



**Residents coping
with floods in
Germany 2005–2011**

S. Kienzler et al.

This discussion paper is/has been under review for the journal Natural Hazards and Earth System Sciences (NHESS). Please refer to the corresponding final paper in NHESS if available.

After the extreme flood in 2002: changes in preparedness, response and recovery of flood-affected residents in Germany between 2005 and 2011

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Received: 22 August 2014 – Accepted: 14 September 2014 – Published: 9 October 2014

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Published by Copernicus Publications on behalf of the European Geosciences Union.

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Abstract

In the aftermath of the severe flood in August 2002, a number of changes in flood policies were launched in Germany and other European countries aiming at an improved risk management. The question arises, whether these changes have already an impact on the residents' capabilities of coping with floods and whether flood-affected private households are now better prepared than in 2002. Therefore, computer-aided telephone interviews with private households in Germany that suffered from property damage due to flooding in 2005, 2006, 2010 or 2011 were performed and analysed with respect to flood awareness, precaution, preparedness and recovery. The data were compared to a similar investigation after the flood in 2002.

After the flood in 2002, the level of private precaution increased considerably. One contribution factor is that a larger part of people knew that they are at risk of flooding. Yet this knowledge did not necessarily result in building retrofitting or flood proofing measures. The best level of precaution was found before the flood events in 2006 and 2011. This might be explained by more flood experience and overall greater awareness of the residents. Still, costs and damage avoiding benefits of these measures have to be communicated in a better way.

Early warning and emergency response were substantially influenced by flood characteristics. In contrast to flood-affected people in 2006 or 2011, people affected by flooding in 2005 or 2010 had to deal with shorter lead times, less time to take emergency measures; consequently they suffered from higher losses. Therefore, it is important to further improve early warning systems and communication channels, particularly in hilly areas with fast onset flooding.

1 Introduction

In August 2002, a severe flood event occurred in Central Europe (Germany, Austria, the Czech Republic and Slovakia). Heavy precipitation due to a Vb weather system with

NHESSD

2, 6397–6451, 2014

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record breaking amounts, e.g. of 312 mm within 24 h had been observed at the gauging station Zinnwald-Georgenwald in the Erzgebirge, Germany, and resulted in high discharges and water levels in the rivers Elbe and Danube and some of their tributaries (see Ulbrich et al., 2003; Engel, 2004). The high hydraulic impact led to the activation of dam spillways as well as to overtopping and breaching of embankments in many places. Among other things, missing or incomplete flood warnings, bad maintenance of flood protection structures as well as a lack of knowledge about adequate behaviour were identified as weaknesses of the flood risk management (DKKV, 2003; Thieken et al., 2007). Altogether, 21 people were killed in Germany and the total damage amounted to €11 600 million (Thieken et al., 2006). This amount exceeded the damage of former disastrous events by far and despite a similar flood event in June 2013, it is still the highest damage record in Germany (EM-DAT, 2014). After the flood in 2002, many activities were launched on the administrative and legislative levels (see DKKV, 2003). Particularly, the German act on precautionary flood protection (*Artikelgesetz zur Verbesserung des vorbeugenden Hochwasserschutzes*) and the European Floods Directive (2007/EC/60; EC, 2007) were important policies, which also indicate a shift from a pure technical-oriented flood defence towards a more integrated flood risk management that also considers non-structural measures to minimise adverse effects of flooding. In general, flood risk management focuses on three aspects (Vis et al., 2003): (1) flood abatement with the aim to prevent peak flows, e.g. by an improvement of the water retention capacities in the whole catchment, (2) flood control that is aimed at preventing inundation by structural measures, e.g. embankments or detention areas and (3) flood alleviation with the goal to reduce flood impacts by non-structural measures (Parker, 2000; de Bruijn, 2005). In the latter, preventive, precautionary and preparative measures can be distinguished. Prevention is aimed at completely avoiding damage in hazard-prone areas, e.g. by land use regulation. Precaution and preparation help to limit and manage adverse effects of a catastrophe and to build up coping capacities by flood-resilient design and construction, development of early warning systems, awareness campaigns, education and training etc. (e.g. Vis et al.,

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2003; DKKV, 2003; PLANAT, 2004; de Bruijn, 2005). If damage occurs despite of these measures, risk transfer mechanisms such as flood insurance help to accelerate recovery (see e.g. Thieken et al., 2006; Schwarze et al., 2011).

The success of precautionary and preparatory measures depends to a high degree on the risk awareness and preparedness of flood-affected residents. Surveys which were performed a few months after the flood in 2002 (Thieken et al., 2005; Kreibich et al., 2007) revealed that flood-affected households and companies had difficulties to cope with the flooding and suffered from high financial losses, particularly along the river Elbe and its tributaries. In these areas, only 3.6 and 7.4%, respectively, had experienced flooding in the ten years prior to the event (Thieken et al., 2007). Hence, flood risk awareness was at a low level.

After the flood in 2002, a substantial increase in the implementation of precautionary measures was detected for private households and companies (Thieken et al., 2007; Kreibich et al., 2005, 2007, 2011). Therefore, the question arises whether German residents at risk of flooding are now better able to cope with flooding than they were in 2002. Since the above-mentioned changes in European and national flood policies have not only been effective in affected regions of 2002, but in all of Germany, flood risk awareness and preparedness should have increased in general, i.e. also in areas that did not experience flooding recently. This aspect will be addressed in this paper by investigating coping capacities of private households during four flood events between 2005 and 2011 that occurred in different regions. Analogue to the paper of Thieken et al. (2007), the disaster management cycle will be used as framework for the analysis. The cycle has widely been used by international and national organisations and various versions have been published (e.g. Silver, 2001; DKKV, 2003; PLANAT, 2004; FEMA, 2004; Kienholz et al., 2004). It distinguishes three (or four) phases: (emergency) response, recovery, (risk analysis and assessment) and disaster risk reduction. During the event, immediate measures are undertaken with the priority to limit adverse effects and the duration of the event (response phase). After the event, the affected society starts to repair damage and to regain the same or a similar standard of living than

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before the disaster happened (recovery phase). Ideally, the recovery phase is already accompanied by an event and risk analysis that leads to a period of disaster risk reduction, in which measures that are aimed at minimising the vulnerability of people and their assets are planned and implemented (Kienholz et al., 2004).

