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

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Abstract. Dealing with flood hazard and risk requires approaches rooted in both 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 overlooks 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 periodic (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.

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 nationwide 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 flood risk management and associated management plans are less well studied (Mazzorana et al., 2012, 2013; Hartmann and Spit, 2016). Of particular importance seems the paradigm of public participation and societal adaptation in assessing local risks, and the legal and institutional settings necessary therefore (Hartmann and Driessen, 2017; Thaler and Levin-Keitel, 2016).

Insights into flood mitigation behaviour are essential because of the ongoing shift to risk-based flood management approaches, which require a contribution from flood-prone households to risk reduction (Bubeck et al., 2013). 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., 2014a; Di Baldassarre et al., 2015; Mechler and Bouwer, 2015). The models proposed in the literature so far (see for example Di Baldassarre et al., 2013a) focus mainly on catchment hydrology as well as the associated long-term response of human actions, such as incorporation of changes in demography, technology, and society. Nevertheless, short-term social aspects as one of the central points of societal adaptation are less well studied (Keiler et al., 2005) but play a major role in social hydrology with respect to an assessment of human–environment interaction. The conceptual models, however, are so far relatively simplistic in mirroring individual responses and coping capacity (Temme et al., 2015). As such differences within a society, especially between rural and urban areas as well as with respect to different flood types and frequencies, still remain fragmentary. Additionally, there is also evidence that sub-regional differences play an important role in the use of adaptation strategies at household level (Higginbotham et al., 2014; Thaler and Priest, 2014; Thaler and Levin-Keitel, 2016). Acknowledging these findings, our paper explores differences in risk perception and individual response to flood risk management strategies within two different sub-regional areas. Actions undertaken across urban and rural farming populations characterized by different socio-economic conditions and affected by different flood hazard types are studied, as well as their different response efficacy in flood risk management. This paper also links management options assessed by individuals who belong to at-risk communities with direct experience of floods in previous years, as well as the demographic profile of these individuals in terms of employment status, education level, and gender. These variables – which focus on social behaviour and adaptation in flood risk management – play a central role in the current socio-hydrology debate, but are so far repeatedly missed in the literature (Gober and Wheater, 2015; Loucks, 2015). Therefore, a further step for including individual responses and coping capacities in socio-hydrology models is made.

1.1 Coupled human–environment interaction in flood risk management

It is widely acknowledged that floodplains have always been attractive settlement areas, and, as a consequence, people and assets are at risk of flooding. The 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; Birkmann et al., 2013). Some aspects of research in hydrology, such as the impact of highly destructive processes on buildings (Mazzorana et al., 2009, 2014; Fuchs et al., 2012), infrastructure (Zischg et al., 2005a, b), and agriculture (Morris and Brewin, 2014), as well as challenges regarding multi-hazard risks (Kappes et al., 2012a, b) contribute to closing the gap between disciplinary approaches in science and humanities. Nevertheless, concepts of mitigation and adaptation may remain fragmentary with respect to the optimal level of protection of exposed societies or elements at risk (Ballesteros Cánovas et al., 2016). Moreover, most analysis has so far been based on a static approach and neglects long-term as well as short-term dynamics in hazard, exposure, and vulnerability (Fuchs et al., 2013). Only recently have such issues been quantitatively analysed, such as shown by e.g. Jongman et al. (2014b) for the Netherlands and Fuchs et al. (2017) for the European Alps.

Flood risk dynamics are linked to a trade-off "between the memory of flooding events (which makes the community move away from the river) versus the willingness to maximize economic benefit by moving close to the river" (Di Baldassarre et al., 2013a, p. 3298). The context of dynamic flood risks is driving transformation regarding 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 organizations 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 centralized to decentralized organization is that local scale may be more efficient in dealing with 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 inhabitants of floodplains, may differ and leads to different levels of public participation in risk management strategies (Thaler and Hartmann, 2016; Thaler et al., 2016).

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 taking into account different theories, methods, and conceptualizations (Fuchs and Keiler, 2013; Keiler and Fuchs, 2016; Goudie, 2017). Strategies to prevent or to reduce losses from hydrological hazards have a long tradition and started in Medieval times; however, concerted action was only taken in the late 19th century when official authorities responsible for flood protection were founded (Holub and Fuchs, 2009). A century later, 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 conceptualized 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, 2008, 2009), in current debates addressed as socio-hydrology. The roots of such approaches can be traced 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 the 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 does 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., 2013a; Viglione et al., 2014), which is largely linked to risk perception and studies on human–environment interaction.

