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PUBLIC PERCEPTION OF THE URBAN PLUVIAL FLOODS RISK—CASE STUDY OF POREČ (CROATIA)

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Abstract: Pluvial floods are rain-related floods that occur when water drainage is not fast enough due to heavy rainfall. One of the key components in the management of the urban pluvial flood risk (UPFR) is risk perception (RP). The objective of this paper was to define factors of RP based on the selected variables and to examine their reliability. Emphasis is placed on the contextualization of five factors related to cognition: awareness of the risk of pluvial floods (F_1) and situation: anthropogenic causes of pluvial floods (F_2), natural causes of pluvial floods (F_3), consequences of pluvial floods in the future (F_4), and preparedness for pluvial floods (F_5). Furthermore, historical pluvial floods data were acquired from multiple sources and used to determine the distance of respondents' homes from frequently flooded places. The results showed that the questionnaire was consistent, i.e., factors are highly reliable. Significant differences were observed in the F_2 regarding the gender of the respondents, and in the F_4 regarding their age. Preparedness for the danger (F_5) is the lowest perceived factor. Results from this study can facilitate communication between experts, decision-makers, and citizens.

Keywords: urban pluvial flood risk; risk perception factors; public perception survey

1. Introduction

Pluvial flooding is caused by intense rainfall events when the amount of precipitation exceeds the stormwater drainage system's capatown and the soil's ability to infiltrate the water (Arisz & Burrell, 2006; Rosenzweig et al., 2018). This type of flooding is related especially to urban areas where it is becoming a growing problem due to a combination of rapid urbanization and a simultaneous climate change-driven increase in heavy precipitation (Bradford et al., 2012). This is a very complex type of flood to manage because it is difficult to predict and has relatively short warning times (Houston et al., 2011). The damage from a hazard is directly related to public risk awareness, preparedness for the danger, and implementation of prevention measures (Kienzler et al., 2015). In order to prevent or minimize pluvial flood-related damage, it is necessary to implement long-term mitigation measures jointly with the public (Netzel et al., 2021).

Perceptions play a major role in motivating individuals to take actions to avoid, mitigate, adapt, or even ignore risks (Wachinger et al., 2013). Taking precautionary measures is

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reducing the householder's vulnerability (Grothmann & Reusswig, 2006; Harvatt et al., 2011). Most studies on the risk of natural hazards have shown that respondents are rarely concerned about dangers from them, and therefore their level of preparedness appears to be low (Birkholz et al., 2014; Bubeck et al., 2013; Buchecker et al., 2013; Maidl & Buchecker, 2015; Siegrist, 2013; Wachinger et al., 2013). The existing results suggest that risk awareness has a weak correlation with preparedness for danger (Bubeck et al., 2012). Therefore, to encourage private precautionary measures it is crucial to understand the factors that influence mitigation behavior, including risk awareness (Harvatt et al., 2011; Siegrist & Gutscher, 2008). The way the public perceives the risk is influenced by cognitive and situational factors and is often the opposite of the scientific definition of the risk (Bradford et al., 2012).

A risk assessed by experts is measured based on the statistical probability of hazard occurrence, exposure, and vulnerability, while a perceived risk reflects the perceived likelihood. Various factors such as attitudes, intuition, expectations, information, and previous experience with floods (Samuels & Gouldby, 2009), influence the risk perception. Previous experience with floods affects both global and personal levels of awareness and impacts risk perception (Netzel et al., 2021).

Socio-economic variables typically used in risk perception analysis are age, education, employment status (Cvetković, 2016; Qasim et al., 2015; Rana & Routray, 2016; Wang et al., 2017), homeownership, and the number of household members (Liu et al., 2018; Rana & Routray, 2016). The main objective of this paper was to define factors of public risk perception based on the selected variables and to examine their reliability. The factors used in the study relate to the (1) cognition (the awareness of the risk) and (2) situation (anthropogenic and natural causes, consequences of pluvial floods, and preparedness). The results from this study can facilitate communication between experts, decision-makers, and citizens regarding urban pluvial flood risks.

2. Study area

The town of Poreč is located on the west coast of the Istrian peninsula and it is the second-most populous town in the County of Istria with 16,666 inhabitants in 2021 (Croatian Bureau of Statistics [CBS], 2021). Poreč is one of the strongest tourist centers in Croatia. The economy of the town is characterized by a mono-economic picture with tourism as a core business. Tourism dominates with the largest share in the structure of the GDP and has been growing steadily since 2009. However, the development of tourism was accompanied by uncontrolled building as a negative consequence (Zenzerović et al., 2015). For the town of Poreč, and for most urban environments (Frick & Tervooren, 2019), the characteristic is an invasive transformation of the natural environment into impervious surfaces that can lead to a decline in life quality and to an increase in various risks such as pluvial floods (Frick & Tervooren, 2019; Šiljeg et al., 2020).