This paper aims to reveal how residents in different regions of Germany were prepared to recent flooding, how they responded to the hazardous events, how they suffered in terms of financial damage and recovered as well as what they changed in precaution after having experienced a flood. We focus on four flood events in Germany that happened in August 2005, March/April 2006, August 2010 and January 2011, respectively. The four events affected different catchment areas: in 2005 and 2006, flooded regions were similar to those in 2002. In 2010 and 2011, however, flooding occurred in regions, where less people experienced a flood within the last ten years, although in some areas in the Rhine catchment the level of precaution is assumed to be high (Bubeck et al., 2012b). In addition, these floods were triggered by different weather patterns. While flooding in (2002) 2005 and 2010 was due to heavy precipitation in connection with a Vb-weather type, floods in 2006 and 2011 were characterised by a “rain on snow” mechanism. Since the level of preparedness and reaction might also depend on the flood characteristics, the four flood events will be described in more detail in the next section. In Sect. 3, data and methods of the analysis will be introduced. Then Sect. 4 focuses on the results of the analyses, while Sect. 5 offers some conclusions on what could further be done to stipulate private precaution and disaster preparedness.

2 The four flood events

In order to provide a basis for the interpretation of the flood characteristics on the reaction and coping capacities of affected residents, the four flood events are described in this section. A description of the 2002 event that serves as reference (see below) was already given in the introduction. Table 1 summarizes hydro-meteorological conditions

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and financial damages of all flood events. In Fig. 1 the mentioned rivers and cities can be found.

2.1 July/August 2005

A considerable flood affected the German part of the Danube catchment in August 2005. Cyclone “Norbert” closely followed the track of a Vb-weather system and induced the advection of moist air from sub-tropical regions to Switzerland, northern Italy, Austria and southern Germany. The encounter with cold air masses and an orographic uplift at the north face of the Alps led to prolonged rainfall with notably high amounts within 12 to 24 h (e.g. 216 mm in 24 h on 22 August 2005 Balderschwang; LfU, 2007). As a result, the alpine foothills were affected by flash floods characterized by a rapid increase in discharges and water levels. Inundations occurred both along the river Danube and its southern tributaries. Return periods of maximum discharges were classified to less than 1 in 100 years at the Iller, Schmutter, Amper, Inn and Isar rivers and to 1 in 20 to 50 years at the rivers Lech, Loisach and Mangfall. At the Danube river, highest return periods occurred at Ingolstadt and Kelheim in the range of 1 in 20 to 50 years (LfU, 2007). Flood protection measures as well as operation of dams and retention areas effectively reduced the flood impact. The total economic damage was estimated to about €175 million in Germany (Kron, 2009). Damage to infrastructure amounted to €50 million, damage to private households and to the commercial sector amounted to about €70 million (LfU, 2006).

2.2 March/April 2006

The river flood in spring 2006 mainly occurred in the Elbe catchment. Due to exceptionally heavy snowfall during the winter of 2005/2006, the amount of water stored as snow was about 2.4 billion m³ at the beginning of 2006 in the upper Elbe catchment (Korndörfer et al., 2006). At the end of March, temperatures rose rapidly to 5 to 15 °C leading to a complete snowmelt within one week also in the upper parts

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the upstream part of the Weser catchment. In Saxony-Anhalt at the rivers Elbe, Saale, Havel, Schwarze Elster, Weiße Elster, Wipper and Bode water levels increased to alarm level 4 around 15 January (LHW, 2011). Flooding occurred and resulted in damage in the catchments of the Rhine, the Danube, the Weser and the Elbe. However, despite the many affected catchments, disastrous damage did not occur. The total damage was estimated to be more than €100 million in Germany (Axa et al., 2012).

3 Data and methods

3.1 Procedure of sampling flood-affected private households

The data set contains information collected by computer-aided telephone interviews with private households that suffered from property damage due to flooding in 2002, 2005, 2006, 2010 or 2011 (Fig. 1). In the following, the flood events 2005, 2006, 2010 and 2011 are referred to as study subsets, and the 2002 event as reference subset (Table 2). Since the compilation of the reference data set was already described by Thieken et al. (2005, 2007), only the collection of the study subsets is described.

On the basis of flood reports or press releases as well as with the help of flood masks derived from radar satellite data (DLR, Centre for Satellite Based Crisis information, www.zki.dlr.de) lists of inundated streets were compiled for each flood event. These lists served as a basis to select telephone numbers of all potentially affected residents/households from the public telephone directory. Computer-aided telephone interviews were undertaken with the VOXCO software package (www.voxco.com) by the Explorare market research institute (www.explorare.de), once in November/December 2006 and once in February/March 2012 (Table 2). Always the person in the household who had the best knowledge about the flood event was **questioned**.

In total, 461 interviews were undertaken in 2006, of which 305 interviewed households had been affected in 2005 and 156 in 2006. The second campaign resulted

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in 658 interviews with 349 households affected in 2010 and 209 households affected in 2011 (Table 2). The remaining 100 interviews were undertaken with households affected by torrential rain in the city of Osnabrück in August 2010; however, these data are not included in the current analyses. The respective numbers and shares of interviews referring to the affected river catchments are listed in Table 3.

3.2 Contents of the questionnaire and data processing

For the two campaigns the questionnaire presented in Thielen et al. (2005, 2007) was slightly adapted. Altogether, the questionnaires contained about 180 questions addressing the following topics: flood impact, contamination of the flood water, flood warning, emergency measures, evacuation, cleaning-up, characteristics of and damage to household contents and buildings, recovery of the affected household, precautionary measures, flood experience as well as socio-economic variables. For our analyses, we selected only those variables which were presented in Thielen et al. (2007) for the flood event in 2002 in order to enable a consistent comparison of the different flood events (Table 4). These variables differed significantly in the regions that were investigated by Thielen et al. (2007) and are hence assumed to provide reasonable information for the comparison of different flood events.

In a number of questions people were asked to assess qualitative or descriptive variables on a rank scale from 1 to 6, where “1” described the best case and “6” the worst case. The meaning of the end points of the scales was given to the interviewee (see Table 4). The intermediate ranks could be used to graduate the evaluation.

To analyse the amounts of financial loss, some assumptions had to be made. In the survey, some respondents did not put a precise figure on their financial damage, but indicated for example that they had “hardly suffered damage” or “only electricity costs for operating the pump”. In order to quantify these kinds of damages, a flat-rate loss of €250 had been attributed to such cases. This amount was determined by the authors and represents approximately the average deductible for natural hazard insurances in

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in the study subsets 2006 or 2011. The impacts of the flood regarding mean water level and contamination were most severe in the study subset 2010, which also reflects the severity of the flood event as described in Sect. 2.3. In comparison, during the 2002 summer flood, both flood characteristics occurred: river floods occurred along the main rivers and rapid onset floods in the headwaters (see Ulbrich et al., 2003). The resulting mean flood duration was comparable to the study subset of 2006. However, the mean water level and contamination had been still much worse than in any of the other study subsets.

