for erosion mitigation in Wallonia. At least, rules for the
12
13 384 location of AEMs should be introduced, whatever the final objective. It is not only important
14
15 385 for erosion mitigation, but also for biodiversity conservation (e.g. Berger et al., 2003).
16
17 386 Actions to increase awareness and to inform the farmers at the local scale proved to be
18
19 387 effective (e.g. in the Hillsland Natural Park, Wallonia). The measures should also be more
20
21 388 targeted. Each year, c. € 2000 millions are spent on AEMs in the EU (European Commission,
22
23 389 2005). However, a very low proportion of this amount is dedicated to erosion mitigation. The
24
25 390 member states should fund specific studies to make sure the measures they support serve their
26
27 391 purpose. AEMs are generally applied to a larger extent in rural and mountainous areas, where
28
29 392 they constitute an important part of the farmers' income. In contrast, in the very productive
30
31 393 loess regions, most farmers still consider that a more intense agricultural use of the soil will
32
33 394 generate higher incomes even over the long term, which explains a lower adoption of AEMs
34
35 395 in those areas. Still most off-site impacts of agriculture are observed in the intensively farmed
36
37 396 regions.

35 397 Even though they generally aim to facilitate their implementation, changes in AEM
36
37 398 schemes and practical requirements can induce discouragement among farmers if they are too
38
39 399 frequent (e.g. transition between CTEs and CADs in France; new Walloon agri-environmental
40
41 400 programme in 2005). A certain stability is needed, as well as support from local agricultural
42
43 401 advisors; this is beginning to happen in England through schemes such as the Catchment
44
45 402 Sensitive Farming Initiative. The links between advisors and the scientific community could
46
47 403 also be improved.

48 404

49 405 **5. Regional mitigation schemes**

50 406

51 407 *5.1. Belgium*

52 408

53 409 In 1997, the Flemish government recognised erosion as an environmental problem,
54
55 410 leading among other consequences to muddy floods. It adopted an 'erosion decree' in
56
57 411 December, 2001, allowing municipalities to receive funding to carry out a local plan against
58
59 412 erosion (€ 12.5 ha¹ covered by the plan) and implement erosion control measures in the field

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2
3 413 (75% of total amount; Verstraeten et al., 2003). By 2007, 85% of the municipalities in the
4
5 414 Flemish loess belt had started the process leading to the drawing up of such a scheme. It does
6
7 415 not mean that control measures are being installed in all of these municipalities. In many
8
9 416 cases, the schemes have been drawn but they have not been applied so far. The Flemish Water
10
11 417 Ordinance ('watertoets') also imposes the evaluation of the impact of any new construction
12
13 418 on water issues before the deliverance of planning permission.

14 419 In Wallonia, the government decided to tackle the flooding problem designing an
15
16 420 integrated scheme called 'Rainfall Scheme' ('Plan Pluies' in French) in 2003. In the near
17
18 421 future, similar schemes to the ones proposed in Flanders will be funded by the Walloon
19
20 422 regional authorities. Maps of flood prone areas (one for river flooding and another for local
21
22 423 flooding) are also being drawn and should serve as a useful decision tool for regional land use
23
24 424 planning.

25 425

26 426 5.2. France

27 427

28 428 In France, several tools are designed at the departmental scale. The creation of specific
29
30 429 schemes at the departmental level was beneficial for their local implementation. Two main
31
32 430 tools are available: risk prevention schemes (PPR- 'Plan de Prévention des Risques') and
33
34 431 SAGE schemes ('Schéma d'Aménagement et de Gestion de l'Eau' – 'Land use and water
35
36 432 management planning schemes').

37 433 PPR schemes have been created to cope with given risks (forest fire, earthquake,
38
39 434 flood). Five maps must be systematically drawn (hazard location, historical evolution,
40
41 435 vulnerability, places that are most at risk, global risk). According to these maps, specific
42
43 436 measures can be prescribed: building of protection installations, rules for new buildings and,
44
45 437 in extreme cases, expropriation. However, the adoption of a PPR does not necessarily lead to
46
47 438 the installation of measures in the field. Furthermore, the latter consist most of the time of
48
49 439 protection measures (e.g. dams) and do not prevent erosion and runoff generation in the
50
51 440 fields.

