Flood risk perception and adaptation capacity: a contribution to the socio-hydrology debate

Sven Fuchs[1], Konstantinos Karagiorgos[1], Kyriaki Kitikidou[2], Fotios Maris[3], Spyridon Paparrizos[4], Thomas Thaler[1]

[1] Institute of Mountain Risk Engineering, University of Natural Resources and Life Sciences, Vienna, Austria
[2] Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, Orestiada, Greece
[3] Department of Civil Engineering, Democritus University of Thrace, Xanthi, Greece
[4] Faculty of Environment and Natural Resources, Albert-Ludwigs-University Freiburg, Germany

Correspondence to: Sven Fuchs (sven.fuchs@boku.ac.at)

Abstract. Dealing with flood hazard and risk requires approaches rooted both in natural and social sciences, which provided the nexus for the ongoing debate on socio-hydrology. Various combinations of non-structural and structural flood risk reduction options are available to communities. Focusing on flood risk and the information associated with it, developing risk management plans is required but often overlooking public perception of a threat. The perception of risk varies in many different ways, especially between the authorities and the affected public. It is because of this disconnection that many risk management plans concerning floods have failed in the past. This paper examines the private adaptation capacity and willingness with respect to flooding in two different catchments in Greece prone to multiple flood events during the last 20 years. Two studies (East Attica and Evros) were carried out, comprised of a survey questionnaire of 155 and 157 individuals, from a peri-urban (East Attica) and a rural (Evros) area, respectively, and they focused on those vulnerable to periodical (rural area) and flash floods (peri-urban area). Based on the comparisons drawn from these responses, and identifying key issues to be addressed when flood risk management plans are implemented, improvements are being recommended for the social dimension surrounding such implementation. As such, the paper contributes to the ongoing discussion on human-environment interaction in socio-hydrology.

Keywords: *flood risk management; adaptation capacity; risk awareness; risk perception; socio-hydrology*

1 Introduction

Increasing flood losses throughout Europe have led the European Commission to issue the "Directive on the Assessment and Management of Flood Risks" (Commission of the European Communities, 2007) as one of the three components of the European Action Programme on Flood Risk Management (Commission of the European Communities, 2004). This directive requires the Member States to establish flood risk maps and flood risk management plans based on a nation-wide evaluation of exposure and vulnerability (Fuchs et al., 2017). While in recent years, considerable efforts have been made towards flood risk maps (Fuchs et al., 2009; Meyer et al., 2012), the requirements with respect to management plans are less-well studied (Hartmann and Spit, 2016). Of particular importance seems the paradigm of public participation in developing management plans for local risks, and the legal and institutional settings necessary therefore (Hartmann and Driessen, 2013; Thaler and Levin-Keitel, 2016).

In parallel, the concept of socio-hydrology was introduced as "a new science of people and water" (Sivapalan et al., 2012). It is argued that dealing with hydrological hazards and resulting adverse socioeconomic consequences requires methods and concepts rooted both in natural sciences (with respect to hazard assessment) and social sciences (with respect to exposure and vulnerability). Whatever the emphasis in flood hazard and risk

management is there is no doubt that its interest is not a study of the environment or of man per se (Kasperson and Kasperson, 1996; Turner II et al., 2003). As a corollary, there is a strong and transdisciplinary need towards studies of coupled human-environment interactions. The emerging field of socio-hydrology claims to explicitly focus on coupled human-environment interactions, above all to observe the co-evolutionary interaction between human development and water flow (Sivapalan, et al. 2012; Di Baldassarre et al., 2013 a, b; Montanari et al., 2013), including various combinations of structural and non-structural flood risk reduction options available to communities (Holub et al., 2012; Loucks, 2015). It is widely acknowledged that floodplains have always been attractive settlement areas, and, as a consequence, people and assets are at risk of flooding. Dynamics behind the spatial and temporal pattern of exposure and vulnerability are dependent on the spatial extent of flood hazards threatening societies, in particular their magnitude and frequency, as well as on the socio-economic changes within society (Keiler et al., 2010). While hazard assessment has a long tradition, the assessment of exposure and the quantification of vulnerability are more recent concerns in hazard and risk research (Merz et al., 2010). Some aspects of research in hydrology, such as the impact of highly destructive processes on buildings (Mazzorana et al., 2009; Fuchs et al., 2012; Mazzorana et al., 2014), infrastructure (Zischg et al., 2005) and agriculture (Morris and Brewin, 2014) and questions regarding multi-hazard risks (Kappes et al., 2012a; Kappes et al., 2012b), contribute to close the gap between disciplinary approaches in science and humanities. Nevertheless, mitigation and adaptation may remain fragmentary with respect to the optimal level of protection of exposed societies or vulnerable elements at risk. Moreover, most analysis has so far been based on a static approach and neglect long-term as well as short-term dynamics in hazard, exposure and vulnerability. Only recently, such issues have been quantitatively analysed, such as shown by e.g. Jongman et al. (2014a) for the Netherlands and Fuchs et al. (2017) for the European Alps.

The main challenge for risk reduction is rooted in the inherently connected dynamic systems driven by both geophysical and social forces, hence the call for an integrative management approach based on multi-disciplinary concepts that take into account different theories, methods and conceptualisations (Fuchs and Keiler, 2013; Keiler and Fuchs, 2016). Strategies to prevent or to reduce losses from hydrological hazards have a long tradition and started in the mediaeval times, however, concerted action started in the 19th century when official authorities responsible for flood protection were funded. Burton et al. (1993) referred to continuously rising flood property losses during the 1970s and 1980s in the US and concluded that the development of floodplain management measures such as levees for flood protection and river training to increase discharge capacities was offset by the continued vulnerability of older buildings, roads and bridges. Already earlier, White (1936) discussed the limit of economic justification of flood protection, which has been confirmed by other studies such as Holub and Fuchs (2008) and Remo et al. (2012) showing that measures other than constructive flood protection may be more cost-efficient. There is a broad spectrum of flood risk management options, usually conceptualised as the flood risk management cycle consisting of mitigation, preparedness, response, and recovery (Carter, 1991; Merz et al., 2010). In particular mitigation and preparedness are targeted at reducing the (physical and social) vulnerability of exposed communities and to increase their resilience and coping capacity (Fuchs, 2009), in current debates addressed as socio-hydrology. The roots of such approaches trace back to very early influential works by the Chicago school (Kates, 1962; Burton and Kates, 1964; White, 1964). Spatiotemporal-based research into vulnerability to hydrological hazards began with attempts to explain the rising level of flood damage in the US in conjunction with unprecedented efforts and expenditures to control them (White, 1945; White et al., 1958). Some of White's most notable work (White, 1945) was a particular benchmark in stimulating subsequent studies, and involved the identification and classification of adjustment mechanisms for flooding, perceptions of natural hazards, and choice of natural hazard adjustments (Hinshaw, 2006). Hence, even before the leading work published by Starr (1969) geoscientists and engineers made an attempt to study human adjustments to risk and associated vulnerability. The main point in this early research was the differentiation between extreme natural events and regular flooding affecting communities, which provided material for the vulnerability discussion up to the present time (White et al., 2001). In particular non-structural adjustments, consisting of arrangements imposed by a governing body (local, regional, or national) to restrict the use of floodplains, or flexible adaptation to flood risk that do not involve substantial investment in flood controls, still remain central with respect to the contemporary management of hazards and vulnerability in many catchments. As such, there is still a need to understand the mutual relations between flooding and societal response as well as between the development within society and the resulting influence on floodplain dynamics (Di Baldassarre et al., 2013b; Viglione et al., 2014).

The context of dynamic flood risks is driving transformation in the role of the state in responsibility sharing and individual responsibilities for risk management and precaution (Mees et al., 2012; Adger et al., 2013). Emerging flood risk strategies place the lead responsibility on local organisations to determine local strategies to manage local risks which demand societal transformation (Driessen et al., 2013) in vulnerability reduction (Fuchs et al., 2011). The main reasons for this shift from centralised to decentralised organisation is that local scale are more efficient in dealing with those tasks relating to risk and emergency management. Societal transformation and

social adaptation requires adaptive capacities and in-depth knowledge on the perception of flood risk within communities. The perception of flood risk among different parts of the population, i.e. citizens affected and the inhabitants of flood plains, may differ and leads to different levels of public participation in risk management strategies (Thaler and Hartmann, 2016; Thaler et al., 2016).