4.2 Preparedness before the flood events

Private preparedness before a flood event is an important component of flood risk management as it can have a significant effect on flood loss mitigation. It includes three types of precautionary measures: (1) information and behavioural precaution, e.g. collecting information about the flood hazard and protection as well as participation in networks, (2) flood proofing and retrofitting measures, e.g. adapting the building structure or usage of the premises and furniture, reconstructing the heating system or purchasing water barriers, and (3) risk precaution, e.g. contracting a flood insurance (LAWA, 1995; ICPR, 2002; DKKV, 2003; BVMBS, 2008; Kreibich et al., 2005, 2011).

With respect to precautionary behaviour before the respective flood event of the study subsets, more than 90 % of all respondents performed at least one precautionary measure; in contrast, only 7 % did not carry out any measure at all. Generally, interviewees mostly gathered information about the flood hazard and how to protect themselves (58 %) as well as participated in networks (43 %) (Fig. 2). Although collection of information is an important first step, these measures do not lead to damage mitigation in the first place. This is only possible if the knowledge is further translated into real action. Hence, damage reduction is achieved exclusively through precautionary measures like flood-proofing and building retrofitting or emergency measures (see ICPR, 2002; Kreibich et al., 2005). With regard to these flood-proofing and building retrofitting actions, adaptation of interior equipment (43 %) and building

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awareness diminishes within seven years and only remains for a longer period after catastrophic disasters. Before the flood event in 2010 for example, many respondents in the Oder–Neisse catchment had only been rarely affected by a flood, which in addition dated back several years. This also applied especially to people who were affected by the severe flood event in 2002. In the light of the above, the lower percentages of performed precautionary measures before 2010 or 2002 might be explained. In this context it is noteworthy, however, that by far most respondents affected by the flood in 2011 knew that they live in a flood-prone area, although they did not experience a previous flood. This reflects a profound awareness of the flood risk in this area and might be a reason for the people's outstanding preparedness before 2011. Yet, the knowledge of one's own potential flood risk and the information about protection did not necessarily result in technical or structural building retrofitting or flood proofing measures. Even before the flood event in 2011, these measures were carried out to a lower extent, though some of these measures were only given to homeowners (see Fig. 2). Nonetheless, the benefits and cost savings of these actions still have to be communicated in a better way.

4.3 Warning and response

Damage mitigation not only depends on long-term preparedness, but also on people's flood awareness and how they react at the time of the approaching flood.

4.3.1 Flood warning and lead time

To respond to a flood, people need to be made aware of the risk. Early warning systems and communication play a decisive role in this context. However, people's response to warnings is above all dependent on the warning lead time, which in turn is strongly dependent on the catchment size and shape as well as on flood characteristics. Longer lead times of several days can be provided in the middle to lower reaches of large river catchments due to the temporally extended flow of the flood wave (river flood).

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view of that, the regional topography and flood characteristics appear to be the most determining factors for the warning sources.

4.3.2 Content of warnings and reaction capabilities

To receive a flood warning is just one of the key preconditions to take emergency measures. As mentioned above, it also depends on the quality of warning content. The information content of flood warnings by authorities was therefore investigated in further detail. The results revealed that warnings were comprehensive in all investigated study subsets. The comparison of the individual subsets showed that in 2010 information about residential areas at risk (52%), advice for damage reduction (49%), evacuation (29%) and levee breaches (17%) were reported more often than in any other study subset (Table 7). Other warning contents like information about maximal water level (68%), time to peak water level (58%) or information about diversions or road blockings (27%) were most often included in 2006 or 2011.

In summary, however, no clear information content improvement can be derived from the study subsets compared to the reference year 2002. Again, it is assumed that the quality of warnings depends to a high degree on the flood characteristics, but also on the number of previously experienced floods as authorities, that disseminate warning information certainly improve with an increasing number of flood events. Furthermore, flood warnings are the responsibility of the individual federal states so that there might be also regional differences in the quality of warnings. Moreover, it has to be acknowledged that the number of valid answers was rather small (see Table 7).

Respondents who received an official flood warning were furthermore asked to evaluate their knowledge to protect themselves and their households, based on the obtained warning. On a scale from 1 (= I knew exactly what to do) to 6 (= I had no idea what to do), approximately 67% (2005), 81% (2006) and 85% (2011) of the study subset interviewees responded 1 or 2 (Fig. 4). Merely in 2010 this share was 50%. However, the corresponding figure of the reference subset 2002 was even lower (28%).

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The data reveal that the awareness of emergency preparedness of flood-affected residents had considerably increased after 2002, also in areas that had not experienced flooding for a longer time, which holds for the subset of 2010 (compare Table 5 and Fig. 4). The question arises whether this knowledge could be used to mitigate damage. Therefore, the next sections deal with emergency measures and resulting losses.

4.3.3 Emergency measures

In case of an imminent flood hazard, flood warnings and emergency measures are predominantly performed to mitigate potential loss and damage (Molinari et al., 2013). On average, more than 50 % of all respondents of the four study subsets performed emergency measures such as putting moveable contents upstairs and driving vehicles to a flood-safe place. Further measures carried out frequently aimed at protecting the building from entering water (e.g. by installing a water pump or mobile barriers) or at safeguarding important documents and valuables. However, data on individual study subsets showed that highest percentages were mostly found for the study subsets 2006 or 2011 (Fig. 5). Merely, gas/electricity was most frequently centrally switched off by public services in 2010.

Looking back at the reference subset 2002, the use of water pumps, redirection of water flow as well as safeguard of domestic animals seemed to be of only little importance in terms of emergency measures. However, this is related to the circumstance that these items were not specifically requested in 2002, but deduced from open answers. In fact, however, more people safeguarded documents and valuables, switched of gas or electricity and protected the building against inflowing water than people in any other investigated study subset. An explanation for this could be that the lower preparedness level in 2002 (see Sect. 4.2.) had to be compensated by an increased performance of emergency measures.

A successful damage reduction not only depends on the general performance of emergency measures, but also on their effectiveness. Therefore, performed emergency

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measures were assessed by respondents according to the effectiveness on a scale ranging from 1 (= very effective) to 6 (= totally ineffective). For the illustration in Fig. 6, the results were averaged for each measure and study year. In general, the performed measures in the study subsets were predominantly evaluated to be effective. Averages ranged from 1.1 to 3.8, whereby “to drive vehicles to a flood-safe place” was the measure with the best evaluations, while “to redirect the water flow” was evaluated by the lowest ranks. Measures aiming at redirecting the water flow and protecting the building against inflowing water were considered rather challenging (Fig. 6). We assume that those actions are often difficult to perform as they require in particular longer time, manpower and know-how. In addition, two different evaluation patterns can be identified within the study subsets. Some measures, e.g. to protect the oil tank or to switch off gas/electricity, show a constant improvement of effectiveness over time, whereas almost all other measures were evaluated as being more effective in 2006 and 2011 than in 2005 and 2010.