The topography of Poreč's surrounding area is predominantly up to 200 m a.s.l. and there are no significant permanent watercourses (Croatian base map [HOK] 1:5000; State Geodetic Administration, 2022). Therefore, floods in the town of Poreč are possible exclusively because of intensive rainfalls (pluvial events) or sea levels rising (coastal floods). In this area carbonate rocks of medium permeability predominate, and to a lesser extent, there are well-permeable carbonate and low-permeability Quaternary rocks (Croatian Geological Survey, 2009). The most exposed parts of the town to floods are coastal areas, agricultural areas, and road networks. The expected annual damage from pluvial floods is related to 30 family houses, specific roads, and 5–6 ha of agricultural areas (Matošević et al., 2018) where the average annual precipitation is from 900 to 1100 mm (Bertoša & Matijašić, 2005). Most precipitation falls in autumn and in the transition period from spring to summer represent a less pronounced secondary peak. The smallest amount of precipitation is expected at the end of winter and the beginning of spring and summer (Bertoša & Matijašić, 2005).

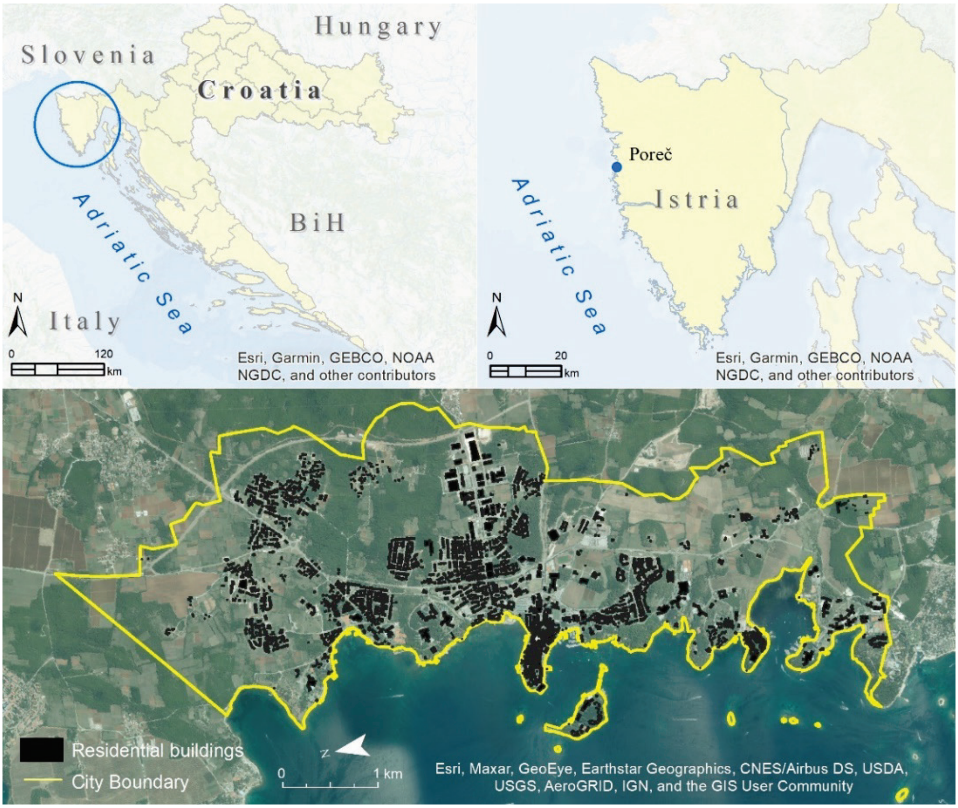

Figure 1. Town of Poreč—geographical position.

2. Materials and methods

The research methodology consisted of several steps. The first step included the acquisition of the data about historical floods to determine the count and spatial distribution of pluvial flood events in the town of Poreč. The second step involved designing the questionnaire based on the relevant literature (Netzel et al., 2021; Rana & Routray, 2016; Samuels & Gouldby, 2009; Wang et. al. 2017) and on the conducted public opinion poll. The third step referred to the geocoding of the respondents' addresses and the creation of a GIS and SPSS database. The fourth step was defining the factors and examining their reliability with the selected statistical methods. In the fifth step, correlation analysis was performed using the Spearman correlation coefficient, and a comparison of the factors with respect to socio-economic characteristics (age and gender). In the last step, the interpretation of the results was performed.