A low risk awareness of residents living in flood-prone areas is considered among the main causes of their low preparedness, which in turns generates inadequate response to the threat (White, 1973; Burton et al., 1993; Scolobig et al., 2012). Risk perception 'denotes the process of collecting, selecting and interpreting signals about uncertain impacts of events' (Wachinger et al., 2013: 1049), and is a very complex framework with multiple influencing factors (Fischhoff et al., 1978; Slovic 1987; Slovic, 2000; Plapp and Werner, 2006; Wagner, 2007). A general distinction is made between situational factors (such as individual experiences and socio-economic circumstances) and cognitive factors (such as personal and psychological components influencing individual behaviour in decision-making process). Therefore, risk perception provides individual interpretation of flood hazards and needs to be integrated in the formal decision-making process (Plattner et al., 2006; Barberi et al., 2008; Fuchs et al., 2009; Bradford et al., 2012). Many studies showed that personal experience is influenced by how exposed people recognise the likelihood of a hazard event, and the magnitude of those events, as well as their attitudes and beliefs concerning responsibilities for mitigation and loss compensation (Bubeck et al., 2012; Damm et al. 2013). In overall, risk perception and awareness demonstrate a central role in flood risk management discussion (Fischhoff, 1995; Renn, 1998; Slovic, 2000; Siegrist and Gutscher, 2006; Soane et al., 2010; Bradford et al., 2012; Bubeck et al., 2012, 2013; Wachinger et al., 2013; Pino González-Riancho et al., 2015; Kienzler et al., 2015; Babcicky and Seebauer, 2016). However, both terms are complex and controversially discussed, especially in terms of successful implementation of local structural protection measures (Karanci et al., 2005; Siegrist and Gutscher, 2008; Hall and Slothower, 2009; Jóhannesdóttir and Gísladóttir, 2010; Harries and Penning-Rowsell, 2011; Scolobig et al., 2012). The literature presents various myths and debates of both risk perception and awareness in flood risk management, especially the relationships between risk perception and awareness and the successful use of local structural protection measures and individual preparedness. Bradford et al. (2012), for example, demonstrated that the aspect of risk awareness shows no clear relationship with the individual preparedness in future flood events. Nevertheless, the authors found a clear relationship between flood experiences and preparedness. Similar results were also found by Harries and Penning-Rowsell (2011), Bubeck et al. (2013) and Kienzler et al. (2015), where people with flood experiences were more likely to undertake precautionary measures. Therefore, generally speaking, risk perception influences the individual adaptation strategy through learning processes from past events (Bubeck et al., 2012; Collenteur et al., 2015). This so-called adaptation effect relates to the development that frequent flood events may decrease individual vulnerability in the floodplain area through the implementation of local structural protection measures (Holub et al., 2012; Jongman et al., 2014b; Di Baldassarre et al., 2015; Mechler and Bouwer, 2015).

Nonetheless, experience of flood victims is only one aspect in the proactive action in flood risk management (Whitmarsh, 2008; Higginbotham et al., 2014). Whitmarsh (2008) argued that experiences have to be paired with the individual value and belief. Therefore, individual actions can also be associated with other factors, such as home ownership (Grothmann and Reusswig, 2006; Burningham et al., 2008), socio-economic status of individuals (Kreibich et al., 2011; Duží et al., 2015) or effective risk communication (Soane et al., 2010; Meyer et al., 2012; Bubeck et al., 2013). On the other hand, on the individual side – social networks and knowledge (social capital), which communicate that the precautionary measures are useful or effective – demonstrate a much higher likelihood to undertake precautionary measures compared to past experiences (Lo, 2013; Poussin et al., 2014; Babcicky and Seebauer, 2016). Nevertheless, other scholars (such as Kellens et al., 2011 and Duží et al., 2015) demonstrated no significant relationship between one of these variables with the positive influence of individual preparedness. Furthermore, high risk perception will not necessarily lead to the successful implementation of local structural protection measures, as presented by different scholars (Karanci et al., 2005; Siegrist and Gutscher, 2006; Hall and Slothower, 2009; Jóhannesdóttir and Gísladóttir, 2010; Soane et al., 2010; Bubeck et al., 2013). In general, different explanations for this development are available, such as that people with experiences can underestimate the threat because they feel helpless during the event (Soane et al., 2010). Other reasons may be the financial burden, difficulty to understand and locate the hazard source as well as the difficulties to install local structural protection measures (Kreibich et al., 2011; Działek et al., 2013; Koerth et al., 2013; Kienzler et al., 2015), or lack of relationship between national authorities dealing with flood risk management and flood victims (Harries, 2013). In this line, a central aspect is the question of responsibility for flood risk management (Parker et al., 2007; Holub and Fuchs, 2009; Soane et al., 2010). In particular, the question about the implementation and payment of local structural protection measures seems to be crucial (Holub et al., 2012), as well as the overall concept used to reduce vulnerability and exposure (Fuchs, 2009; Fuchs et al., 2015). Additionally, there is also evidence that sub-regional differences play an important role in the

1   use of adaptation strategies at household level (Higginbotham et al., 2014; Thaler and Priest, 2014; Thaler and
2   Levin-Keitel, 2016).

3   Taking these findings as basis for discussion, the present paper explores differences in risk perception and
4   individually response to flood risk management within two different sub-regional areas. Different actions
5   undertaken across urban and rural farming populations characterised by different socio-economic conditions and
6   affected by different flood hazard types are studied, as well as their different response efficacy in flood risk
7   management. This paper also links management options assessed by individuals who belong to at-risk
8   communities with direct experience with floods of previous years, as well as the profile demographic of the
9   individuals in terms of employment status, education level, and gender. These variables – which concentrate on
10   the social behaviour in the flood risk management discussion – play a central role in the current socio-hydrology
11   debate, but are so far repeatedly missed in the literature (Gober and Wheater, 2015; Loucks, 2015). The models
12   proposed in the literature so far (see for example Di Baldassarre et al., 2013b) focus mainly on catchment
13   hydrology as well as associated long-term response of human actions, such as incorporation of changes in
14   demography, technology and society. Nevertheless, social aspects as one of the central points within the
15   assessment of human-environment interaction play a major role in social-hydrology. The conceptual models,
16   however, are so far relatively simplistic to mirror individual responses and coping capacity. As such differences
17   within a society, especially between rural and urban areas as well as with respect to different flood types and
18   frequencies still remain a gap. Therefore, in this paper a next step for incorporating individual responses and
19   coping capacity into socio-hydrology models is proposed.

20   **2 Materials and methods**

21   In this paper, we selected two different sub-regional areas in Greece characterised by two different types of
22   flooding: low onset river flooding in the Evros catchment and rapid flash flood hazards in the East Attica region.
23   Apart from these two different flood types, the selection of the study sites was made because of their contrasting
24   socio-economic characteristics.

25   The river Evros is one of the largest in length of the Balkan peninsula. The total watershed area is 53,000 km^2
26   with 320 km river length and an average slope of 0.77%. About 66% of the total surface area is in the Bulgarian
27   territory, about 28% in the Turkish territory and about 6% in the Greek territory. The Greek part of the river is a
28   rural area of about 3,300 km^2 with a population of 85,000 concentrated in few small towns and villages. The
29   river is known for a long series of serious and devastating flood events with high socio-economic costs and
30   environmental impacts on the riparian communities and even on the national economies of the three
31   neighbouring countries (Angelidis et al., 2010; Skias et al., 2013; see Fig. 1a). The area is dominantly rural
32   oriented, where agricultural activities play a major role in the local economy. Besides the great importance of the
33   river for the three riparian countries there are no common routes of collaboration between the states with respect
34   to flood risk management. The complexity of the river is mainly due to political and historical reasons.

35   The second case study is the region of East Attica located east of Athens, which is characterised by flash flood
36   events due to the prevailing climatic, geomorphologic, and anthropogenic conditions (Massari et al, 2014;
37   Karagiorgos et al., 2016a, b; see Fig. 1b). The study area extends from the municipality of Oropos in the north to
38   the municipality of Lavreotiki in the south and is subdivided into the provinces of Marathon, Mesogia and
39   Lavriotiki. The district covers an area of 1,513 km^2 between sea level and 1,109 m a.s.l. with a plain hilly relief
40   and a population amounting to 502,348 inhabitants (Hellenic Statistical Authority, 2011). The study area is
41   characterised by extensive anthropogenic activities with settlements continuously growing for more than 30
42   years (Papathanasiou et al., 2012). The economic development of this area is closely related to the construction
43   of the international airport of Athens in 2001. In the period 1998-2010, the annual rate of increase of building
44   development was within a range of 5% to 30% (Sapountzaki et al., 2011). As reported by Mantelas (2010) the
45   province of Mesogia has developed faster than any other area in Attica during the last 20 years. Specifically the
46   urban land cover increased from 60 km^2 in 1994 to 75 km^2 in 2000, and to 125 km^2 in 2007. In other words,
47   while the urbanised area had grown by 25% during 1994-2000, it grew by 66% during 2000-2007.

48   We conducted a questionnaire survey between June and November 2012, based on a door to door survey, with
49   flood victims in two different sub-regions in Greece. In total we selected 312 interviewees, 155 respondents from
50   the East Attica study area and 157 interviews from the Evros study area.

51   Based on a pilot study in East Attica (Karagiorgos et al., 2016b), the core of the survey was formed according to
52   the following key questions: (1) socio-economic circumstances about the interviewee (such as gender, current
53   job position, education, etc.), (2) social vulnerability (such as local embeddedness in the communities, social

networks/social capital, household structure, etc.), (3) the impact and experience of the past flood events as well as about compensation, (4) risk constructions and awareness, and (5) responsibilities in flood risk management.

The questionnaires were distributed in the research areas by researchers trained for this survey. The distribution of the questionnaires was based on geographical criteria in order to represent the research areas. To provide a good spread of answers, pre-coded and prompted nature with a meaningful Likert-type scale were used. Data were analysed separately for the two research locations (rural and peri-urban area) using SPSS (Statistical Package for the Social Sciences) for Windows, version 21.0 (IBM SPSS Statistics 21 Documentation, 2015). Statistical significance tests were used through Mann-Whitney U test (Mann and Whitney, 1947), logistic regression (Cox, 1958) and Recursive Partitioning Analysis (Breiman et al., 1984) in analysing the differences about the perception of individuals in the peri-urban and the rural area as well as for impacts of several variables on risk awareness. Further, the tests were conducted in order to analyse the impacts of past flood events on the individual risk perception and awareness as well as the impact of past events on the likelihood to undertake precautionary measures.