In 2002, the general picture was very similar to that of the study subsets. People found it also most difficult to protect their building and household contents, though rated these measures even more ineffective. The evaluation of other emergency measures resulted approximately in the same range as in the other study subsets.

Though, despite the better protection knowledge (in comparison to the reference dataset of 2002), 2005 and 2010 were years in which the highest percentage of people performed no emergency measures (22 and 15 %, respectively). In 2006 and 2011, the fraction of households not performing emergency measures amounted only to 8 % (Table 8).

Like in 2002, the main reason for this fact was lack of time. Respectively, 65 and 56 % of respondents in 2005 and 2010 stated that it was too late to do anything (Table 8). In fact, 45 and 39 % of the people in those years argued that they could have done more if they had been warned earlier. In 2006 and 2011, respective shares were only 23 and 10 % (data not shown).

In summary, it can be said that the warning sources and contents have not improved continuously over time. Rather, the regional topography and flood characteristics seem to influence the extent of warnings considerably. This is also reflected by the fact that people affected by floods in 2005 and 2010 had to deal with shorter lead times than people in 2006 or 2011. Hence, dissemination and quality of (official) flood warnings was limited, with the result that in 2005 and 2010 less people knew exactly how to protect themselves. In addition, people affected in 2005 or 2010 were less flood experienced (see Table 5) and probably less familiar with safeguarding measures. This lack of time, knowledge and experience not only seems to explain why fewer people performed emergency measures in these two study subsets, but also why most of the emergency measures were evaluated less effectively than in 2006 and 2011. Nevertheless, it is apparent that people, who were officially warned, knew much better how to protect themselves as it was the case in 2002. It can therefore be concluded that the flood response capacity of the people had improved after 2002. However, it is still important to further improve early warning systems and communication channels, especially in hilly areas with rapid onset floods, to enable more people to respond to the threat of a flooding.

4.4 Adverse effects of the flood events

4.4.1 Flood damage

Damages that result from flooding can affect different sectors and may have adverse effects on private households (e.g. buildings, furniture), the economy (e.g. public infrastructure, industrial companies, business interruptions, agriculture), the cultural heritage, the environment, or on the people (e.g. health effects, traumata or even loss of life). These kinds of damages can be classified into direct or indirect damages, which might be further subdivided into tangible or intangible damages (Messner and Meyer, 2006; Merz et al., 2010). In this study, only direct tangible damage to buildings and contents of private households was analysed.

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Looking at all four study subsets, 609 of total 1019 respondents (60%) suffered damage to residential buildings, 479 interviewees (47%) suffered damage to household contents, in terms of repair and replacement costs. The comparison of the single study subsets showed that the shares of people that sustained building losses were about in the same range. Highest percentages were found in 2010 (65%) and lowest in 2005 (52%). In 2006 and 2011, 56 and 64% were recorded, respectively. However, striking differences in values can be identified with respect to household damage. Far fewer people were affected by damages in 2006 and 2011 (31 and 23%, respectively) than in 2005 and 2010 (51 and 64%, respectively). This reflects the differences in flood characteristics, but also in precaution, warning and response that was described in the previous sections. The proportion of people suffering building damage in the reference subset 2002 amounted to 64% and was about equal to that in 2010 and 2011. Though, the share of people affected by damage to household contents was highest, reaching 75% (data not shown).

Tables 9 and 10 list the financial building and household damages per year, respectively. The proportions of minor damages up to €250 (including a flat-rate loss; see Sect. 3) are additionally specified. The median building damage, given in prices as at 2013 by correcting the actual amounts by the building cost index of June 2013 (DESTATIS, 2014a), was highest in 2010 and lowest in 2011, reaching €21 436 and €2112, respectively. The corresponding median loss in 2002 amounted to €30 037 (Table 9). A classification of these damages can be seen in Fig. 7. It is noteworthy that in 2011 the share of damage up to €5000 accounted for about two third of all reported damages. In the other three study years, this proportion did not even cover half of the damages, but higher costs were more often reported.

Median damages of household contents in prices as at June 2013, corrected by the consumer price index (DESTATIS, 2014b) were much lower than building damages. However, highest and lowest losses were again recorded in 2010 and 2011 and amounted to €10 560 and €2069, respectively. The median loss of household contents in 2002 amounted to €10 131 and was comparable to 2010 (Table 10). In contrast to

the classification of building damages, the share of damages to household contents up to €5000 was highest in the study subsets 2006 (70 %) and 2011 (64 %) and reached nearly 50 % in 2005. Only in 2010, this proportion was merely 33 %, which in turn indicates a large number of higher damages (see Fig. 8).

In summary, the median losses show that highest damages were always recorded in 2010 (and 2005, with regard to household contents) and lowest in 2011 (and 2006, with regard to household contents). This pattern can only be explained by taking into account several factors, e.g. flood characteristics, flood experience and awareness and precaution. Hence, losses were higher the shorter the lead time, the lower the previous flood experience, the lower the knowledge about how to protect oneself and the lower the precaution level. However, these interdependencies apply to damages to household contents, yet are only partly explanatory for building damages.

Besides, the expected trend is that households with lower losses recover faster after the flood. This assumption will be addressed in the following.

4.4.2 Recovery

In this study, the recovery status is a simplified measure for the regained standard of living after a flood event compared to the status before the event; knowing that the recovery process in fact needs to be seen in a more nuanced light and is influenced by several factors (e.g. Whittle et al., 2010).

In the surveys, respondents were asked to assess the state of their building and contents at the time of the interview compared to their state before the flood on a scale from 1 (= building/household contents is completely restored/replaced) to 6 (= still considerable damage to the building/household contents). For the analyses, the investigated flood events were grouped into two groups as described in Sect. 3.2. The comparison between the flood events in 2006 and 2002 after 8–10 months after the flood showed: in 2006, the building and furniture status had been valued at 1 or 2 by 62 % and even 73 % of interviewees, respectively. Thus, people recovered faster than in 2002, where the equivalent shares amounted only to 46 and 59 %, respectively. The

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Best precaution was performed before the flood events in 2011 and 2006, which might be explained by more flood experience and overall greater risk awareness of the residents. However, on average 53% of all respondents had only undertaken information precaution or participated in networks, which is not per se leading to a damage reduction. Accordingly, investments in flood-proofing or retrofitting measures still need to be stimulated in order to reduce future damage more efficiently.