2.1. Acquisition of historical pluvial floods data

Historical pluvial flood data are used to determine the distance of the respondents' homes from the frequently flooded locations. Considering that there is no official pluvial floods database for the town of Poreč, historical data were collected and integrated from all available sources. These sources included: (1) public fire brigades, (2) civil protection, town institutions, departments, and institutions, (3) public opinion polls, (4) online sources, newspapers, and (5) Croatian base map (HOK). The Croatian Base Map is the official state map on a scale of 1: 5,000 and it consists of more than 900 sheets. This research uses sheets related to the town of Poreč (Poreč 5B 18–32, 42, 43 and Kanfanar 5B 17–2; State Geodetic Administration, 2022). Collected data had a temporal and spatial attribute and, depending on the source, a documentary attribute. All available data were digitized, filtered, geocoded, and transferred to GIS format. Distance analysis is performed in GIS using the Multiple Ring Buffer tool. Three categories of distance were generated: <100 m, 100–200 m, and >200 m.

2.2. Statistical methods

To evaluate the public perception of urban pluvial flood risk (UPFR), the survey was conducted among adults (18+ years old) and it included 0.5% (N = 85) of the population of Poreč (CBS, 2011). The survey was conducted in August 2021 and data were obtained via face-to-face interviews using standardized questionnaires. The type of sample was stratified, and the selection was random. Special care was taken to ensure that the spatial sample is evenly distributed. The exclusion criteria were the unwillingness to complete the questionnaire. Each questionnaire was filled out at a different address within the town. Respondents' addresses were geocoded using the Google Earth mapping tools and imported into the GIS.

Since risk perception is a latent variable that is not directly measurable (Netzel et al., 2021), it has been operationalized through the assessment of multiple statements (items) on a rating scale. The questionnaire included the total of 46 items related to cognition and situation which have been used to create five factors depending on the measurement scale and according to theoretical assumptions. The defined factors are:

- F_1: Awareness of the pluvial flood risk;
- F_2: Anthropogenic causes of pluvial floods;
- F_3: Natural causes of pluvial floods;
- F_4: Consequences of pluvial floods in the future; and
- F_5: Preparedness for pluvial floods.

Statistical analyses were performed in SPSS Statistics (26.0) and include descriptive and inferential statistics. To conduct the analysis, five factors were created according to theoretical assumptions and depending on the measurement scale. For each factor, mean values (median and interquartile range) are calculated and minimum and maximum values are presented. The calculation of Cronbach's Alpha coefficients sought to determine the level of reliability of the applied measurement scales, i.e., whether they are confirmed as valid instruments for measuring the attitudes and opinions of the respondents. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to determine how the observed variables were distributed. Mentioned tests showed that data is not normally distributed, so for further analysis Mann-Whitney U test has been used to examine the differences of factors with respect to the selected socio-economic characteristics: gender and age. The correlation of the factors was determined by Spearman's correlation coefficient, which sought to determine whether a change in the value of one factor affects the change in the value of another factor.

3. Results and discussion

3.1. Historical floods data and spatial distribution of the surveyed inhabitants

The collected data on historical pluvial floods showed that there are 27 locations in the town of Poreč that flood frequently. At these locations, firefighters are doing technical interventions (such as water pumping) at least once a year. Of the total number of collected geocoded survey questionnaires 15.38% are located less than 100 m from critical locations, 16.47% are 100–200 m far from them, and the rest are at the distance of more than 200 m (Figure 2).