3 Results

3.1 Demographic characteristics

Demographically, our sample profiles of Evros and East Attica were compared in Table 1. The selected sample was found to have a strong over-representation of males (75%), and older respondents (45%) for the Evros case study. Additionally, the high retirement rate for Evros (41%) reflects the age bias within the sample, while the unemployment rate is under-represented (1%) in compare to the population, which is also typical for the region with the result of a relative social homogeneity of the sample (similar to Steinführer and Kuhlicke, 2012). On the other hand, the East Attica sample fairly represents the population.

[insert table 1 about here]

3.2 Causation belief

We asked the interviews for the main roots of past flood events. Table 2 presents the results from the questioners, where a lack of structural measures being the most frequently listed reason for past flood events. Categorising the answers, 18.1% in Evros and 28.0% in East Attica identified the lack of protective constructions as one key factor for flood events. Additionally, in Evros, 18.1% saw the lack of maintenance of protective constructions as a central issue of ongoing flood events, while in East Attica, deforestation (61.8%), building in high-risk areas (55.4%), interventions on the riverbed (58.6%) respondents saw as central arguments for the past flood events. Therefore, most of the affected people listed anthropogenic factors as a central problem for past flood events; in contrast to the low onset flood events in Evros.

[insert table 2 about here]

3.3 Risk perception and awareness

Fig. 2 shows the results for evaluation of individual risk construction, distinguishing the sampling group into whether they were seriously affected in the past. One should expect that people who were evacuated should report perceiving the risk significantly higher than those who were not evacuated. In neither region, however, there was a significant difference between the evacuated and non-evacuated clusters with respect to risk perception (Mann-Whitney U tests: affected and non-affected people, p = 0.453 for Evros, p = 0.489 for East Attica). All the respondents in Evros and the majority in East Attica (53%) answered that they believe that a flood will happen again; from these respondents 69% in Evros and 63% in East Attica believe that a flood will happen in the next year, while 31% in Evros and 13% in East Attica believed that a flood will happen in the next two years. Risk communication processes embedded in local hazard knowledge (mainly from elderly people and flood experiences from neighbours and friends) and to a lesser extend also directly from the government through official training and information initiatives were the main reasons that respondents were aware of living in a dangerous area.

[insert fig. 2 about here]

Additionally, the Recursive Partitioning Analysis (Breiman, 1984), for the East Attica dataset showed that only the variable "income" has a significant impact on individual risk awareness; in fact, people with a higher income are more likely aware of the flood risk. Analysing the correlation between age and perception of the hydro-geological environment was found to be non-significant ($\tau = 0.063$ and $p = 0.355$ for Evros and $\tau = -0.019$, $p = 0.766$ for East Attica). In neither case, age demonstrate an increasing in risk perception.

3.4 Implementation of local structural protection measures

Table 3 and 4 presents the correlation matrixes for the different measured variables. A strong positive correlation can be found between the variables income and the use of local structural protection measures. In particular, the interviewees from East Attica responded positively between both variables ($r = 0.902$, $p < 0.01$). Also, the results from East Attica demonstrated a higher understanding of cause-and-effect relationships in comparison to the rural area of Evros, where the interviewees mainly blame the state for not having undertaken sufficient structural flood defence schemes. However, the Evros results showed that suffering material damages in the past, interestingly, did not correlate with any other variables.

[insert table 3 about here]

[insert table 4 about here]

In rural communities of Evros, where the sample had various experiences with periodical flooding, risk awareness was found to be significant positively correlated to the individual preparation (Kendall's tau correlation coefficient $\tau = 0.286$, $p = 0.000$). On the contrary, in the urban area of East Attica, the risk awareness was found to be uncorrelated to flood preparation ($\tau = -0.102$, $p = 0.120$). Nevertheless, the majority of respondents (72% and 67% for Evros and East Attica, respectively) stated that they feel safe against floods. In contrast, 25 % and 14% of the respondents, for Evros and East Attica respectively, consider their region being maximal at risk. However, only 24.8% of the sampling in Evros, but 73.4% of the respondents in East Attica undertook practical steps to protect their private property. Furthermore, in contrast to Harries (2013), fatalism play a much stronger role in the rural area of Evros compared to the semi-urban area of East Attica. In the latter case study, citizens were usually less likely involved in professions or skilled to response adequately and quickly to flood hazards, which typically can be found in rural areas. A key reason is the lack of relationship between a national authority dealing with flood risk management and flood victims with the outcome that flood victims take over the strategy of fatalism and blaming instead of increasing willingness to take precautionary measures (Harries, 2008, 2012). In particular, Tables 5 and 6 encourage this argument that in fact the public government has to lead the responsibility for the Greek flood risk management system. Main reasons for the low willingness are the low number of damages in the past (for East Attica see also Karagiorgos et al., 2016a, b), historical socio-economic developments (especially for the Evros region as a periphery border region with strong state support in the past 30 years) and the missing link between risk perception, previous flood experiences and preparedness (Bradford et al., 2012). On the other hand, and similar to other studies, such as De Marchi et al. (2007) or Steinführer and Kuhlicke (2007), the role of the citizens is marginal.

[insert table 5 about here]

[insert table 6 about here]

These results show the classical free rider problem, because citizens request a flood protection scheme without contributing to the actual costs, which raise the challenge and conflict of social justice and equity in flood risk management (Johnson et al., 2007; Thaler and Hartmann, 2016). Having been evacuated during a flood event had no differences in this statement (49% of evacuated and 50% of non-evacuated people in Evros thought

strongly that the state should pay, and 75% of evacuated and 79% of non-evacuated people in East Attica thought strongly that the state should pay). The Mann-Whitney U test for the difference in ratings between evacuated and non-evacuated people gave p = 1.000, both for Evros and East Attica. These results were in straight line with the question of which flood risk management strategy should be followed. They also showed that lay people indicated a strong tendency to hard flood defences, such as building new dikes and embankments, which were thought to be more effective than non-structural flood risk management concepts, such as an improvement of the local land use management plan or individually preparedness (see also Table 7). Also other studies, such as Felgentreff (2000, 2003) and Plapp (2004), found similar results where residents see structural defences as the most useful instrument in flood risk management. In Evros the key conflict issues are related to the unsolved transboundary cooperation in the region (more than 86.3%).

[insert table 7 about here]

4 Discussion

The increasing impact of human activities on hydrological dynamics has led to a growing interest in the study of water-society interactions (Di Baldassarre et al., 2015). It is the findings within this study that have helped to advance the understanding of risk management and preparedness in flood risk management, with a particular focus on two different types of hydrological hazards in an Mediterranean environment (Table 8). The variable personal experiences of flood incidents showed no influence in the willingness to take precautionary measures, which is different to the studies from Thieken et al. (2007), Kreibich et al. (2009, 2011), Bubeck et al. (2012, 2013) or Poussin et al. (2014, 2015). The rural sample showed a lower individual responsibility to undertake practical local structural protection measures in contrast to the semi-urban community, which is surprising because the communities in Evros were affected by several annually flood events in the past years. Therefore, also the adaptation effect could not be observed in the results since the observation that the occurrence of more frequent flooding is often associated with decreasing social vulnerability was not proven. This is in clear contrast to results provided by Bubeck et al. (2012) or Collenteur et al. (2015), especially for rural communities with large experiences on river floods. Main reason is the individual perception and interpretation of risk. Kasperson et al. (1988) called this cognitive bias as a result of societal amplification of risk, whereabouts social structure and processes influence individual behaviour. Similarly, Wisner et al. (2004) reported that people who are economically and politically marginal are more likely to stop trusting their own methods for self-protection, and to lose confidence in their own local knowledge. In particular, the Evros respondents showed main concerns mainly against upstream conflicts with Bulgaria; instead of individual responsibility. This behaviour get intensify by the social institutions and organisations (Kasperson and Kasperson, 1996) in the Greek flood risk management policy. Consequently, the citizens of Evros were blaming the neighbourhood country instead of increasing their own resilience capacity at local level. Further, in contrast to Harries (2013), fatalism played a much stronger role in the rural area of Evros compared to the semi-urban area of East Attica, where usually citizens were less likely to be involved in professions or gained protected skills to response adequately and quickly to flood hazards; which we usually can find within the rural areas. A key reason is the lack of relationship between national authority dealing with flood risk management and flood victims with the outcome that flood victims take over the strategy of fatalism and blaming instead of increasing willingness to take precautionary measures (Harries, 2012, 2013).

A central reason is the historical socio-economic development of the area as a periphery border region with strong state support in the past decades. In addition, the results showed that with respect to the perception of the geohydrological environment, a surprising 32% for Evros and 39% for East Attica thought that their environment is not at all dangerous. Nevertheless, all the respondents in Evros and the majority in East Attica (53%) said that they believe that a flood will happen again. On the other side, a correlation between age and perception of the hydro-geological environment was found to be insignificant; people did not seem to have more accurate perceptions for the environment they live in as they age. Many respondents did underestimate the hazard associated with flooding, both in the rural area with periodical flooding, and in the urban area with flash floods. Nevertheless, for many individuals within the study areas, the recent events still vivid within their memories, which has been described as availability heuristic (Tversky and Kahneman, 1973, 1974). Moreover, the sampling (especially for the rural areas) showed a strong affect heuristic decision behaviour (Slovic et al., 2004). Therefore, action should be taken and appropriate methods should be developed by flood risk managers to best provide flood-related information in order to raise the appropriate awareness. Based on our findings, there is an increased challenge in areas where communities believe that it is the flood risk agencies and emergency

responders being solely responsible for the implementation of preventative measures, where the self-protection of individuals is far less important. Further, the East Attica sample saw new structural protection measures as the key flood risk management strategy instead of improving individual preparedness (White, 1945; Di Baldassarre et al., 2013a, 2015) – the non-occurrence of flooding did not lead to a substantial increase in social vulnerability and exposure to flooding. A larger emphasis was placed by residents upon measures to reduce the risk of flooding, rather than focusing on the improvement of better planning which could avoid certain activities (such as construction of new buildings) in hazard-prone areas.