52 441 SAGE schemes aim at water resource planning and management. This planning
53
54 442 document is designed at the river basin scale by different regional agencies. Since it has legal
55
56 443 power, the other decisions related to water management must take the SAGE provisions into
57
58 444 account. This tool has several advantages compared to the flood prevention scheme. First, it
59
60 445 works at the catchment scale. Second, it is an integrated tool that not only focuses on runoff
446 and muddy floods but it also deals with water pollution, water protection and fish breeding.

1
2
3 447 Stakeholder meetings to increase awareness are organised in the framework of the SAGE
4
5 448 schemes. They are therefore potential measures for a possible centralisation of competences,
6
7 449 but they remain rather complex to implement. By 2005, 31 SAGE schemes had been created
8
9 450 in France, and 101 more schemes are being implemented.

10 451 The Upper Rhine department also proposes a specific integrated tool called 'Gerplan'
11
12 452 to promote landscape multifunctionality and, if relevant, to control muddy floods. It aims to
13
14 453 define concrete management proposals for the different landscape components (cropland,
15
16 454 orchards, riparian zones). Actions are planned for a 10 year-period and funding is provided by
17
18 455 the departmental authorities. Planned actions (e.g. changes of farming practices, construction
19
20 456 of retention ponds) are detailed for each field at an operational scale (1: 5000). By 2007, 22
21
22 457 local boards grouping several municipalities in Upper Rhine had decided to implement
23
24 458 Gerplans, which are drawn up by consultants on behalf of farmers' trade unions and
25
26 459 agriculture local state agencies.

27 460 The French government also adopted a law on natural risks in 2003 according to
28
29 461 which a commission dealing with such risks has to be created in each department (Auzet et
30
31 462 al., 2006). This law implies that during the sale of a property, potential owners are
32
33 463 systematically informed of the risks relative to its location. This measure is not only applied
34
35 464 to natural risks (earthquakes, floods) but also to technological risks (e.g. presence of Seveso
36
37 465 factories).

38 466 Moreover, a decree of 2005 specifically deals with erosion mitigation. The
39
40 467 departmental authorities have the possibility to delineate erosion prone areas and to draw up a
41
42 468 mitigation scheme. Local stakeholders must meet the objectives prescribed by the authorities
43
44 469 in the scheme within three years.

45 471 *5.3. England*

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48
49 473 Initiatives relevant to control of muddy flooding are the Environmentally Sensitive
50
51 474 Area scheme (established in 1987), which funds farmers to revert arable fields to grassland.
52
53 475 On the South Downs, 5000ha have been entered into the scheme (SDMP, 2004). In
54
55 476 partnership with other agencies, the Environment Agency has funded a Landcare scheme
56
57 477 aimed at reducing runoff from farmers' fields into the River Rother around Midhurst (Horsey,
58
59 478 2006). This has now been discontinued. In 2005, Defra identified 42 catchments in England
60
479 and are funding a Catchment Sensitive Farming scheme (2005-08) to address issues of diffuse
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pollution (Defra, 2007). None of the priority catchments are in the area under consideration;

1
2
3 481 some of the 42 have muddy flooding problems such as the Lugg in Herefordshire (Walker,
4 482 2007). Defra have also published a First Soil Action Plan for England (Defra, 2006); and
5 483 most usefully a guide to controlling soil erosion (Defra, 2007). There are several over-lapping
6 484 and non-coordinated schemes some of which are funded for a short time.
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11 486 *5.4. Diagnosis: spatial mismatch*

12 487

13
14 488 Multiplicity of state agencies and splitting-up of the initiatives is apparent (Table 4).
15 489 Based on the stakeholders involved and the main tools available for erosion and flood
16 490 mitigation, two main types of measures can be pointed out:

17 491 (i) AEMs that are directly installed by farmers, but the objective and the practical
18 492 requirements of which are defined by national (France and England) or regional (Belgium)
19 493 authorities;

20 494 (ii) Specific schemes at the municipal scale (flood risk prevention schemes in France; erosion
21 495 mitigation scheme in Flanders) or at the river basin scale (SAGE schemes in France). The
22 496 latter do not exist at present in Wallonia but specific AEMs for erosion mitigation requiring
23 497 an expert's approval are proposed.

24 498 Overall, there is a spatial mismatch between, on the one hand, the scale at which
25 499 muddy floods are triggered (small catchment scale) and, on the other hand, the scale at which
26 500 farmers (farm-scale) and public authorities (municipality- or region scale) can operate. This is
27 501 mainly true in small Belgian municipalities as well as in France. In England neither County
28 502 Councils nor District Councils have any responsibility for flood protection either with regard
29 503 to rivers or muddy floods from agricultural land.