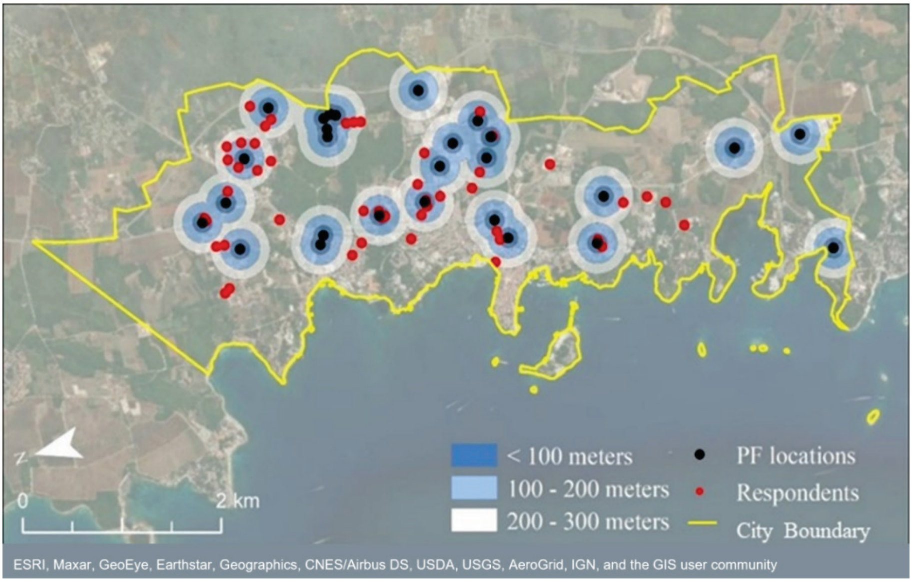

Figure 2. Town of Poreč – geographical position.

3.2. Socio-economic characteristics

According to the demographic characteristics, 64% of the respondents were female while 36% were male. The sample population comprised different age groups with the age group 18–59 years accounting for 77% of total respondents. All the respondents have the minimum primary level of education so there are no respondents without any formal education and the majority, 76% of them, are employed. The ground floor of a residential building is where 34% of the respondents live on.

3.4. Statistical analysis of parameters

The Cronbach's Alpha coefficient for all the observed factors is greater than 0.7, indicating a very high-reliability level. The highest reliability has been noticed for F_1. The mean values by factors (median) and the indicator of their dispersion (the interquartile range was used as an absolute measure of dispersion) are presented in Table 1. The highest median value is for F_3, while IQR is the highest for F_2 (Table 1).

Descriptive analysis of items by factors showed that the higher mean values within F_2 and F_3 were related to climate change, excessive building, and urbanization. Given the topicality of climate change, the respondents assumed the possibility of a connection with pluvial floods. Since this is an urban tourist environment, the presence of impermeable surfaces is increasing. Many respondents pointed out that anthropogenic causes are the main ones in creating floods.

Table 1. Mean values by factors (median) and the indicator of their dispersion

	Awareness of the PFR (F_1)	Anthropogenic causes of PF (F_2)	The natural causes of PF (F_3)	Consequences of PF in the future (F_4)	Preparedness for PF (F_5)
Median	3.27	3.56	3.60	3.20	3.13
(IQR)	(2.27–4.00)	(2.89–4.11)	(2.80–4.00)	(2.80–3.80)	(2.81–3.31)
Minimum	1.00	1.78	1.40	1.00	1.31
Maximum	5.00	5.00	5.00	5.00	4.19
Cronbach's α	0.942	0.826	0.775	0.760	0.749

The analysis resulted in a medium level of risk awareness (3.27). However, significant variability in response was observed within F_1, which can be related to the previous experience of respondents with pluvial floods. People who have had direct experience with PF have a higher level of awareness (Netzel et al., 2021). Preparedness for pluvial flood risk is perceived as lower (3.13) compared to risk awareness. This factor has the lowest variability in respondents' answers which indicates that respondents agree on the issue of low preparedness. The willingness to take risks is directly related to the level of awareness (Netzel et al., 2021). Since the level of awareness is not high, a lower level of preparedness is expected.

Natural causes of pluvial floods are the highest perceived factor according to the median value (3.60). Since pluvial floods are the result of heavy rainfall, respondents perceive the cause of the floods as primarily natural. Still, anthropogenic causes such as concretization and urbanization (3.56) are highly perceived as causes of pluvial floods. This is related to the fact that Poreč is one of the strongest tourist centers in Croatia. Intensive tourism development often brings various negative effects for the locals such as excessive building which is related to poor planning, inadequate development, and incompetent management (Marušić & Prebežac, 2004). Furthermore, many respondents complained about the problem of not regularly maintaining run-off canals and drains. The expectation of damage from pluvial floods in the next 10 years is the second-lowest factor by median value (3.20).

Kolmogorov-Smirnov and Shapiro-Wilk tests were performed to determine the normality of distribution for these factors (Table 2). To correct the significance value, the Lilliefors Significance Correction is used. The Shapiro-Wilk test is typically used to test normality for small and medium samples (Conover, 1999), and the results of the test suggest that only F_2 is significant (p = .075) and has a normal distribution, but the same is not established for any of the other factors. Since the significance and normality of the distribution for the other factors, F_1, F_2, F_3, and F_4, have not been established, for further analysis, Mann-Whitney U test has been used.