[insert table 8 about here]

5 Conclusion

Our results have shown that both, the levee as well as the adaptation effect have considerable different characteristics in the study sites. As such, if risk is quantified from a dynamic perspective and using approaches from coupled human-environment interaction, changes in the management strategies become obvious compared to traditional approaches of mitigation and adaptation. The coupled dynamics between hazards and exposure call for further studies in similar environments in order to test whether our results have to be interpreted in terms of singularities, and how the approach of socio-hydrology may be further used to enhance our understanding of underlying risk perception patterns. Flood risk management plans are becoming increasingly important for the European countries as these management strategies take in both the social factors and physical nature of risk, inherently calling for a coupled human-environment interaction approach, public perception of these risks must be at the core. Because of the different notion of risk between the general public and the scientific community, those who are responsible for developing and implementing flood risk management strategies need to understand and to include the individual risk construction of those affected people. It is due to a lack of understanding of the authorities in charge that flood risk management policies have failed in many places so far. This study represents a social approach and provides some explanations for this failure, and is targeted towards incorporating public perceptions in developing risk management plans. Although fear is often used to advocate an increase in risk perception, the results show that this is not a way to promote the desired response within the people; the majority feel safe against floods, while many people believe that their environment is not at all dangerous, both in the rural area with periodical flooding and the urban area with flash floods. Gathered through an innovative approach, the practical findings presented here will help to facilitate flood managers in their developments of national and local flood risk management strategies that integrate the complexity of individual risk perceptions, such as preparing risk communication strategies to raise awareness within the community. Finally, the proposed methodological approach within the debate on socio-hydrology is to incorporate the individual response to different flood frequency (sudden vs. continuously), different socio-economic environment (semi-urban vs. rural) as well as type of processes (flash floods vs. river floods). This allows to extend the current socio-hydrological concepts as well as to support practitioners in the development of enhanced flood risk management strategies at local level.

References

Adger, W. N., Quinn, T., Lorenzoni, I., Murphy, C., and Sweeney, J.: Changing social contracts in climate-change adaptation, Nature Climate Change, 3, 330-333, 2013.

Angelidis, P., Kotsikas, M., and Kotsovinos, N.: Management of upstream dams and flood protection of the transboundary river Evros/Maritza, Water Resources Management, 24, 2467-2484, 2010.

Babcicky, P., and Seebauer, S.: The two faces of social capital in private flood mitigation: opposing effects on risk perception, self-efficacy and coping capacity, Journal of Risk Research, Online First, 2016.

Barberi, F., Davis, M., Isaia, R., Nave, R., and Ricci, T.: Volcanic risk perception in the Vesuvius population, Journal of Volcanology and Geothermal Research, 172, 244-258, 2008.

Brakenridge, G.R.: Global active archive of large flood events, Dartmouth Flood Observatory, University of Colorado, http://floodobservatory.colorado.edu/Archives/index.html, 2016 (accessed 05 October 2016).

Bradford, R. A., O'Sullivan, J. J., Van Der Craats, I. M., Krywkow, J., Rotko, P., Aaltonen, J., Bonaiuto, M., De Dominicis, S., Waylen, K., and Schelfaut, K.: Risk perception - Issues for flood management in Europe, Natural Hazards and Earth System Sciences, 12, 2299-2309, 2012.

Breiman, L., Friedman, J. H., Olshen, R. A., and Stone, C. J.: Classification and regression trees, Wadsworth, Belmont, 1984.

Bubeck, P., Botzen, W. J. W., Kreibich, H., and Aerts, J. C. J. H.: Long-term development and effectiveness of private flood mitigation measures: an analysis for the German part of the river Rhine, Natural Hazards and Earth System Sciences, 12, 3507-3518, 2012.

Bubeck, P., Botzen, W. J. W., Kreibich, H., and Aerts, J. C. J. H.: Detailed insights into the influence of flood-coping appraisals on mitigation behaviour, Global Environmental Change, 23, 1327-1338, 2013.

Burningham, K., Fielding, J., and Thrush, D.: 'It'll never happen to me': Understanding public awareness of local flood risk, Disasters, 32, 216-238, 2008.

Burton, I., and Kates, R.: The perception of natural hazards in resource management, Natural Resources Journal, 4, 412-441, 1964.

Burton, I., Kates, R., and White, G.: The environment as hazard, Guilford Press, New York, 290 pp., 1993.

Carter, W.: The disaster management cycle, in: Disaster management: A disaster manager's handbook, edited by: Carter, W., Asian Development Bank, Manila, 51-59, 1991.

Collenteur, R.A., de Moel, H., Jongman, B., and Di Baldassarre, G.: The failed-levee effect: do societies learn from flood disasters?, Natural Hazards, 76, 373-388, 2015.

Commission of the European Communities: Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – Flood risk management – Flood prevention, protection and mitigation, http://eur-lex.europa.eu/legal-content/en/txt/html/?uri=celex:52004dc0472&rid=14 (accessed 08 June 2016), 2004.

Commission of the European Communities: Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the Assessment and Management of Flood Risks, Official Journal of the European Union, L 288, 27-34, 2007.

Cox, D.: The regression analysis of binary sequences (with discussion), Journal of the Royal Statistical Society: Series B, 20, 215-242, 1958.

Damm, A., Eberhard, K., Sendzimir, J., and Patt, A.: Perception of landslides risk and responsibility: a case in eastern Styria, Austria, Natural Hazards, 69, 165-183, 2013.

De Marchi, B., Scolobig, A., Zotti, G. D., and Del Zotto, M.: Risk construction and social vulnerability in an Italian alpine region. Country Report Italy, www.floodsite.net/html/partner_area/project_docs/task11_p33_06-08_final.pdf (accessed 07 June 2016), 2007.

Di Baldassarre, G., Kooy, M., Kemerink, J.S., and Brandimarte, L.: Towards understanding the dynamic behaviour of floodplains as human-water systems, Hydrology and Earth System Sciences, 17, 3235-3244, 2013a.

Di Baldassarre, G., Viglione, A., Carr, G., Kuil, L., Salinas, J. L., and Blöschl, G.: Socio-hydrology: conceptualising human-flood interactions, Hydrology and Earth System Sciences, 17, 3295-3303, 2013b.

Di Baldassarre, G., Viglione, A., Carr, G., Kuil, L., Yan, K., Brandimarte, L., Blöschl, G.: Debates – perspectives on socio-hydrology: capturing feedbacks between physical and social processes, Water Resources Research, 51, 4770-4781, 2015.

Driessen, P. P. J., Behagel, J. H., Hegger, D. L. T., Mees, H. L. P., Almesjo, L., Andresen, S., Eboli, F., Helgenberger, S., Hollaender, K., Jacobsen, L., Jaervelae, M., Laessoe, J., Oberthuer, S., Avelar, D., Brand, U., Brunnengraeber, A., Bulkeley, H., Compagnon, D., Davoudi, S., Hackmann, H., Knieling, J., Larrue, C., Linner, B.-O., Martin, O., O'Brien, K., O'Neill, S., van Rijswick, H. F. M. W., Siebenhuener, B., Termeer, K., and Verbruggen, A.: Societal transformations in the face of climate change; research priorities for the next decade, JPI Climate, Brussels, Belgium, 2013.

Duží, B., Vikhrov, D., Kelman, I., Stojanov, R., and Juřička, D.: Household measures for river flood risk reduction in the Czech Republic, Journal of Flood Risk Management, Online first, 2015.

Działek, J., Biernacki, W., and Bokwa, A.: Challenges to social capacity building in flood-affected areas of southern Poland, Natural Hazards and Earth System Sciences, 13, 2555-2566, 2013.

Felgentreff, C.: Impact of the 1997 Odra flood on flood protection in Brandenburg, FRG: The Dyke broke, but the people's trust in technical solutions remained unbroken, In: European conference on advances in flood research (PIK-Report 65), edited by Bronstert, A., Bismuth, C., and Menzel, L., Potsdam Institute for Climate Impact Research (PIK), 614-626, 2000.

Felgentreff, C.: Post-disaster situations as "windows of opportunity"? Post-flood perceptions and changes in the German Odra river region after the 1997 flood, Die Erde, 134, 163-180, 2003.

Fischhoff, B., Slovic, P., Lichtenstein, S., Reads, S., and Combs, B.: How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits, Policy Science, 9, 127-152, 1978.

Fischhoff, B.: Risk communication and perception unplugged: twenty years of process, Risk Analysis, 15, 137-145, 1995.

Fuchs, S., and Keiler, M.: Space and time: coupling dimensions in natural hazard risk management?, in: The spatial dimension of risk – how geography shapes the emergence of riskscapes, edited by: Müller-Mahn, D., Earthscan, London, 189-201, 2013.