Early warning and emergency response were apparently strongly dependent on the floods characteristics and the regional topography, but were also influenced by previous flood experiences of the respondents. Therefore, a constant improvement over the years could not be observed, but rather corresponding results of flood events in 2005 and 2010 tended to be lower than those of 2006 and 2011. Hence, it is important to further improve early warning systems and communication channels, especially in hilly areas with rapid onset floods, to enable more people to respond to the threat of flooding.

Flood losses and the recovery status also seem to be influenced by the flood characteristics. The overall improved flood precaution and the larger share of people knowing how to protect themselves could counteract damages only to a certain extent. However, flood damages are most likely the result of additional influencing factors. Accordingly, more detailed studies are needed to investigate essential key factors to estimate and describe flood damages more precisely.

After the flood event, respondents became more aware of their risk exposure and were motivated to invest in flood proofing and building retrofitting measures in future. Yet, the challenge remains to increase the precaution level of private households, especially in areas with low previous flood experience and risk awareness.

The investigations of this study were primarily descriptive. For future investigations, it would therefore be interesting to focus on single key factors and to perform theory- or model-based analyses. E.g. it is known that flood experience is an important precondition for the implementation of precautionary measures. But there are studies that question the importance of the relationship between risk awareness and the

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adoption of private mitigation measures and assume other factors more influential (Bubeck et al., 2012a; Scolobig et al., 2012), e.g. policy changes, people’s perception regarding the responsibility for flood protection, trust in public flood protection, severity of the experienced adverse flood consequences, negative emotions, coping appraisal or socio-economic and geographic variables (Grothmann and Reusswig, 2006; Siegrist and Gutscher, 2008; Botzen et al., 2009; Zaalberg et al., 2009; Kreibich et al., 2011; Terpstra, 2011). Therefore, more detailed investigations are needed to analyse what (other) factors influence people’s precautionary behaviour. This could optionally be examined on the basis of the protection motivation theory introduced by Rogers (1975).

Furthermore, some aspects seem to be mainly influenced by the region, e.g. behaviour seems to be influenced by a certain “risk culture”. In contrast, other variables, such as flood warning (lead time) seem to be dominantly influenced by the flood event and its flow characteristics (intensity, velocity of onset etc.). These aspects also have to be investigated in more detail in the near future. And finally, based on these results it should be investigated how flood damage models can be improved.

Appendix A:

Due to the lower number of affected households in both telephone surveys 2006 and 2012, all available phone numbers were researched and called. In the 2006 survey, these were 9964 phone numbers and 20 262 phone numbers in 2012, broken down as listed in Tables A1 and A2.

Acknowledgements. The present work was partially developed within the framework of the Panta Rhei Research Initiative of the International Association of Hydrological Sciences (IAHS). The two surveys were undertaken within the MEDIS project funded by the German Ministry for Education and Research (BMBF; No. 0330688) and by a joint venture between the University of Potsdam, the GeoForschungsZentrum Potsdam and the Deutsche Rückversicherung AG, Düsseldorf, respectively. Data analysis was supported by the BMBF project No. 13N13017. We are furthermore indebted to Ute Dolezal (University of Potsdam) for the graphical design of all figures.

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Table 3. Numbers and shares of interviews with respect to the affected river catchment.

Catchment	Reference subset		Study subsets							
	2002		2005		2006		2010		2011	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Danube	449	26.5	276	90.5	41	26.3				
Elbe/Labe	1248	73.5	29	9.5	115	73.7	162	46.4	21	10.0
Oder/Odra							157	45.0	5	2.4
Rhine							30	8.6	183	87.6
Total	1697		305		156		349		209	

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Table 4. Items of the survey that were used in this paper.

Item	Units and labels
Socio-economic variables	
Age of the interviewee	Number of years
Education	Type of degree
Household size	Number of people
Monthly net income of the household	Euro
Living area per person	m ²
Homeowners	tenant/homeowner/owner of a flat
Flood experience <i>before</i> the flood event	
Previously experienced floods	Number of events
Time period since the last flood event	Number of years
Knowledge about the flood hazard of the residence/plot (only questioned when no previous flood had been experienced)	0: no knowledge, 1: knowledge of flood hazard
Preparedness (<i>before/after</i> the flood) and risk awareness	
Informational precaution	Type of measures and time of performance
Flood insurance	0: no insurance, 1: insurance, and time of contract conclusion
Flood-proofing measures and retrofitting	Type of measures and time of implementation
Characteristics of the inundation	
Water level	cm above top ground surface
Flood duration	Hours
Contamination of the flood water	0: no contamination, 1: sewage, 2: chemicals (and sewage), 3: oil (and chemicals or sewage)
Warning and response <i>before/during</i> the flood event	
Lead time	Hours
Perceived knowledge about self-protection	Rank from 1 (I knew exactly what to do) to 6 (I did not know what to do)
Emergency measures	Type of performed measure and perceived effectiveness of each measure evaluated on a scale from 1 (very effective) to 6 (totally ineffective)
Adverse effects of the flood events	
Damage to the building	Euro
Damage to household contents	Euro
Recovery	
Perceived status of restoration of the building/replacement of household contents at the time of the interview	Rank from 1 (buildings/household contents are already completely restored/replaced) to 6 (there is still considerable damage to the building/to household contents)

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Table 5. Description of the different flood events with respect to socio-economic variables, previously experienced floods and flood impact (figures do not refer to all interviews, but to the respective number of valid responses).

Flood event	2002	2005	2006	2010	2011	Germany
Socio-economic variables						
Mean age of the interviewees [years]	52	52	55	57	57	male: 42.8, female: 45.5 (2012) ^b unknown
People with high school graduation/university degree (German Abitur/Fachabitur/Hochschul-/Fachhochschulabschluss) [%]	30.7	37.8	39.1	27.8	32.7	
Mean household size [number of people]	2.8	2.9	2.7	2.5	2.6	2.0 (2010) ^c
Households with a monthly net income < €1500 [%]	29.9	19.0	28.2	25.5	14.4	25.9 (2008) ^d
Mean living area per person [m ²]	47.9	48.7	51.1	46.0	63.2	45.1 (2010) ^e
Homeowners [%]	75.8	76.7	83.3	84.8	89.0	46.0 (2010) ^e
Flood experience BEFORE the respective event						
People who experienced at least one previous flood [%]	21.9	55.4	82.7	52.1	77.5	
thereof: People who experienced a flood in the last ten years [%]	58.1	74.0	89.1	57.6	75.3	
People who had not experienced at least one previous flood [%]	77.8	41.6	13.5	47.0	21.5	
thereof: People with knowledge about the flood hazard of their property [%]	30.6	52.0	52.4	40.9	68.9	
Characteristics of the flood impact						
Mean flood duration [h]	143	52	146	67	104	
Mean water level above top ground surface [cm] ^a	64.2	−19.4	18.8	58.3	−19.5	
Interviews that reported oil or petrol contamination [%]	38.5	13.8	13.5	15.5	6.7	

^a assuming a basement depth of 2.50 m below top ground surface.