Table 2. Distribution normality testing

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	*df*	Sig.	Statistic	*df*	Sig.
Awareness of the pluvial flood risk (F_1)	.111	85	.011	.946	85	.001
Anthropogenic causes of pluvial floods (F_2)	.079	85	.200*	.973	85	.075
Natural causes of pluvial floods (F_3)	.083	85	.200*	.970	85	.043
Consequences of pluvial floods in the future (F_4)	.108	85	.015	.967	85	.027
Preparedness for pluvial floods (F_5)	.120	85	.004	.935	85	.000

Note. *This is a lower bound of the true significance; [a]Lilliefors Significance Correction.

To determine the correlation between the observed factors, Spearman’s correlation coefficient was calculated (Table 3). A correlation was observed between all factors. The most pronounced positive correlation is between F_2 and F_3 (r = .798; p < .01). A high correlation is also between F_1 and F_3 (r = .632; p < .01). Medium intensity of correlation is between F_1 and F_2 (r = .610; p < .01). The high correlation between F_2 and F_3 can be explained by the fact that the hinterland of Poreč has a natural predisposition to floods due to many sinkholes, and at a time when the town was expanding, residential buildings were built in areas where construction should not have been allowed, i.e., in natural depressions.

Table 3. Spearman 's correlation coefficient between the observed factors (N = 85)

Factors		F_1	F_2	F_3	F_4	F_5
Awareness of the pluvial flood risk (F_1)	*r*	1.000	.610**	.632**	.556**	.468**
	p	.	.000	.000	.000	.000
Anthropogenic causes of pluvial floods (F_2)	*r*	.610**	1.000	.798**	.232*	.282**
	p	.000	.	.000	.033	.009
Natural causes of pluvial floods (F_3)	*r*	.632**	.798**	1.000	.278**	.340**
	p	.000	.000	.	.010	.001
Consequences of pluvial floods in the future (F_4)	*r*	.556**	.232*	.278**	1.000	.477**
	p	.000	.033	.010	.	.000
Preparedness for pluvial floods (F_5)	*r*	.468**	.282**	.340**	.477**	1.000
	p	.000	.009	.001	.000	.

Note. **Correlation is significant at the .01 level (2-tailed); *Correlation is significant at the .05 level (2-tailed).

Socio-economic variables used in this study are gender, age, education, and employment status. Some of the previous studies showed that risk perception is influenced by age and gender (Ho et al., 2008; Lee et al., 2021) and some showed weak or no influence (Plapp & Werner, 2006; Siegrist & Gutscher, 2008). Table 4 presents the factors related to variable gender. For the F_2, with a confidence level of 95% (p < .05), it can be said that there is a statistically significant difference with respect to the gender of the respondents. Female respondents rated higher variables within F_2, so the value scale is higher. The reasons why women add more value to F_2 variables can be explained by the fact that they are more aware of the risks of pluvial floods and that they are generally more sensitive to the risks to the household. In addition, according to the study Disaster Risk Assessment for the Republic of Croatia prepared by the Government of the Republic of Croatia (2019), in several cases, women seek medical help when it comes to various risks. Furthermore, if we analyze the responses of women by all factors, then it can be concluded that women generally rated variables within almost all factors with higher values.

Table 4. Comparison of the observed factors regarding the gender of the respondents

	Gender		*p**
	Female	Male	
Awareness of the pluvial flood risk (F_1)	3.45 (2.55–4.00)	2.91 (1.73–3.91)	.161
Anthropogenic causes of pluvial floods (F_2)	3.67 (3.11–4.22)	3.33 (2.44–3.78)	.035
Natural causes of pluvial floods (F_3)	3.60 (3.20–4.00)	3.20 (2.40–4.00)	.141
Consequences of pluvial floods in the future (F_4)	3.20 (2.80–3.80)	3.00 (2.60–3.80)	.429
Preparedness for pluvial floods (F_5)	3.13 (2.81–3.38)	3.13 (2.69–3.31)	.436

Note. *p**= Statistical significance.