Fuchs, S., Keiler, M., and Zischg, A.: A spatiotemporal multi-hazard exposure assessment based on property data, Natural Hazards and Earth System Sciences, 15, 2127-2142, 2015.

Fuchs, S., Kuhlicke, C., and Meyer, V.: Editorial for the special issue: vulnerability to natural hazards – the challenge of integration, Natural Hazards, 58, 609-619, 2011.

Fuchs, S., Ornetsmüller, C., and Totschnig, R.: Spatial scan statistics in vulnerability assessment – an application to mountain hazards, Natural Hazards, 64, 2129-2151, 2012.

Fuchs, S., Spachinger, K., Dorner, W., Rochman, J., and Serrhini, K.: Evaluating cartographic design in flood risk mapping, Environmental Hazards, 8, 1, 52-70, 2009.

Fuchs, S., Thaler, T., Röthlisberger, V., Zischg, A., and Keiler, M.: Natural hazard management from a co-evolutionary perspective: the cycle of exposure and policy response in the European Alps, Annals of the Association of American Geographers, 107, 2, 2017 (in press).

Fuchs, S.: Susceptibility versus resilience to mountain hazards in Austria – Paradigms of vulnerability revisited, Natural Hazards and Earth System Sciences, 9, 337-352, 2009.

Gober, P., and Wheater, H. S.: Debates – perspectives on socio-hydrology: modelling flood risk as a public policy problem, Water Resources Research, 51, 4782-4788, 2015.

Grothmann, T., and Reusswig, F.: People at risk of flooding: Why some residents take precautionary action while others do not, Natural Hazards, 38, 101-120, 2006.

Hall, T. E., and Slothower, M.: Cognitive factors affecting homeowners' reactions to defensible space in the Oregon Coast Range, Society and Natural Resources, 22, 95-110, 2009.

Harries, T., and Penning-Rowsell, E.: Victim pressure, institutional inertia and climate change adaptation: The case of flood risk, Global Environmental Change, 21, 188-197, 2011.

Harries, T.: Feeling secure or being secure? Why it can seem better not to protect yourself against a natural hazard, Health, Risk and Society, 10, 479-490, 2008.

Harries, T.: Responding to flood risk in the UK, in: Cities at risk: living with perils in the 21st century, edited by: Joffe, H., Rossetto, T., and Adams, J., Springer, Dordrecht, 45-72, 2013.

Harries, T.: The anticipated emotional consequences of adaptive behaviour impacts on the take-up of household flood-protection measures, Environment and Planning A, 44, 649-668, 2012.

Hartmann, T., and Driessen, P. P.: The flood risk management plan: towards spatial water governance, Journal of Flood Risk Management, Online first, 2013.

Hartmann, T., and Spit, T.: Implementing the European flood risk management plan, Journal of Environmental Planning and Management, 59, 360-377, 2016.

Hellenic Statistical Authority: Population census 2011, www.statistics.gr/portal/page/portal/esye/page-census2011 (accessed 10 May 2014), 2011.

Higginbotham, N., Connor, L. H., and Baker, F.: Subregional differences in Australian climate risk perceptions: coastal versus agricultural areas of the Hunter Valley, NSW, Regional Environmental Change, 14, 699-712, 2014.

Hinshaw, R.: Living with nature's extremes: The life of Gilbert Fowler White, Johnson Books, Boulder, 339 pp., 2006.

Holub, M., and Fuchs, S.: Benefits of local structural protection to mitigate torrent-related hazards, in: Risk Analysis VI, edited by: Brebbia, C., and Beriatos, E., WIT Transactions on Information and Communication Technologies 39, WIT, Southampton, 401-411, 2008.

Holub, M., and Fuchs, S.: Mitigating mountain hazards in Austria - legislation, risk transfer, and awareness building, Natural Hazards and Earth System Science, 9, 523-537, 2009.

Holub, M., Suda, J., and Fuchs, S.: Mountain hazards: Reducing vulnerability by adapted building design, Environmental Earth Sciences, 66, 1853-1870, 2012.

IBM SPSS Statistics 21 Documentation: US IBM, www-01.ibm.com/support/docview.wss?uid=swg27024972 (accessed 07 June 2016), 2015.

Jóhannesdóttir, G., and Gísladóttir, G.: People living under threat of volcanic hazard in southern Iceland: vulnerability and risk perception, Natural Hazards and Earth System Sciences, 10, 407-420, 2010.

Johnson, C., Penning-Rowsell, E., and Parker, D.: Natural and imposed injustices: The challenges in implementing 'fair' flood risk management policy in England, Geographical Journal, 173, 374-390, 2007.

Jongman, B., Koks, E. E., Husby, T. G., and Ward, P. J.: Increasing flood exposure in the Netherlands: implications for risk financing, Natural Hazards and Earth System Sciences, 14, 1245-1255, 2014a.

Jongman, B., Hochrainer-Stigler, S., Feyen, L., Aerts, J.C.J.H., Mechler, R., Botzen, W.J.W., Bouwer, L.M., Pflug, G., Rojas, R., and Ward, P.J.: Increasing stress on disaster-risk finance due to large floods, Nature Climate Change, 4, 264-268, 2014b.

Kappes, M., Keiler, M., von Elverfeldt, K., and Glade, T.: Challenges of analyzing multi-hazard risk: a review, Natural Hazards, 64, 1925-1958, 2012a.

Kappes, M., Papathoma-Köhle, M., and Keiler, M.: Assessing physical vulnerability for multi-hazards using an indicator-based methodology, Applied Geography, 32, 577-590, 2012b.

Karagiorgos, K., Thaler, T., Hübl, J., Maris, F., and Fuchs, S.: Multi-vulnerability analysis for flash flood risk management, Natural Hazards 82, Supplement 1, S63-S87, 2016a.

Karagiorgos, K., Thaler, T., Heiser, M., Hübl, J., and Fuchs, S.: Integrated flash flood vulnerability assessment: insights from East Attica, Greece, Journal of Hydrology 541, Part A, 553-562, 2016b.

Karanci, A. N., Aksit, B., and Dirik, G.: Impact of a community disaster awareness training program in Turkey: Does it influence hazard-related cognitions and preparedness behaviors, Social Behavior and Personality, 33, 243-258, 2005.

Kasperson, R. E., and Kasperson, J. X.: The social amplification and attenuation of risk, Annals of the American Academy of Political and Social Science, 545, 95-105, 1996.

Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., Kasperson, J. X., and Ratick, S.: The social amplification of risk: a conceptual framework, Risk Analysis, 8, 177-187, 1988.

Kates, R.: Hazard and choice perception in flood plain management, Department of Geography. Research Paper ed., University of Chicago, Chicago, 157 pp., 1962.

Keiler, M., and Fuchs, S.: Vulnerability and exposure to geomorphic hazards - some insights from mountain regions, in: Geomorphology and society, edited by: Meadows, M., and Lin, J.-C., Springer, Tokyo, 165-180, 2016.

Keiler, M., Knight, J., and Harrison, S.: Climate change and geomorphological hazards in the eastern European Alps, Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences, 368, 2461-2479, 2010.

Kellens, W., Zaalberg, R., Neutens, T., Vanneuville, W., and De Maeyer, P.: An analysis of the public perception of flood risk on the Belgian coast, Risk Analysis, 31, 1055-1068, 2011.

Kienzler, S., Pech, I., Kreibich, H., Müller, M., and Thieken, A. H.: After the extreme flood in 2002: changes in preparedness, response and recovery of flood-affected residents in Germany between 2005 and 2011, Natural Hazards and Earth System Sciences, 15, 505-526, 2015.

Koerth, J., Vafeidis, A., Hinkel, J., and Sterr, H.: What motivates coastal households to adapt pro-actively to sea-level rise and increasing flood risk?, Regional Environmental Change, 13, 897-909, 2013.

Kreibich, H., Christenberger, S., and Schwarze, R.: Economic motivation of households to undertake private precautionary measures against floods, Natural Hazards and Earth System Sciences, 11, 309-321, 2011.

Kreibich, H., Piroth, K., Seifert, I., Maiwald, H., Kunert, U., Schwarz, J., Merz, B., and Thieken, A. H.: Is flow velocity a significant parameter in flood damage modelling, Natural Hazards and Earth System Sciences, 9, 1679-1692, 2009.

Lo, A. Y.: The likelihood of having flood insurance increases with social expectations, Area, 45, 70-76, 2013.

Mann, H., and Whitney, D.: On a test of whether one of two random variables is stochastically larger than the other, The Annals of Mathematical Statistics, 18, 50-60, 1947.

Loucks, D. P.: Perspectives on socio-hydrology: Simulating hydrologic-human interactions, Water Resources Research, 51, 4789-4794, 2015.

Mantelas, L., Prastacos, P., Hatzichristos, T., and Koutsopoulos, K.: Using fuzzy cellular automata to access and simulate urban growth, GeoJournal, 77, 13-28, 2010.

Massari, C., Brocca, L., Barbetta, S., Papathanasiou, C., Mimikou, M., and Moramarco, T.: Using globally available soil moisture indicators for flood modelling in Mediterranean catchments, Hydrology and Earth System Sciences, 18, 839-853, 2014.

Mazzorana, B., Hübl, J., and Fuchs, S.: Improving risk assessment by defining consistent and reliable system scenarios, Natural Hazards and Earth System Sciences, 9, 145-159, 2009.