30 504 In Flanders, the Melsterbeek Water Board (264 km²), a grouping of five municipalities
31 505 as well as the local water agency, is the only area where erosion and flood control measures
32 506 are installed in the framework of a catchment-integrated approach. Even though the EU Water
33 507 Framework Directive requires that countries set up management plans at the river basin scale
34 508 by December 2009, the French government has rather encouraged the creation of municipal-
35 509 scale risk prevention schemes since 2000. Five years later, it has been updated with
36 510 significant financial investment to 5000 schemes. In such a context, prevention schemes
37 511 aimed at mitigating risk, largely dominate. The advantage is that creating one tool for all
38 512 types of risks facilitates collective actions. Inverting the trend by strengthening catchment
39 513 agencies which should be better known to the population and the authorities is the major
40 514 challenge for the future. It presupposes that municipalities learn to work together. The

1
2
3 515 municipalities of central Belgium also have to take up the challenge. In twenty hotspot
4 516 municipalities of central Belgium that were studied in detail (Evrard et al., 2007a), the runoff
5 517 generation area and the flooded zone were located in different municipalities in 62 cases (17%
6 518 of flooded areas). Of these 62 areas, an important part of the drainage basin was located in the
7 519 other Belgian region (24% of the cases), or even in another country in six cases (10%). A
8 520 similar situation is observed in the Upper Rhine department where 20% of muddy floods are
9 521 generated in a municipality and affect another village located downstream.

10 522 In England also, the Catchment Sensitive Farming (CSF) scheme concentrates on
11 523 perceived hotspots of risk to rivers and targets catchments which have nature conservation
12 524 value where sediments or nutrients are a threat. The scheme however is voluntary and farmers
13 525 can opt-in or out. Grants are available for capital works and the CSF officer provides advice
14 526 on prevention of erosion and runoff to the farmers. The scheme is funded for two years and is
15 527 at present under review. Many bodies are putting emphasis on the Environmental Stewardship
16 528 scheme since most farmers are expected to opt-in in order to receive payments. Potentially,
17 529 though the options are very limited (buffer strips and land use change), the scheme may have
18 530 a positive impact. Unknown factors are whether there will be rigorous policing of measures
19 531 and their effectiveness, and if the monetary incentives will be sufficient to attract growers of
20 532 high-value crops (e.g. maize, potatoes and sugar beet) on high erosion risk land. However, if
21 533 there are muddy floods from a farmer's land he is not complying with GAEC conditions of
22 534 the Single Payment Scheme, which may make it easier to enforce the regulations providing
23 535 such floods are reported. This is a matter of educating the general public.

24 536

25 537 **6. Local measures against muddy floods**

26 538

27 539 *6.1. Measures taken by the municipalities*

28 540

29 541

30 542 In Flanders, the municipalities frequently affected by muddy floods or severe erosion
31 543 can decide to implement a municipal mitigation scheme. This is not the case in the other
32 544 regions, but similar tools will soon be available for erosion prone areas in France and
33 545 Wallonia. Following a visit to frequently flooded Walloon municipalities (n=12; Evrard et al.,
34 546 2007a), two main observations could be made: 1) muddy floods are considered a major
35 547 problem for the population in 42% of the cases and they got worse during the last decade
36 548 according to 83% of the local authorities; 2) there is no integrated flood management in 83%
37 549 of the cases. Furthermore, in 83% of the municipalities, the only actions considered are

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2
3 550 modifications to the sewage system or construction of retention ponds. The construction of a
4
5 551 retention pond is very expensive (mean cost of € 380,000 (Verstraeten and Poesen, 1999), and
6
7 552 does not prevent runoff generation. Still the local authorities consider that rainfall intensity is
8
9 553 the most influential natural factor and frequently quote large-scale potato and maize crops as
10
11 554 important human factors triggering muddy floods. Certain municipalities therefore decided to
12
13 555 tackle the problem. For instance, a Walloon municipality confronted with 37 areas affected by
14
15 556 muddy floods grants specific subsidies to local farmers for the installation of GBS in flood
16
17 557 prone areas. In the Walloon Brabant province, the Rural Foundation of Wallonia organises
18
19 558 municipal commissions ('commissions agricoles communales') where local authorities,
20
21 559 farmers and inhabitants can discuss specific matters such as erosion mitigation. Finally,
22
23 560 certain river management committees ('contrats rivières') intend to inform and increase
24
25 561 awareness of erosion among the population and the farmers. They can help solving problems
26
27 562 in individual cases.