^b BiB (2014a).

^c BiB (2014b).

^d Kott and Behrends (2011).

^e DESTATIS (2013).

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Table 6. Answers to the question: “How did you become aware of the danger of flooding?”; given in percentage of all interviewed people per flood event (multiple answers possible) and average lead time per subsample.

Flood event	2002	2005	2006	2010	2011	Total (2005–2011)
Own observation	33.4 %	28.9 %	29.5 %	41.0 %	56.9 %	38.9 %
Flood warning by authorities	40.5 % ^a	32.8 %	34.0 %	23.5 %	45.0 %	32.3 %
Severe weather warning by radio, TV etc.	13.3 %	23.6 %	41.7 %	20.1 %	42.1 %	28.9 %
Warning by neighbours, friends etc.	13.9 %	12.1 %	16.7 %	16.3 %	15.8 %	15.0 %
General reporting in nationwide news	13.9 % ^a	8.5 %	13.5 %	5.7 %	12.0 %	9.0 %
Gauge information		^a	^a	0.3 % ^a	3.3 % ^a	1.4 % ^b
Warning and evacuation at the same time	1.2 %	^a	^a	^a	^a	
Other warning sources (sms, public services)	0.4 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
No warning	26.8 %	26.9 %	11.5 %	32.4 %	6.2 %	22.2 %
No answer	0.7 %	1.0 %	1.3 %	0.3 %	0.0 %	0.6 %
Number of valid interviews	1697	305	156	349	209	1019
Average lead time [h]	37	16	40	11	23	20
Number of valid interviews	1005	156	103	173	158	590

^a Data were not requested.

^b Total value results from calculations of years 2010 and 2011.

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Table 8. Reasons why people did not perform emergency measures (multiple answers possible).

Flood event	2002	2005	2006	2010	2011	Total (2005–2011)
It was too late to do anything	61.1 %	65.2 %	33.3 %	56.1 %	35.3 %	55.9 %
Nobody was at home	18.3 %	18.2 %	25.0 %	17.5 %	11.8 %	17.8 %
I did not think the flood would become so severe	5.3 %	12.1 %	16.7 %	15.8 %	0.0 %	12.5 %
I thought emergency measures would be ineffective	8.8 %	4.5 %	16.7 %	5.3 %	11.8 %	6.6 %
I did not know what to do	3.5 %	1.5 %	0.0 %	7.0 %	5.9 %	3.9 %
I was not capable to do anything	2.8 %	1.5 %	8.3 %	0.0 %	11.8 %	2.6 %
I thought emergency measures wouldn't be necessary	8.8 %					
Others	1.8 %	3.0 %	0.0 %	17.5 %	23.5 %	10.5 %
Flood adapted building/contents use		0.0 %	0.0 %	5.3 %	23.5 %	4.6 %
No warning		0.0 %	0.0 %	12.3 %	0.0 %	4.6 %
Recently moved in/irresponsible		3.0 %	0.0 %	0.0 %	0.0 %	1.4 %
Not specified/no answer	3.2 %	1.5 %	0.0 %	3.8 %	0.0 %	2.0 %
Number of valid interviews	284	66	12	57	17	152
Percentage of valid interviews (i.e. people performed no emergency measures)	16.7 %	21.6 %	7.7 %	16.3 %	8.1 %	14.9 %

* Data were not requested since distinction between "I did not think the flood would become so severe" or "I thought emergency measures would be ineffective" was found to be difficult.

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Table 9. Flood damage of buildings.

Flood event	Flat-rate loss					Mean direct damage reported by GDV (2013) [€]		
	Excluding					Including		
	<i>n</i>	Mean damage [€]	Median damage [€]	Mean damage corrected by building cost index (June 2013) [€]	Median damage corrected by building cost index (June 2013) [€]	<i>n</i>	Minor damage up to €250 [%]	
2002	1079	42 093	24 000	52 681	30 037	1080	2.5	13 500
2005	158	19 302	7400	23 626	9058	160	6.2	no data
2006	85	24 814	10 000	30 191	12 167	88	6.8	no data
2010	224	43 695	20 000	46 832	21 436	228	5.3	14 000
2011	119	10 765	2000	11 369	2112	133	21.8	2100

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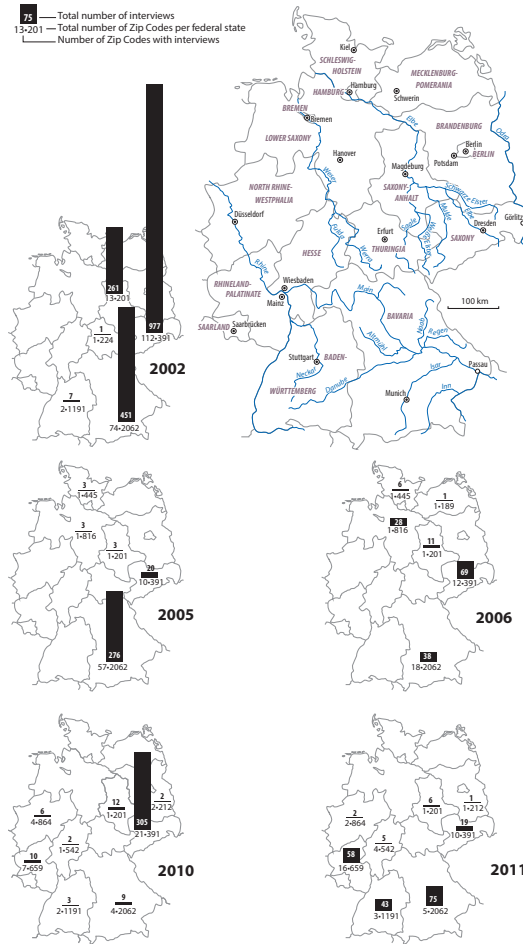


Figure 1. Federal states, where interviews of the respective subsamples were conducted.