Mazzorana, B., Simoni, S., Scherer, C., Gems, B., Fuchs, S., and Keiler, M.: A physical approach on flood risk vulnerability of buildings, Hydrology and Earth System Sciences, 18, 3817-3836, 2014.

Mechler, R., and Bouwer, L.M.: Understanding trends and projections of disaster losses and climate change: is vulnerability the missing link?, Climate Change, 133, 23-35, 2015.

Mees, H. L. P., Driessen, P. P. J., and Runhaar, H. A. C.: Exploring the scope of public and private responsibilities for climate adaptation, Journal of Environmental Policy and Planning, 14, 305-330, 2012.

Merz, B., Hall, J., Disse, M., and Schumann, A.: Fluvial flood risk management in a changing world, Natural Hazards and Earth System Sciences, 10, 509-527, 2010.

Meyer, V., Kuhlicke, C., Luther, J., Fuchs, S., Priest, S., Dorner, W., Serrhini, K., Pardoe, J., McCarthy, S., Seidel, J., Scheuer, S., Palka, G., Unnerstall, H., and Viavatenne, C.: Recommendations for the user-specific enhancement of flood maps, Natural Hazards and Earth System Sciences, 12, 5, 1701-1716, 2012.

Montanari, A., Young, G., Savenije, H. H. G., Hughes, D., Wagener, T., Ren, L. L., Koutsoyiannis, D., Cudennec, C., Toth, E., Grimaldi, S., Blöschl, G., Sivapalan, M., Beven, K., Gupta, H., Hipsey, M., Schaefli, B., Arheimer, B., Boegh, E., Schymanski, S. J., Di Baldassarre, G., Yu, B., Hubert, P., Huang, Y., Schumann, A., Post, D. A., Srinivasan, V., Harman, C., Thompson, S., Rogger, M., Viglione, A., McMillan, H., Characklis, G., Pang, Z., and Belyaev, V.: Panta Rhei – Everything Flows: Change in hydrology and society – The IAHS Scientific Decade, 2013–2022, Hydrological Sciences Journal, 58, 1256-1275, 2013.

Morris, J., and Brewin, P.: The impact of seasonal flooding on agriculture: the spring 2012 floods in Somerset, England, Journal of Flood Risk Management, 7, 128-140, 2014.

Papathanasiou, C., Alonistioti, D., Kasella, A., Makropoulos, C., and Mimikou, M.: The impact of forest fires on the vulnerability of peri-urban catchments to flood events (the case of the Eastern Attica region) Global NEST Journal, 14, 294-302, 2012.

Papathanasiou, C., Massari, C., Pagana, V., Barbetta, S., Brocca, L., Moramarco, T., Makropoulos, C., and Mimikou, M.: Hydrological study of Rafina catchment, LIFE11 ENV GR 975 – FLIRE: Floods and fire risk assessment and management. Report of Deliverable B1: Catchment hydrological modelling, National Technical University, Athens, 54 pp., 2013.

Parker, D., Tapsell, S., and McCarthy, S.: Enhancing the human benefits of flood warnings, Natural Hazards, 43, 397-414, 2007.

Pino González-Riancho, P., Gerkensmeier, B., Ratter, B. M. W., González, M., and Medina, R.: Storm surge risk perception and resilience: A pilot study in the German North Sea coast, Ocean and Coastal Management, 112, 44-60, 2015.

Plapp, T., and Werner, U.: Understanding risk perception from natural hazards: examples from Germany, Risk Analysis, 21, 101–108, 2006.

Plapp, T.: Wahrnehmung von Risiken aus Naturkatastrophen. Eine empirische Untersuchung in sechs gefährdeten Gebieten Süd- und Westdeutschlands, Dissertation Universiy of Karlsruhe, Karlsruher Reihe II – Risikoforschung und Versicherungsmanagement, Bd. 2, Karlsruhe, 2004.

Plattner, T., Plapp, T., and Hebel, B.: Integrating public risk perception into formal natural hazard risk assessment. Natural Hazards and Earth System Sciences, 6, 471-483, 2006.

Poussin, J. K., Botzen, W. J. W., and Aerts, J. C. J. H.: Effectiveness of flood damage mitigation measures: Empirical evidence from French flood disasters, Global Environmental Change, 31, 74-84, 2015.

Poussin, J. K., Botzen, W. J. W., and Aerts, J. C. J. H.: Factors of influence on flood damage mitigation behaviour by households, Environmental Science and Policy, 40, 69-77, 2014.

Remo, J. W. F., Carlson, M., and Pinter, N.: Hydraulic and flood-loss modeling of levee, floodplain, and river management strategies, Middle Mississippi River, USA, Natural Hazards, 61, 551-575, 2012.

Renn, O.: The role of risk communication and public dialogue for improving risk management, Risk Decision and Policy, 3, 5-30, 1998.

Sapountzaki, K., Wanczura, S., Casertano, G., Greiving, S., Xanthopoulos, G., and Ferrara, F.F.: Disconnected policies and actors and the missing role of spatial planning throughout the risk management cycle, Natural Hazards, 59, 1445-1474, 2011.

Scolobig, A., De Marchi, B., and Borga, M.: The missing link between flood risk awareness and preparedness: Findings from case studies in an Alpine region, Natural Hazards, 63, 499-520, 2012.

Siegrist, M., and Gutscher, H.: Natural hazards and motivation for mitigation behavior: People cannot predict the affect evoked by a severe flood, Risk Analysis, 28, 771-778, 2008.

Sivapalan, M., Savenije, H.H.G., and Blöschl, G.: Socio-hydrology: a new science of people and water. Hydrological Process, 8, 1270-1276, 2012.

Skias, S., Pliakas, F., and Kallioras, A.: Application of SWOT analysis for the management of transboundary river Evros (Bulgaria, Greece, Turkey), International Journal of Water, 7, 104-121, 2013.

Slovic, P., Finucane, M.L., Peters, E., and MacGregor, D.G.: Risk as analysis and risk as feelings: some thoughts about affect, reason, risk, and rationality, Risk Analysis, 24, 311-322, 2004.

Slovic, P.: Perception of risk, Science, 236, 280-285, 1987.

Slovic, P.: The perception of risk, Earthscan Publications, London, 2000.

Soane, E., Schubert, I., Challenor, P., Lunn, R., Narendran, S., and Pollard, S.: Flood perception and mitigation: The role of severity, agency, and experience in the purchase of flood protection, and the communication of flood information, Environment and Planning A, 42, 3023-3038, 2010.

Starr, C.: Social benefit versus technological risk, Science, 165, 1232-1238, 1969.

Steinführer, A., and Kuhlicke, C.: Social vulnerability to flooding: Lessons learned from the Elbe flood 2002, Gaia, 21, 202-209, 2012.

Thaler, T., and Hartmann, T.: Justice and flood risk management: reflecting on different approaches to distribute and allocate flood risk management in Europe, Natural Hazards, 83, 129-147, 2016.

Thaler, T., and Levin-Keitel, M.: Multi-level stakeholder engagement in flood risk management – A question of roles and power: Lessons from England. Environmental Science & Policy, 55, 292-301, 2016.

Thaler, T., and Priest, S.: Partnership funding in flood risk management: new localism debate and policy in England, Area, 46, 418-425, 2014.

Thaler, T., Priest, S., and Fuchs, S.: Evolving interregional co-operation in flood risk management: distances and types of partnership approaches in Austria, Regional Environmental Change, 16, 841-853, 2016.

Thieken, A. H., Kreibich, H., Müller, M., and Merz, B.: Coping with floods: a survey among private households affected by the August 2002 flood in Germany, Hydrology Sciences Journal, 52, 1016-1037, 2007.

Turner II, B., Matson, P., McCarthy, J., Corell, R., Christensen, L., Eckley, N., Hovelsrud-Broda, G., Kasperson, J., Kasperson, R., Luers, A., Martello, M., Mathiesen, S., Naylor, R., Polsky, C., Pulsipher, A., Schiller, A., Selin, H., and Tyler, N.: Illustrating the coupled human-environment system for vulnerability analysis: Three

case studies, Proceedings of the National Academy of Sciences of the United States of America, 100, 8080-8085, 2003.

Tversky, A., and Kahneman, D.: Availability: a heuristic for judging frequency and probability, Cognitive Psychology, 5, 207-232, 1973.

Tversky, A., and Kahneman, D.: Judgment under uncertainty: heuristics and biases. Science, 211, 1124-1131, 1974.

Viglione, A., Di Baldassarre, G., Brandimarte, L., Kuil, L., Carr, G., Salinas, J. L., Scolobig, A., and Blöschl, G.: Insights from socio-hydrology modelling on dealing with flood risk – Roles of collective memory, risk-taking attitude and trust, Journal of Hydrology, 518, 71-82, 2014.

Wachinger, G., Renn, O., Begg, C., and Kuhlicke, C.: The risk perception paradox-implications for governance and communication of natural hazards, Risk Analysis, 33, 1049-1065, 2013.

Wagner, K.: Mental models of flash floods and landslides, Risk Analysis, 27, 671-682, 2007.

White, G., Calef, W., Hudson, J., Mayer, H., Sheaffer, J., and Volk, D.: Changes in urban occupance of flood plains in the United States, Department of Geography. Working Paper ed., University of Chicago, Chicago, 235 pp., 1958.

White, G.: Choice of adjustment to floods, Department of Geography. Resource Paper ed., University of Chicago, Chicago, 150 pp., 1964.