28
29 563 French local authorities (e.g. in the Upper Rhine) are subjected to pressure from the
30
31 564 population to instigate control measures. They can expropriate agricultural fields to install
32
33 565 them. Even though they are aware of the implication that floods may be triggered by
34
35 566 inappropriate land use planning, pressure is sometimes too important. In some cases, the
36
37 567 mayors demand a concerted implementation of measures at the catchment scale, implicating
38
39 568 their counterparts in upstream villages (Heitz, 2005). Local urban schemes (PLUs or 'Plans
40
41 569 Locaux d'Urbanisme') take risk areas into account to define land approved for development.
42
43 570 They are the only official document of land use planning available at the local scale in France.
44
45 571 They are drawn up on behalf of the municipal authorities but also approved by departmental
46
47 572 and regional authorities.

48
49 573 In England local authorities have no statutory responsibility to protect people from
50
51 574 muddy flooding as the first case of its kind made quite clear (Stammers and Boardman, 1984).
52
53 575 In practice, whenever people and their properties are damaged by flooding, they appeal to
54
55 576 their political representatives and they put pressure on local councils. Councils therefore have
56
57 577 often acted as organisers of emergency defence measures such as ditches, dams and pipes.
58
59 578 Councils have attempted to organise protection over longer time periods but have been less
60
579 successful and have been reluctant to commit resources to this process. Evans and Boardman
580
581 (2003) describe repeated flooding of houses in the Sompting catchment on the South Downs
582
583 and the political process in achieving success. In fact, limited land use change driven by Set
584
585 Aside regulations led to control of flooding. Highway authorities also have power under the
586
587 Highways Act (1980) to control runoff from fields that reaches roads. This has only been used

1
2
3 584 in the Isle of Wight (Boardman, 1994). In exceptional cases, where local councils own
4
5 585 agricultural land, they have instituted either land use change or the building of dams in order
6
7 586 to protect communities from flooding (Boardman et al., 2003). In areas such as the South
8
9 587 Downs where flooding does not occur every year or in the same place perhaps for many
10
11 588 years, there is a problem of lack of institutional memory within local councils in that they deal
12
13 589 with muddy flood problems occasionally. No councils have specialists to deal with erosion
14
15 590 and runoff problems but generally rely on all-purpose engineers. There is also the temptation
16
17 591 to believe that measures put in place at one time will solve the problem without constant
18
19 592 maintenance (e.g. ditch clearance). Finally, there is no co-ordinating body to bring together
20
21 593 the experience of local councils.

22 594 23 595 *6.2. Measures taken by farmers*

24 596
25
26 597 Numerous farmers feel responsible for erosion processes (e.g. Bielders et al., 2003). A
27
28 598 couple of them have decided on their own initiatives to alleviate muddy floods. In the Aisne
29
30 599 department, the 'erosion task force' can propose the installation of several measures (e.g.
31
32 600 GBS, dams and buffer ditches) in their fields. Moreover, in the Aisne, several farmers sow
33
34 601 alternate strips of maize and wheat to limit runoff generation and concentration. In the
35
36 602 Belgian Melsterbeek catchment, farmers similarly decided to implement double sowing in the
37
38 603 thalweg of their fields (Gyssels et al., 2002). On the South Downs, southern England, several
39
40 604 farmers have built retention dams to protect their own or others property from muddy floods.
41
42 605 These have usually been built as an emergency response to flooding. In some cases they have
43
44 606 failed. Changes in land use or farming practice directly attributable to the risk of muddy
45
46 607 flooding are difficult to confirm (but see Evans and Boardman, 2003). Direct drilling
47
48 608 (minimal cultivation) is rare but is being used by one farmer to reduce the risk of flooding his
49
50 609 neighbour. Another example of a farmer's individual actions to mitigate erosion in England is
51
52 610 described by Evans (2006).