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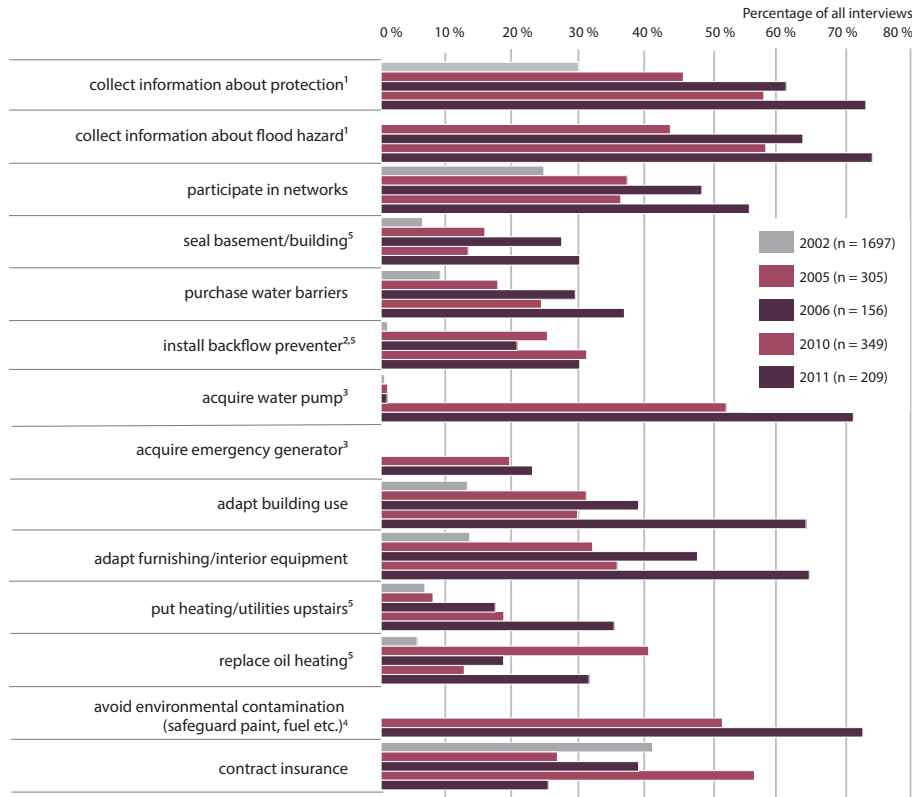
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¹in 2002, collection of information about protection and flood hazard have not been requested individually but summarized in category "collect information about protection"

²measures were not explicitly requested in 2002, but deduced from open answers

³measures were not explicitly requested in 2002, 2005 and 2006, but deduced from open answers. Additionally, no distinction was made between acquisition of pumps and emergency generators. Measures were therefore summarized in the category "acquire water pump"

⁴measures were retrieved only from surveys 2010 and 2011

⁵measures were only given to homeowners

Figure 2. Precautionary measures performed by private households before the respective flood event.

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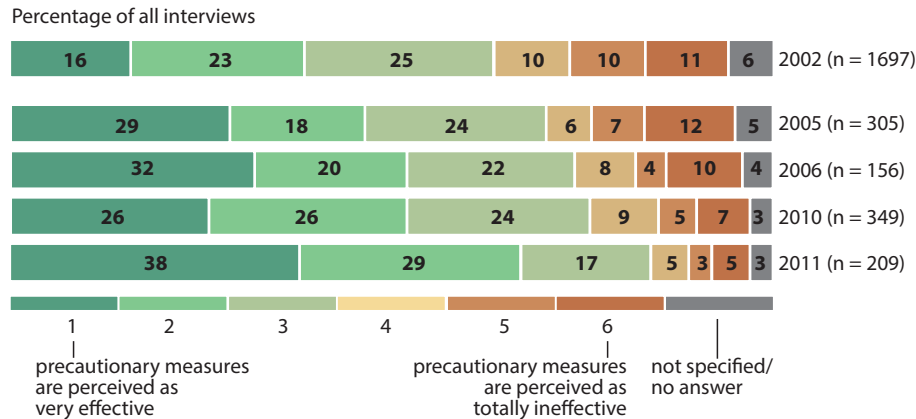


Figure 3. Perceived effectiveness of private precautionary measures.

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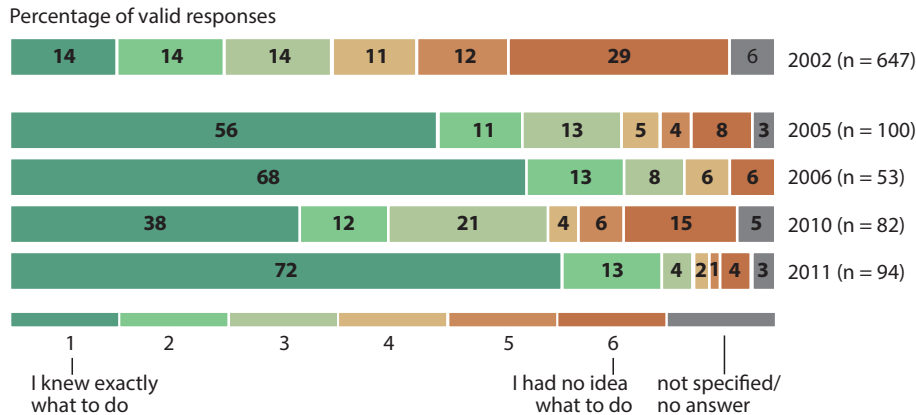


Figure 4. People’s knowledge about how to protect themselves and their households against the flood.

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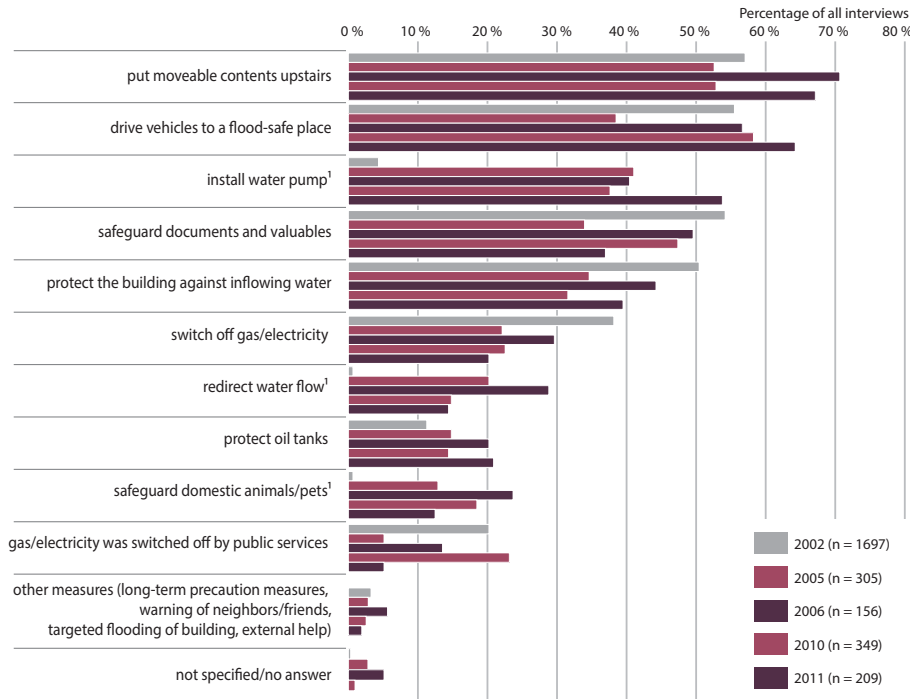
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¹ these measures were not specifically requested in 2002 but deduced from open answers

Figure 5. Emergency measures performed (in descending order), as a percentage of all interviewed people per year (multiple answers possible).