White, G.: Human adjustment to floods: A geographical approach to the flood problem in the United States, Department of Geography. Research Paper ed., University of Chicago, Chicago, 225 pp., 1945.

White, G.: Natural hazards research, in: Directions in geography, edited by: Chorley RD, Methuen, London, 193-216, 1973.

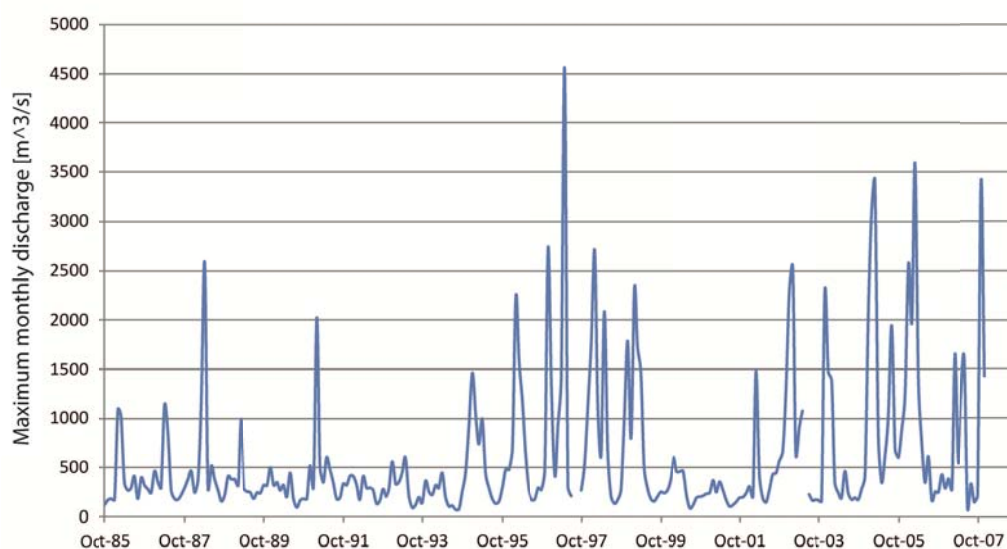
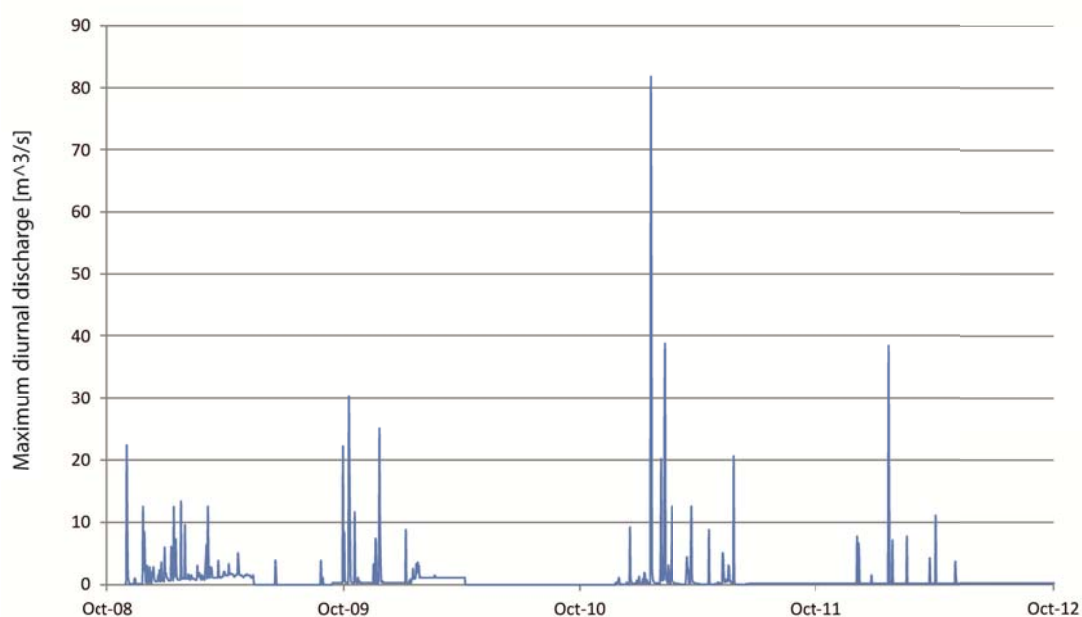
White, G.: The limit of economic justification for flood protection, The Journal of Land and Public Utility Economics, 12, 133-148, 1936.

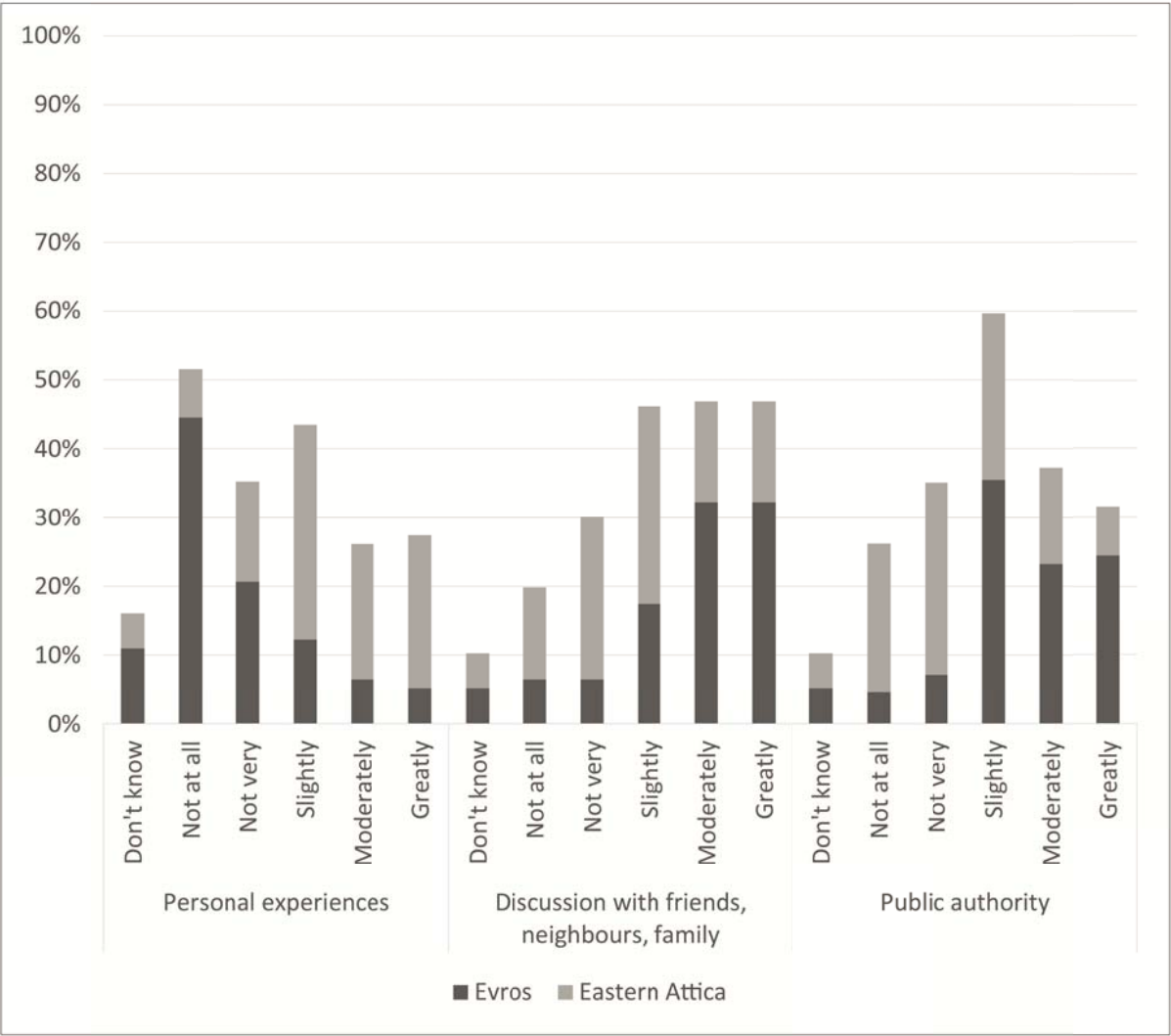
White, G., Kates, R., and Burton, I.: Knowing better and losing even more: The use of knowledge in hazards management, Environmental Hazards, 3, 81-92, 2001.

Whitmarsh, L.: Are flood victims more concerned about climate change than other people? the role of direct experience in risk perception and behavioural response, Journal of Risk Research, 11, 351-374, 2008.

Wisner, B., Blaikie, P., Cannon, T., and Davis, I.: At risk. Natural hazards, people's vulnerability and disasters, Routledge, London, 471 pp., 2004.

Zischg, A., Fuchs, S., Keiler, M., and Stötter, J.: Temporal variability of damage potential on roads as a conceptual contribution towards a short-term avalanche risk simulation, Natural Hazards and Earth System Sciences, 5, 235-242, 2005.