53 611 Consultation between several farmers of the same municipality is also possible. They
54
55 612 can decide to coordinate the location of the different crops to limit runoff generation at the
56
57 613 catchment scale (Joannon et al., 2006). Certain municipalities in the Upper Rhine department
58
59 614 (e.g. Morschwiller-le-Bas) have organised such consultation. However, these initiatives
60
61 615 remain very local (Christen and Wintz, 2006). The importance of this consultation
62
63 616 phenomenon is impossible to quantify, but it seems to be more widespread in France than in
64
65 617 Belgium, given the much larger mean size of the French farms (Table 2). Furthermore, in

1
2
3 618 Belgium, many farmers are reluctant to discuss it. Many of them have commitments with
4
5 619 agro-food companies to produce crops (e.g. carrots, peas). It becomes difficult to combine
6
7 620 their different commitments with the consultation about crop location at the catchment scale.

8
9 621 In France, the Supreme Court of Appeal has perhaps set a precedent for conflicts
10
11 622 between farmers due to erosion. A fish breeder whose basins were damaged by runoff loaded
12
13 623 with sediments instituted proceedings against the farmer cultivating the upstream slope. The
14
15 624 Supreme Court quashed a sentence stipulating that runoff and erosion were due to heavy
16
17 625 rainfall. The Supreme Court argued that the farmer cultivating the upstream fields was
18
19 626 responsible for the damage induced to the downstream fish breeding basins.

20
21 627 In England, there is some history of legal attempts to protect properties from runoff
22
23 628 from agricultural land and to sue those responsible for the damage for negligence. Legal
24
25 629 advice in several cases suggests that to be successful, it must be shown that the farmer was
26
27 630 aware of the risk to his neighbour e.g by previous flooding; that the rainfall event was not
28
29 631 'exceptional'; that farming practices including land use decisions were the cause of the
30
31 632 flooding; that no measures were taken to protect the neighbour (Boardman, 2003). Out-of-
32
33 633 court settlements in the Breaky Bottom flooding incidents show that these criteria can be met
34
35 634 in some cases. In future the threat of legal action may act as a deterrent at sites with a history
36
37 635 of previous flooding.

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39 636

37 637 **7. Conclusions**

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41 638

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43 639 Muddy floods are a frequent and widespread phenomenon in the European loess belt.
44
45 640 However, there is no standard database recording these events and data on damage costs
46
47 641 remain rare or limited to certain municipalities. A comparison of flood frequency between
48
49 642 different European regions is not easy, since administrative units do not correspond to
50
51 643 homogeneous natural regions. Over the last decade, there has been a raising of consciousness
52
53 644 among all the stakeholders involved in muddy flood management. Huge costs induced by the
54
55 645 floods in numerous villages help justify the rapid installation of control measures. However,
56
57 646 people and farmers remain insufficiently informed of the processes involved and the
58
59 647 mitigation tools available. French investigations showed that the affected populations
60
61 648 particularly appreciate the construction of retention ponds, considering that they protect them
62
63 649 efficiently. Consultation between stakeholders at the local scale should be encouraged, e.g. in
64
65 650 the framework of municipal agricultural commissions. Farmers are often overwhelmed with
66
67 651 administrative tasks. Thanks to local coordinators' help, the adoption of AEMs aiming at

1
2
3 652 erosion mitigation is more successful. The creation of an integrated scheme to mitigate
4
5 653 erosion and muddy floods is now considered in all the studied regions. Furthermore,
6
7 654 concerted actions between municipalities must be a priority, given that the limits of
8
9 655 municipalities do not coincide with hydrological units. A solution to the observed ‘spatial
10
11 656 mismatch’ would be to enhance existing structures that are efficient (Belgian water agencies
12
13 657 and natural parks, French SAGE schemes, English Catchment Sensitive Farming schemes) or
14
15 658 to widen the application field of existing tools (e.g. flood prevention schemes at the catchment
16
17 659 scale). Catchment agencies concentrating legal, environmental and financial competences
18
19 660 (like the water boards in the Netherlands) could also help control floods and erosion.
20
21 661 Individual measures (AEMs) installed by farmers after an expert’s approval could also be
22
23 662 stimulated. Alternatively, rules for an optimal location of AEMs should be imposed.
24
25 663 Furthermore, the effectiveness of the current AEMs should be assessed. A comparison of the
26
27 664 tools available in different countries to combat erosion and muddy floods should be carried
28
29 665 out to see whether they serve their purpose. Muddy flood management can either focus on soil
30
31 666 and water conservation or on property protection. Conflicts of viewpoints can arise and
32
33 667 influence the type of measures that will finally be implemented. Farmers’ conversion to
34
35 668 alternative farming practices limiting runoff and erosion production in the fields must also be
36
37 669 progressively encouraged to complete the ‘palliative’ approach currently pursued and
38
39 670 assessed in pilot areas. This could be achieved through the creation of new specific AEMs.