1.2 Linking flood risk, perception, and adaptation

A low risk awareness of residents living in flood-prone areas is considered one of the main causes of their low preparedness, which in turn 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, p. 1049), and is a very complex framework with multiple influencing factors (Fischhoff et al., 1978; Slovic, 1987, 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 processes). Therefore, risk perception provides individual interpretation of flood hazards and needs to be integrated into 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 recognize 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). 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, 2017). 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.

Nonetheless, experience of flood victims is only one aspect in proactive action in flood risk management (Higginbotham et al., 2014). Whitmarsh (2008) argued that experiences have to be paired with individual values 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., 2017), 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 of undertaking precautionary measures compared to past experiences (Lo, 2013; Poussin et al., 2014; Babcicky and Seebauer, 2017). Nevertheless, other scholars (such as Kellens et al., 2011, and Duží et al., 2017) 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 in understanding and locating the hazard source as well as the difficulties in installing local structural protection measures (Kreibich et al., 2011; Działek et al., 2013; Koerth et al., 2013; Kienzler et al., 2015), or the lack of a relationship between national authorities dealing with flood risk management and flood victims (Harries, 2013). In this vein, 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).

2 Materials and methods

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

The river Evros is one of the longest in length of the Balkan Peninsula. The total watershed area is 53 000 km^2, with 320 km river length and an average slope of 0.77 %. About 66 % of the total surface area is in Bulgarian territory, about 28 % in Turkish territory, and about 6 % in Greek territory. The Greek part of the river is a rural area of about 3300 km^2, with a population of 85 000 concentrated in a few small towns and villages. The river is known for a long series of serious and devastating flood events with high socio-economic costs and environmental impacts on the riparian communities and even on the national economies of the three neighbouring countries (Angelidis et al., 2010; Skias et al., 2013; see Fig. 1a). The area is predominantly rurally oriented, where agricultural activities play a major role in the local economy. Besides the great importance of the river for the three riparian countries, there are no common routes of collaboration between the states with respect to flood risk management. The complexity of the river is mainly for political and historical reasons.

The second case study is the region of East Attica located east of Athens, which is characterized by flash flood events due to the prevailing climatic, geomorphologic, and anthropogenic conditions (Massari et al., 2014; Karagiorgos et al., 2016a, b; see Fig. 1b). The study area extends from the municipality of Oropos in the north to the municipality of Lavreotiki in the south and is subdivided into the provinces of Marathon, Mesogia, and Lavriotiki. The district covers an area of 1513 km^2 between sea level and 1109 m a.s.l., with a plain hilly relief and a population amounting to 502 348 inhabitants (Hellenic Statistical Authority, 2011). The study area is characterized by extensive anthropogenic activities with settlements continuously growing for more than 30 years (Papathanasiou et al., 2012). The economic development of this area is closely related to the construction of the international airport of Athens in 2001. In the period 1998–2010, the annual rate of increase in building development was within the range of 5 % to 30 % (Sapountzaki et al., 2011). As reported by Mantelas et al. (2010), the province of Mesogia has developed faster than any other area in Attica during the last 20 years. Specifically, the 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, while the urbanized area had grown by 25 % during 1994–2000, it grew by 66 % during 2000–2007.

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

Based on a pilot study in East Attica (Karagiorgos et al., 2016b, c), the core of the survey was formed according to the following key questions: (1) socio-economic circumstances about the interviewee (such as gender, current 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. Data were analysed separately for the two research locations (rural and peri-urban areas)