1 Figure 1. Maximum monthly discharge (Evros river, Fig. 1a) and maximum daily discharge (Rafina torrent, Fig.
2 1b) for available time series. The event of 3-5 February 2011 was taken as a reference event within the Rafina
3 catchment, East Attica, since it was the event with the largest magnitude over the measurement interval (12.5
4 hours duration, 18 mm/hr. rainfall intensity, and 80 m^3/s and 56 m^3/s maximum daily discharge (04 and 05
5 February, respectively, see also Papathanasiou et al., 2013)). Please note that after the November-
6 December/2007 event the gauging station at Evros (Pythio) was destroyed and has not yet been reinstalled.
7 Therefore, the event of 16 November-02 December 2007 (3,400 m^3/s, an area of 52,800 km^2 affrected, 5
8 fatalities and around 300 people displaced, see Brakenridge 2016) was the reference for the case study of Evros,
9 where in general flooding occurs if discharge exceeds 2,500 m^3/s (Angelidis et al., 2010). Data source for
10 Rafina: Hydrological Observatory of Athens, http://hoa.ntua.gr/timeseries/d/897 (Rafina Fladar, access 04
11 October 2016); data source for Evros: Regional Authority of Eastern Macedonia and Thrace, see also Angelidis
12 et al., 2010.

2   Figure 2. Local knowledge about hydro-geologically processes.

5

1   Table 1. Demographic characteristics in the study sites of East Attica and Evros

Demographic variables		East Attica	Evros
Gender	Male	51.9%	74.7%
	Female	48.1%	25.3%
Education	1st level	7.9%	49.0%
	2nd level	57.9%	45.0%
	3rd level	34.3%	6.0%
Employment	Entrepreneur, free-lance, manager	22.1%	8.4%
	Trader, craftsman, farmer	16.2%	27.1%
	Teacher, employee, military	29.9%	7.1%
	Worker, store clerk, domestic collaborator	10.4%	6.5%
	Housewife	1.9%	5.8%
	Unemployed	7.8%	1.3%
	Retired	3.9%	40.7%
	Student or in search of first occupation	7.8%	0.0%
	Other	0.0%	3.2%
Age	<25 years	5.1%	2.0%
	25-35 years	24.8%	4.7%
	35-45 years	24.2%	6.7%
	45-55 years	23.6%	14.0%
	55-65 years	15.3%	28.0%
	≥65 years	7.0%	44.7%

1   Table 2. Respondents level of agreement as the causes of floods

Activities		East Attica	Evros
Deforestation	Don't know	3.2%	100.0%
	Not at all	0.6%	0.0%
	Not very	3.2%	0.0%
	Slightly	12.7%	0.0%
	Moderately	18.5%	0.0%
	Greatly	61.8%	0.0%
Building in risk areas	Don't know	3.2%	6.5%
	Not at all	0.6%	27.1%
	Not very	5.7%	10.3%
	Slightly	17.2%	10.3%
	Moderately	17.8%	17.4%
	Greatly	55.4%	28.4%
Lack of protective constructions	Don't know	15.3%	2.6%
	Not at all	5.7%	18.7%
	Not very	21.0%	12.9%
	Slightly	16.6%	27.1%
	Moderately	14.6%	20.6%
	Greatly	26.8%	18.1%
Lack of maintenance of protective constructions	Don't know	14.6%	5.2%
	Not at all	8.3%	17.4%
	Not very	21.0%	9.7%
	Slightly	14.0%	32.9%
	Moderately	14.0%	20.0%
	Greatly	28.0%	14.8%
Interventions on the riverbed	Don't know	7.6%	6.5%
	Not at all	3.8%	17.4%
	Not very	5.7%	7.7%
	Slightly	5.7%	30.3%
	Moderately	18.5%	23.9%
	Greatly	58.6%	14.2%

Table 3. Correlation matrix East Attica

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Perception before last flood event	1	-.209*	-.293**	.102	.091	.182*	-.032	.016	.044	.008	-.047	.180*	.232**	-.092	-.058	.122
2	Evacuated at the event		1	.199*	-.064	-.176*	.023	-.230**	-.248**	.032	-.113	-.057	.025	-.069	-.069	-.077	-.079
3	Suffered material damages			1	-.087	.035	.061	.040	.106	-.120	.088	.250**	.193*	-.024	.002	-.028	-.084
4	Personal experiences				1	.460**	.155	-.305**	-.229**	.191*	.120	.125	.365**	.377**	.109	.080	.379**
5	Local knowledge					1	.245**	.210**	.264**	.165*	.180*	.220**	.030	.087	-.099	-.099	.091
6	Official training and information initiatives						1	.043	.048	-.036	.056	.132	.146	.189*	.163*	.099	.127
7	Personal precautions taken							1	.902**	-.265**	.184*	.323**	-.362**	-.396**	-.192*	-.161*	-.402**
8	Sufficient household income								1	-.185*	.248**	.417**	-.332**	-.378**	-.211**	-.191*	-.363**
9	Period of living at the current residence									1	-.059	-.203*	.010	.148	-.031	-.010	.110
10	Retrospectively preparedness level										1	.520**	.043	-.031	.034	.058	.066
11	Present individual preparedenss level											1	-.061	-.124	-.063	-.113	-.157*
12	Deforestation causing the problem												1	.652**	.400**	.350**	.504**
13	Construction of buildings in areas at risk causing the problem													1	.373**	.351**	.635**
14	Lack of structural devices causing the problem														1	.917**	.502**
15	Lack of structural devices maintenance causing the problem															1	.509**
16	Interventions on rivers bed causing the problem																1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4. Correlation matrix Evros

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Perception before last flood event	1	**-.507****	**-.372****	.001	.006	.118	-.093	-.061	.125	.009	.060	.^{b}	**-.249****	**-.204***	**-.217****	-.043
2	Evacuated at the event		1	**.363****	-.074	.065	.115	.013	.125	-.070	.055	-.004	.^{b}	**.265****	**.209****	**.183***	.042
3	Suffered material damages			1	-.116	-.118	-.095	-.061	.106	-.146	.030	-.017	.^{b}	.150	.043	-.086	-.147
4	Personal experiences				1	**-.286****	**-.251****	-.064	-.051	.132	-.075	-.121	.^{b}	**-.300****	-.016	.066	.062
5	Local knowledge					1	**.643****	-.127	-.058	**.243****	**.379****	**.346****	.^{b}	**.242****	.154	.028	-.129
6	Official training and information initiatives						1	-.058	.101	.103	**.260****	**.216****	.^{b}	**.328****	.067	**.168***	.024
7	Personal precautions taken							1	-.020	-.050	-.134	**-.222****	.^{b}	.083	.073	**.196***	**.194***
8	Sufficient household income								1	-.024	.127	.073	.^{b}	.103	.060	-.007	-.103
9	Period of living at the current residence									1	**.167***	.135	.^{b}	.055	-.031	-.136	-.101
10	Retrospectively preparedness level										1	**.523****	.^{b}	.091	.125	.020	-.150
11	Present individual preparedenss level											1	.^{b}	.072	.014	.022	-.071
12	Deforestation causing the problem												.^{b}	.^{b}	.^{b}	.^{b}	.^{b}
13	Construction of buildings in areas at risk causing the problem													1	**.472****	.153	-.061
14	Lack of structural devices causing the problem														1	**.284****	.113
15	Lack of structural devices maintenance causing the problem															1	**.657****
16	Interventions on rivers bed causing the problem																1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

5   b. Cannot be computed because at least one of the variables is constant.

Table 5. Contributions to the costs for flood protection in East Attica

	N		*M*	SD
People at risk	157	1=strongly disagree; 5= strongly agree	2.401	1.386
Local authority	157	1=strongly disagree; 5= strongly agree	3.815	1.363
District	157	1=strongly disagree; 5= strongly agree	4.331	1.162
Government	157	1=strongly disagree; 5= strongly agree	4.503	1.180

Table 6. Contributions to the costs for flood protection in Evros

	N	Response scale	*M*	SD
People at risk	155	1=strongly disagree; 5= strongly agree	0.000	0.000
Local authority	155	1=strongly disagree; 5= strongly agree	1.761	1.305
District	155	1=strongly disagree; 5= strongly agree	3.226	1.506
Government	155	1=strongly disagree; 5= strongly agree	3.955	1.369

Table 7. Perception of the effectiveness of adaptation measures

Measures	East Attica	Evros
New protection works (such as levees or dams)	79.6%	2.0%
Ensure appropriate maintenance of existing protection works	13.8%	2.6%
Ensure better local land use management plans	3.9%	2.6%
Improve preparedness of people living in risk areas (e.g. information. training drills etc.)	2.6%	6.5%
Other	0.0%	86.3%

Table 8. Overview of the main results between both sub-regions

	East Attica	Evros
Flood preparation	On the contrary, in East Attica (the urban area that experiences flash floods) risk awareness found to be uncorrelated to flood preparation.	In Evros, i.e. the rural area that experiences periodical flooding, risk awareness found to be positively correlated to flood preparation, i.e. the more aware, the more prepared.
Local structural protection measures	73.4% of residents in East Attica undertook concrete steps to protect their family and property	A posteriori, 24.8% of residents in Evros undertook concrete steps to protect their family and property
Risk communication	The main reasons that respondents are aware that they are living in a dangerous area, where knowledge about hydro-geological phenomena is gained mainly by personal experience.	The main reasons that respondents are aware that they are living in a dangerous area, in Evros, are informal information, i.e. from family and friends, and formal information
Payments	49% in East Attica believe that the state should pay for mitigation measures, while people who were evacuated and people who were not did not seem to be different.	A remarkable 77% in Evros believe that the state should pay for mitigation measures, while people who were evacuated and people who were not did not seem to be different.