671

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679

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

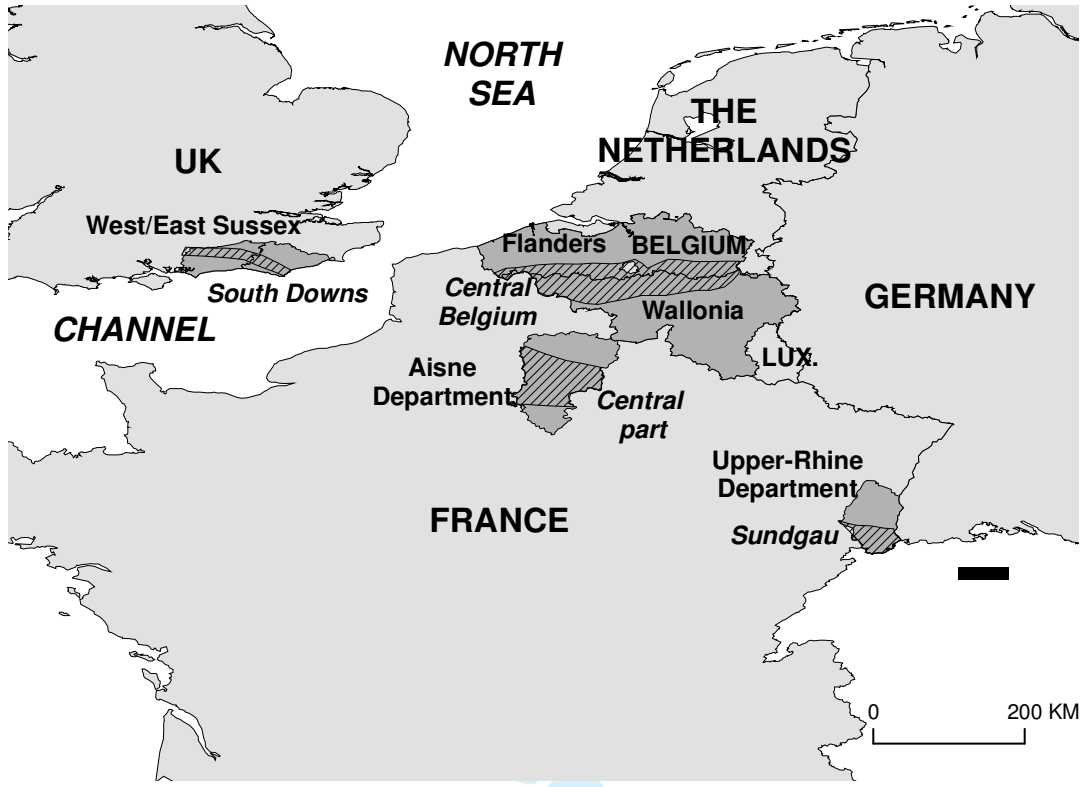
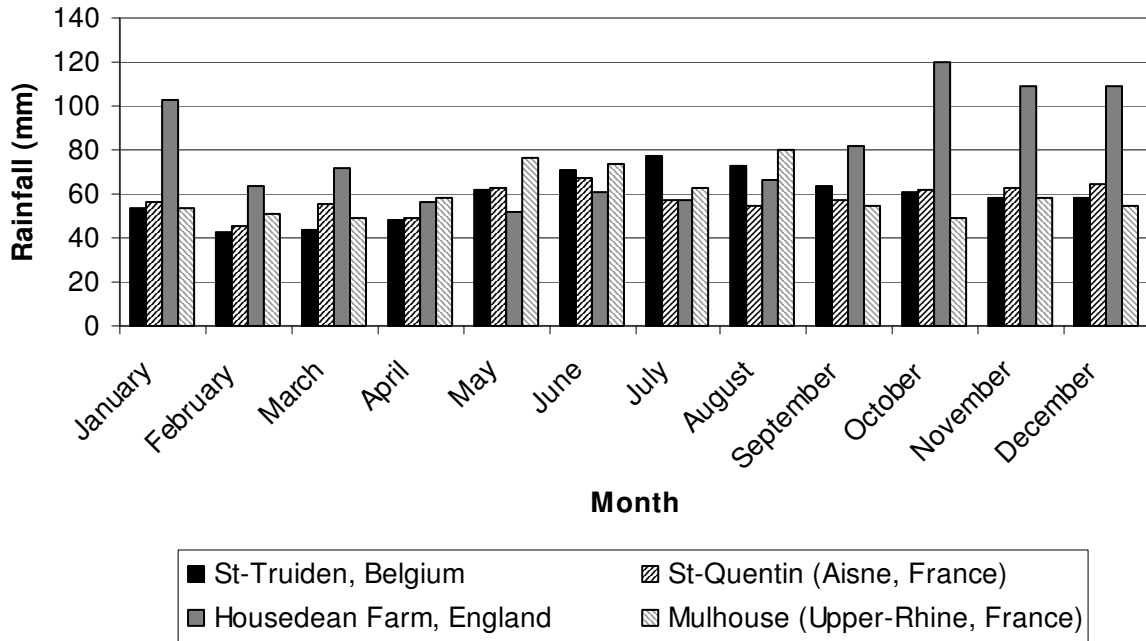