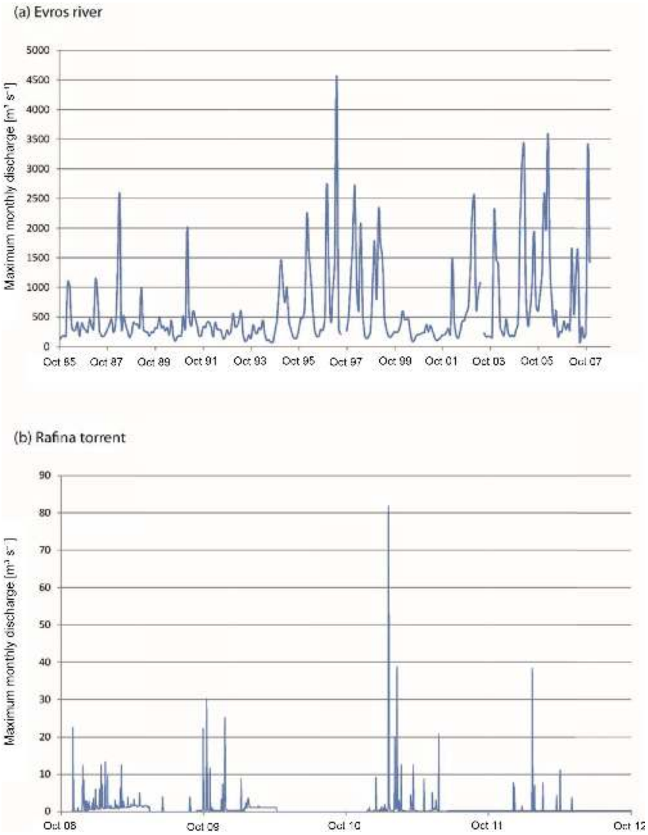

Figure 1. Maximum monthly discharge (Evros River, Fig. 1a) and maximum daily discharge (Rafina torrent, Fig. 1b) for available time series. The event of 3–5 February 2011 was taken as a reference event within the Rafina catchment, East Attica, since it was the event with the largest magnitude over the measurement interval (12.5 h duration, 18 mm h^{-1} rainfall intensity, and 80 and 56 $m^3 s^{-1}$ maximum daily discharge (4 and 5 February, respectively; see also Papathanasiou et al., 2013). Please note that after the November–December/2007 event the gauging station at Evros (Pythio) was destroyed and has not yet been reinstalled. Therefore, the event of 16 November–2 December 2007 (3400 $m^3 s^{-1}$, an area of 52 800 km^2 affected, 5 fatalities and around 300 people displaced; see Brakenridge 2016) was the reference for the case study of Evros, where in general flooding occurs if discharge exceeds 2500 $m^3 s^{-1}$ (Angelidis et al., 2010). Data source for Rafina: Hydrological Observatory of Athens, http://hoa.ntua.gr/timeseries/d/897 (Rafina Fladar, access 4 October 2016); data source for Evros: Regional Authority of Eastern Macedonia and Thrace; see also Angelidis et al. (2010).

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 a Mann–Whitney U test (Mann and Whitney, 1947), logistic regression (Cox, 1958), and recursive partitioning analysis (Breiman et al., 1984) in analysing the differences in the perception of individuals in the peri-urban and rural areas 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 of undertaking 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 comparison with 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.

3.2 Causation belief

We asked the interviewees for the main roots of past flood events. Table 2 presents the results from the questioners, with a lack of structural measures being the most frequently listed reason for past flood events. Categorizing 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, respondents saw as central arguments for the past flood events deforestation (61.8 %), building in high-risk areas (55.4 %), and interventions on the riverbed (58.6 %). 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.

3.3 Risk perception and awareness

Figure 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 to be significantly higher than those who were not evacuated. In neither region, however, was there 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

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, freelance, 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 %

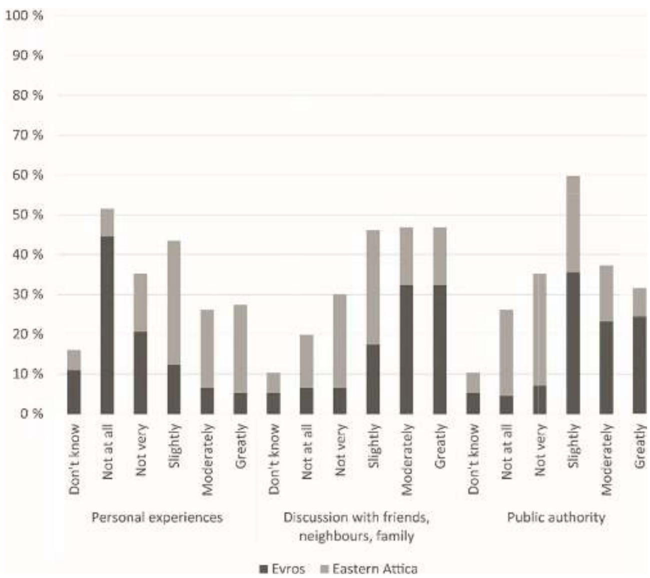

Figure 2. Local knowledge about hydro-geological processes.

13 % in East Attica believed that a flood will happen in the next 2 years. Risk communication processes embedded in local hazard knowledge (mainly from elderly people and flood experiences from neighbours and friends) and to a lesser extent 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.

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 $\tau = -0.019$ and $p = 0.766$ for East Attica). In neither case does age demonstrate an increase in risk perception.

3.4 Implementation of local structural protection measures

Tables 3 and 4 present the correlation matrixes for the different measured variables. A strong positive correlation can be found between the variable "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.