Factors were also compared regarding the age of the respondents, using the Mann-Whitney U test (Table 5). For the F_4, with a confidence level of 95% ($p < .05$), it can be said that there is a statistically significant difference considering the age of the respondents. The value of the scale is higher for the middle-aged group. The assumption was that the older respondents would be more worried about PFR because of a higher level of experience. They mostly expect heavy rainfall events to increase in frequency and intensity in the next 10 years in Poreč, and as consequence, they expect more damage to tangible assets. The potential reason is that the young and middle age groups are more prone to use the internet and therefore more informed about climate change and its possible consequences. Generally, in the next 10 years, respondents are expecting a moderate increase in material damage because of PF. Most are not expecting any material damage to their own property, but they are expecting an increase in pluvial risk awareness among residents and an increase in financial investment for mitigation measures.

Table 5. Comparison of the observed factors with regard to the age of the respondents

	Age		*p**
	18–59	> 60	
Awareness of the pluvial flood risk (F_1)	3.32 (2.27–3.91)	2.73 (1.45–4.09)	.891
Anthropogenic causes of pluvial floods (F_2)	3.56 (3.00–4.00)	3.67 (2.56–4.44)	.993
Natural cause of pluvial floods (F_3)	3.60 (2.80–4.00)	3.80 (2.80–4.20)	.564
Consequences of pluvial floods in the future (F_4)	3.40 (3.00–3.80)	2.60 (1.60–3.80)	.014
Preparedness for pluvial floods (F_5)	3.13 (2.81–3.31)	3.13 (2.75–3.38)	.924

Note. *Mann-Whitney U.

It is interesting to point out that respondents from both age groups evaluated the variables within F_5 factor almost identically, which confirms non-preparedness for PF (Table 5). Most respondents believe that they are not well prepared for PF and that they cannot defend themselves from the flood on their own. Variables that are particularly low rated within F_5 related to the awareness of fellow citizens of the PFR and to the poorly executed flood defense system. Also, it is pointed out that the decision-makers are not doing everything they can to mitigate the risk. The highlighted problems are the following: the existing stormwater drainage system is not maintained and cleaned regularly, no investments are made in reconstruction, and citizens are not sufficiently educated to react. The question about familiarity with the term *pluvial floods* ("Have you ever heard of the term?") showed that 88% of the respondents are familiar with it and that 12% have never heard of the term. The majority (85%) of respondents believe that the town of Poreč is not an area of high risk of pluvial floods and, compared to other Croatian cities, it is not in greater danger. Pluvial floods occur once a year in the town of Poreč according to 42% of respondents, most often during the autumn. For the factor awareness, respondents estimated the level of pluvial flood risk for tangible assets, residential objects, and urban public infrastructure as moderate. Most of them perceived that the lowest PFR is for their home. That indicates that personal risk perception is lower than risk perception for their town (global). This correlates to Netzel et al. (2021) who found that people are aware that heavy precipitation is a potential hazard but most of them do not perceive it as a risk for themselves. The risk of the emergence of heavy rainfall side effects such as landslides or erosions is considered insignificant because of the topography of the terrain.

4. Conclusion

The perception of the PFR in this paper was analyzed through five formed factors related to awareness (F_1), anthropogenic (F_2) and natural causes (F_3) of floods, expectations (F_4) and preparedness (F_5). The conducted statistical analysis and the applied test showed that the questionnaire was consistent and that all the defined factors have a high level of reliability. It has been established that all factors have a positive relationship and are sensitive to each other. The highest level of agreement with the statements is prominent in the factor related to causes of PF, where anthropogenic causes are considered primary.

The prevailing view is that the citizens cannot defend themselves against floods, and at the same time they are expressing distrust toward decision-makers. The highest level of agreement was found in F_2 and F_3 concerning anthropogenic and natural causes of pluvial floods (PF), which is related to the economic characteristics of Poreč, and the legislative framework in Croatia. Spatial planning documentation does not regulate the construction zone well, i.e., the construction permit can be issued regardless of the natural preconditions for flooding. Significant differences are observed in the perception of anthropogenic causes of floods regarding gender.

Also, a significant difference is noticed in the expectations of PF in the future regarding the age of respondents. Nevertheless, the analysis showed that women generally rated variables within all factors with higher values. Also, it is important to mention that all the respondents have at least the primary level of education and there are no respondents without any formal education. Still, most respondents believe that additional education for citizens about PFR is necessary. Likewise, education should be held for decision-makers to achieve better communication with the town population and to encourage protective measures at all levels.

This research can be a guideline for other activities within the INTERREG Italy-Croatia STREAM (Strategic Development of Flood Management). The derived results can facilitate communication between experts, decision-makers, and citizens regarding urban pluvial flood risks. Also, results can be used in identifying critical locations of UPFR, where protection measures can be taken in advance.

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