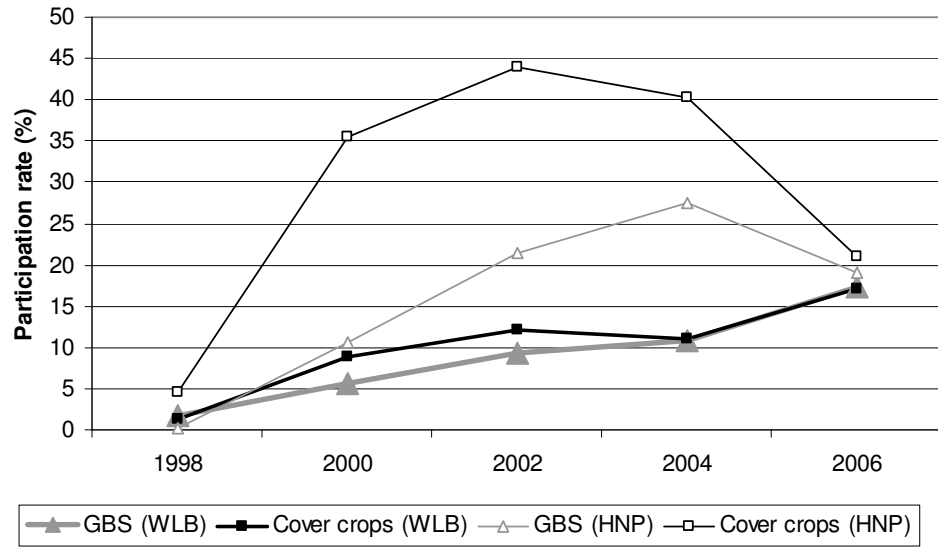
Fig. 2. Mean monthly rainfall distribution in central Belgium, northern France and southern England.



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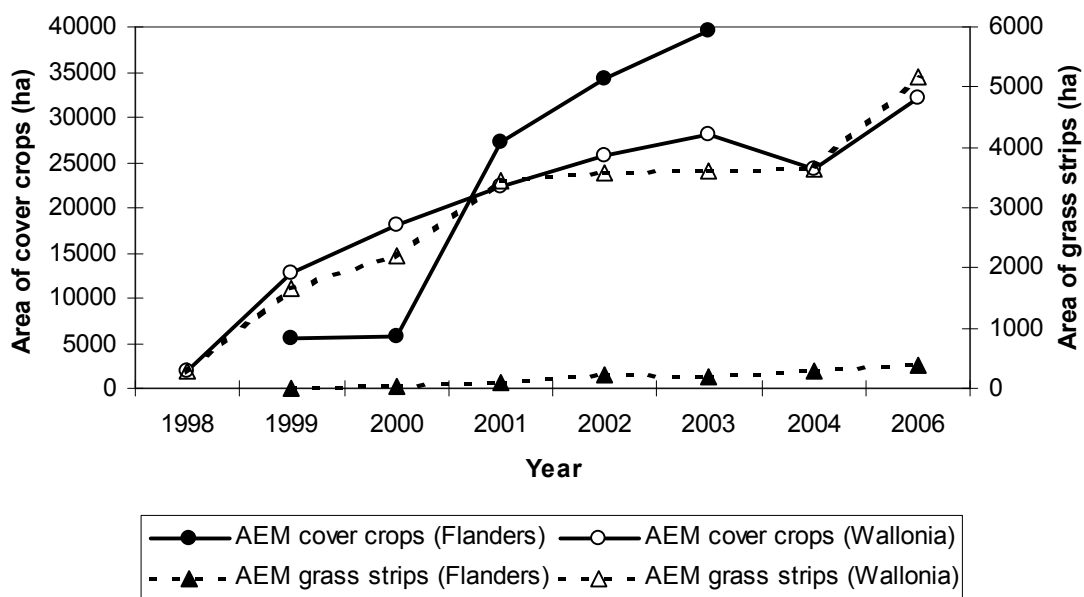
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1 Figure 3. Evolution (1998-2006) of farmers' participation rate to two AEMs (GBS – Grassed
2 Buffer Strips; cover crops during the dormant period) in the Walloon loess belt (WLB) and
3 the Hillsland natural park (HNP), Belgium. Data available from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