In rural communities of Evros, where the sample had various experiences with periodical flooding, risk awareness

Table 2. Respondents' level of agreement as to 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 %

was found to be significant positively correlated with the individual preparation (Kendall's tau correlation coefficient $\tau = 0.286$, $p = 0.000$). In contrast, in the urban area of East Attica, the risk awareness was found to be uncorrelated with 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 to be maximally at risk. However, only 24.8 % of the sample 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 plays 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 respond adequately and quickly to flood hazards, which typically can be found in rural areas. A key reason is the lack of a relationship between a national authority dealing with flood risk management and flood victims, with the outcome that flood victims adopt 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. The 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.

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

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	−0.209[a]	−0.293[b]	0.102	0.091	0.182[a]	−0.032	0.016	0.044	0.008	−0.047	0.180[a]	0.232[b]	−0.092	−0.058	0.122
2	Evacuated at the event		1	0.199[a]	−0.064	−0.176[a]	0.023	−0.230[b]	−0.248[b]	0.032	−0.113	−0.057	0.025	−0.069	−0.069	−0.077	−0.079
3	Suffered material damages			1	−0.087	0.035	0.061	0.040	0.106	−0.120	0.088	0.250[b]	0.193[a]	−0.024	0.002	−0.028	−0.084
4	Personal experiences				1	0.460[b]	0.155	−0.305[b]	−0.229[b]	0.191[a]	0.120	0.125	0.365[b]	0.377[b]	0.109	0.080	0.379[b]
5	Local knowledge					1	0.245[b]	0.210[b]	0.264[b]	0.165[a]	0.180[a]	0.220[b]	0.030	0.087	−0.099	−0.099	0.091
6	Official training and information initiatives						1	0.043	0.048	−0.036	0.056	0.132	0.146	0.189[a]	0.163[a]	0.099	0.127
7	Personal precautions taken							1	0.902[b]	−0.265[b]	0.184[a]	0.323[b]	−0.362[b]	−0.396[b]	−0.192[a]	−0.161[a]	−0.402[b]
8	Sufficient household income								1	−0.185[a]	0.248[b]	0.417[b]	−0.332[b]	−0.378[b]	−0.211[b]	−0.191[a]	−0.363[b]
9	Period of living at the current residence									1	−0.059	−0.203[a]	0.010	0.148	−0.031	−0.010	0.110
10	Retrospective preparedness level										1	0.520[b]	0.043	−0.031	0.034	0.058	0.066
11	Present individual preparedness level											1	−0.061	−0.124	−0.063	−0.113	−0.157[a]
12	Deforestation causing the problem												1	0.652[b]	0.400[b]	0.350[b]	0.504[b]
13	Construction of buildings in areas at risk causing the problem													1	0.373[b]	0.351[b]	0.635[b]
14	Lack of structural devices causing the problem														1	0.917[b]	0.502[b]
15	Lack of structural devices maintenance causing the problem															1	0.509[b]
16	Interventions on rivers bed causing the problem																1

[a] Correlation is significant at the 0.05 level (two-tailed). [b] Correlation is significant at the 0.01 level (two-tailed).

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 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 in 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 %).

4 Discussion

The increasing impact of human activities on hydrological dynamics has led to a growing interest in the study of socio-hydrology (Di Baldassarre et al., 2015). Focusing on such human–environment interaction, the findings within the presented study contributed to advancing the understanding of risk management and preparedness in flood risk management, with a particular focus on two different types of

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	−0.507[b]	−0.372[b]	0.001	0.006	0.118	−0.093	−0.061	0.125	0.009	0.060	.[c]	−0.249[b]	−0.204[a]	−0.217[b]	−0.043
2	Evacuated at the event		1	0.363[b]	−0.074	0.065	0.115	0.013	0.125	−0.070	0.055	−0.004	.[c]	0.265[b]	0.209[b]	0.183[a]	0.042
3	Suffered material damages			1	−0.116	−0.118	−0.095	−0.061	0.106	−0.146	0.030	−0.017	.[c]	0.150	0.043	−0.086	−0.147
4	Personal experiences				1	−0.286[b]	−0.251[b]	−0.064	−0.051	0.132	−0.075	−0.121	[c]	−0.300[b]	−0.016	0.066	0.062
5	Local knowledge					1	0.643[b]	−0.127	−0.058	0.243[b]	0.379[b]	0.346[b]	.[c]	0.242[b]	0.154	0.028	−0.129
6	Official training and information initiatives						1	−0.058	0.101	0.103	0.260[b]	0.216[b]	[c]	0.328[b]	0.067	0.168[a]	0.024
7	Personal precautions taken							1	−0.020	−0.050	−0.134	−0.222[b]	.[c]	0.083	0.073	0.196[a]	0.194[a]
8	Sufficient household income								1	−0.024	0.127	0.073	.[c]	0.103	0.060	−0.007	−0.103
9	Period of living at the current residence									1	0.167[a]	0.135	.[c]	0.055	−0.031	−0.136	−0.101
10	Retrospective preparedness level										1	0.523[b]	.[c]	0.091	0.125	0.020	−0.150
11	Present individual preparedness level											1	.[c]	0.072	0.014	0.022	−0.071
12	Deforestation causing the problem												.[c]	.[c]	.[c]	.[c]	.[c]
13	Construction of buildings in areas at risk causing the problem													1	0.472[b]	0.153	−0.061
14	Lack of structural devices causing the problem														1	0.284[b]	0.113
15	Lack of structural device maintenance causing the problem															1	0.657[b]
16	Interventions on rivers bed causing the problem																1