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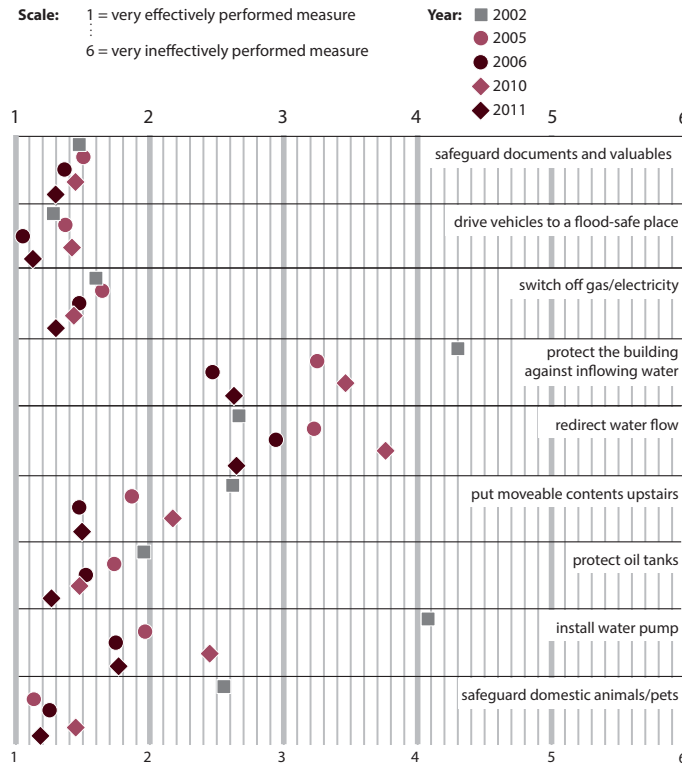


Figure 6. Average effectiveness of emergency measures as evaluated by the people interviewed on a scale from 1 (= measure was very effective) to 6 (= measure was very ineffective).

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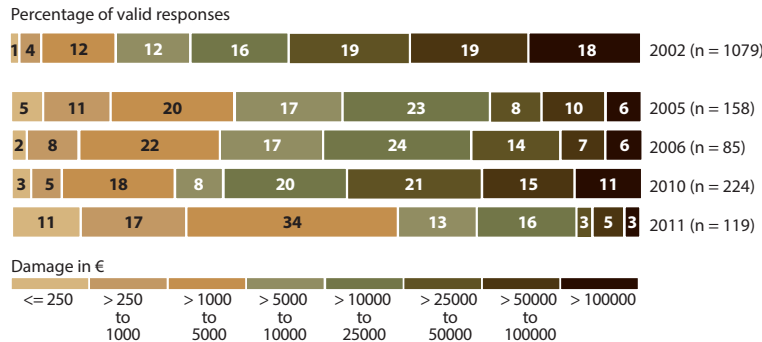


Figure 7. Classified damage to residential buildings (excluding minor damage flat-rate), prices as at June 2013.

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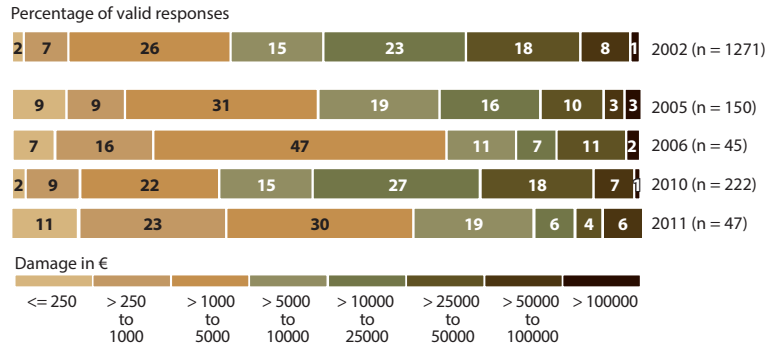


Figure 8. Classified damage to household contents (excluding minor damage flat-rate), prices as at June 2013.

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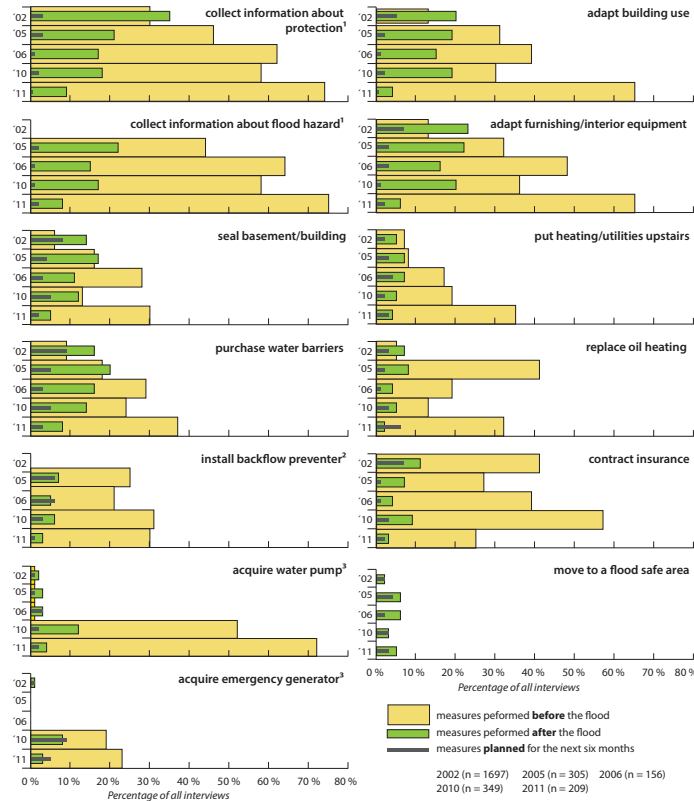
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¹ in 2002, collection of information about protection and flood hazard have not been requested individually but summarized in category "collect information about protection".
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³ measures were not explicitly requested in 2002, 2005 and 2006 but deduced from open answers.
 Additionally, no distinction was made between acquisition of pumps and emergency generators. Measures were therefore summarized in the category "acquire water pump".

Figure 9. Precautionary measures undertaken in private households before and after the respective flood events, and measures that are planned for the next six months.