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

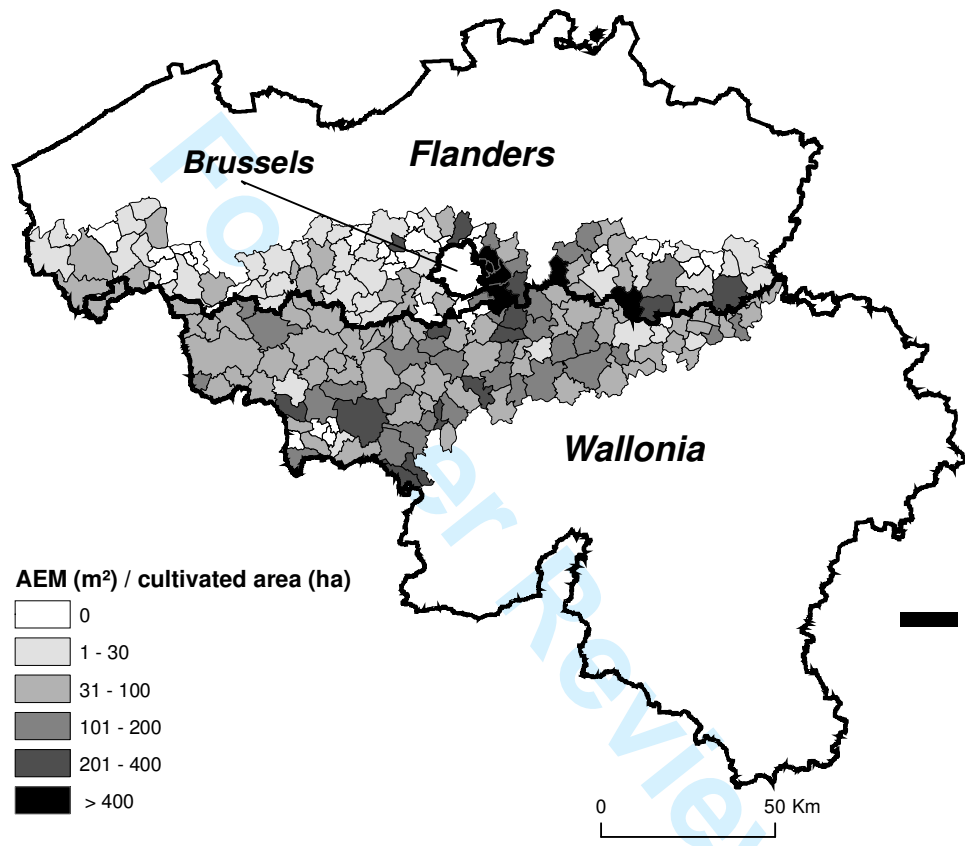


Table 1. Physical characteristics of the studied regions.

Characteristic	Flanders	Wallonia	Aisne	Upper Rhine	South Downs
Total area (km ²)	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.

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1 Table 2. Demographic characteristics of the studied regions.

2	3	4	5	6	7
Characteristics	Flanders ^a	Wallonia ^b	Aisne	Upper Rhine	South Downs
Number of municipalities	100	104	816	377	15 ^e
Mean municipal area (km ²)	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) High erosion score according to a RUSLE-derived model (Flanders)	GBS / no row crop planting 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) GBS / dams / alternatives farming techniques (Flanders)	Needs an expert's approval
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

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