[a] Correlation is significant at the 0.05 level (two-tailed). [b] Correlation is significant at the 0.01 level (two-tailed). [c] 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

hydrological hazards in a 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 by 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 annual flood events in the past years. Therefore, the adaptation effect could also 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 in river floods.

The 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, where 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 their main concerns mainly regarding upstream conflicts with Bulgaria, instead of individual responsibility. This behaviour is intensified by the social institutions and organizations (Kasperson and Kasperson, 1996) in the Greek flood risk management policy. Consequently, the citizens of Evros were blaming the neighbouring 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 gain protective skills to respond adequately and quickly to flood hazards, which we usually can find within the ru-

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)	2.6 %	6.5 %
Other	0.0 %	86.3 %

ral areas. A key reason is the lack of a relationship between national authorities dealing with flood risk management and flood victims, with the result that flood victims take over strategies of fatalism and blaming instead of increasing their 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 hydrological 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 %) expressed their belief that flooding will happen again. On the other side, a correlation between age and perception of the hydrogeological 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 were 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 strong 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 the flood risk agencies and emergency responders are 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 of flood risk management strategies instead of improving individual preparedness (White, 1945; Di Baldassarre et al., 2013b, 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 reduce settlement activities (such as construction of new buildings) in hazard-prone areas.

5 Conclusion

Our results have shown that both the levee effect as well as the adaptation effect have considerably different characteristics in the study sites. Besides, our results have shown that assumptions in socio-hydrology are highly complex, such as how different levels of memory influence risk awareness and how risk awareness is linked to adaptation response. Memory is accumulated via direct experience and is proportional to the actual damage experienced by individuals. However, flood experience alone is not sufficient to encourage local adaptation strategies, as shown in the Evros catchment.

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 major-

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

	East Attica	Evros
Flood preparation	In East Attica (the urban area that experiences flash floods) risk awareness found to be uncorrelated with flood preparation.	In Evros (the rural area that experiences periodical flooding) risk awareness was found to be positively correlated with flood preparation, i.e. the more aware, the more prepared.
Local structural protection measures	73.4 % of residents in East Attica took concrete steps to protect their family and property.	A posteriori, 24.8 % of residents in Evros made concrete steps to protect their family and property.
Risk communication	The main reasons are that respondents are aware that they are living in a dangerous area, where knowledge about hydrogeological 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.

ity 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. Whatever the emphasis in flood 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). 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). As a corollary, there is a strong and transdisciplinary need for studies of coupled human–environment interactions. The concept of socio-hydrology was introduced as "a new science of people and water" (Sivapalan et al., 2012, p. 1270). The emerging field of socio-hydrology claims to explicitly focus on such interactions, above all to observe the co-evolutionary interaction between human development and hazard management (Sivapalan, et al., 2012; Di Baldassarre et al., 2013a, 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). Finally, the proposed methodological approach within the debate on socio-hydrology is to incorporate the individual response to different flood frequencies (sudden vs. continuously), different socio-economic environments (semi-urban vs. rural), as well as types of processes (flash floods vs. river floods).

Flood risk management plans are becoming increasingly important for the European countries as these management strategies take in both the social factors and the physical nature of risk, inherently calling for a coupled human–environment interaction approach. 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. This allows us 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.

Data availability. The survey data used in this study are confidential and cannot be made publicly available. Interested parties may wish to contact the corresponding author for further information. The runoff data from the Rafina catchment (Fig. 1) are available from the Hydrological Observatory of Athens (http://hoa.ntua.gr/timeseries/d/897, Hydrological Observatory of Athens, 2012) and the runoff data from the Evros River are available from the Regional Authority of Eastern Macedonia and Thrace (2008) of Eastern Macedonia and Thrace.

Competing interests. The authors declare that they have no conflict of interest.

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