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Abstract

This article analyses the scope for individual adaptation to flood risk in the South of France. We collected data concerning the implementation of individual adaptation measures and the willingness to pay for individual and collective measures in a survey of 418 respondents living in two flood-prone areas. First, we observed the current level of adaptation and compared the willingness to pay for individual versus collective measures. We then analysed the drivers of implementation and of willingness to pay. We then provide a cost–benefit analysis of individual adaptation. The survey results show that, despite willingness to pay for reduced risk, few adaptation measures have been implemented. Perceptions of hazards and of damage are important drivers but have different influences: the first favours the implementation of measures; the second increases willingness to pay for measures. Finally, our cost–benefit analysis suggests that completely dry proofing a house up to a height of one metre may not be economically viable. This calls for the promotion of cheaper and more cost-efficient measures.

KEYWORDS

contingent valuation, cost–benefit analysis, damage mitigation, dichotomous choice, flood, France, individual adaptation, willingness to pay

1 | INTRODUCTION

Floods are considered the main natural hazard in France, 46% of municipalities being at risk. Among available risk-reduction tools, household adaptations have received increased attention in recent decades. Measures, such as erecting flood barriers, installing electrical fittings higher in walls, and protecting valuables (e.g., upstairs), appear to be effective and relatively low-cost options (Bubeck, Botzen, & Aerts, 2012; Bubeck, Botzen, Kreibich, & Aerts, 2012; Bubeck, Botzen, Suu, & Aerts, 2012; Kreibich, Bubeck, Van Vliet, & De Moel, 2015; Kreibich, Christenberger, & Schwarze, 2011; Kreibich, Thieken, Petrow, Müller, & Merz, 2005). We refer to these as individual adaptation measures (Erdlenbruch & Bonté, 2018; Richert, Boisgontier, & Grelot, 2019; Richert, Erdlenbruch, & Grelot, 2019 as opposed to collective mitigation measures.[1] This article investigates people's willingness to reduce flood risks at the household level. We analyse the implementation of measures and assess willingness to pay (WTP) for further measures. Our study produced three main results: first, the level of investment in individual adaptation is low and is mainly implemented by those who have already experienced a flood. Second, the number of protest votes against private participation in flood protection was significant. Third, even among the non-protest voters, the WTP for private precautionary measures is not enough to cover the cost. This result contrasts with many findings in the literature. Our results highlight the particularity of the French vision of disaster risk reduction.

A vast literature has focused on the determinants of individual adaptation measures. For example, Osberghaus (2015) conducted a nation-wide study of 4,200 households in Germany and found that adaptations such as appropriate use of buildings, structural measures and flood barriers tended to be applied when individuals had experienced flooding and believed that worse damage would occur in the future due to climate change. Direct experience was also found to be important in several other smaller case studies, (e.g., Grothmann & Reusswig, 2006; Richert, Erdlenbruch, & Figuières, 2017). Bubeck, Botzen, and Aerts (2012) and Bubeck, Botzen, Kreibich, and Aerts (2013) stressed the importance of coping appraisal as a determinant of adaptation decisions[2] in line with other studies based on the protection motivation theory (Grothmann & Reusswig, 2006; Reynaud, Aubert, & Nguyen, 2013; Richert et al., 2017). For instance, in a survey of 752 German households exposed to flood risk along the River Rhine, Bubeck, Botzen, and Aerts (2012) and Bubeck et al. (2013) showed that "self-efficacy" was a significant factor in the implementation of structural measures and flood barriers, and that "response efficacy" was significant in explaining the implementation of flood-adapted use of buildings and flood barriers, whereas risk perception played a minor role. Bubeck, Botzen, Suu, and Aerts (2012) studied risk perception as a factor in decisions to adapt by distinguishing between perceived probability and perceived consequences. They showed that both are weak predictors of the intention to implement measures. Interestingly, they found that the variable "perceived consequences" was a strong predictor of the demand for flood mitigation policies in general. Finally, several studies underlined the importance of socio-demographic variables, such as home ownership, education and income (e.g., Grothmann & Reusswig, 2006; Richert et al., 2017).

Although individual adaptation measures can be cost efficient (Bubeck et al., 2013; Kreibich et al. (2015, 2011, 2005); Owusu et al., 2015; Poussin, Bubeck, Aerts, J, and Ward (2012); Poussin, Wouter Botzen, and Aerts (2015); Richert, Boisgontier, & Grelot, 2019; Richert, Erdlenbruch, & Grelot, 2019; Sairam, Schröter, Lüdtke, Merz, & Kreibich, 2019), many factors may prevent their implementation, such as underestimating the likelihood of flooding, focusing on short-term, financial constraints, or relying on government assistance, as discussed in Kunreuther (2006). Other concerns included the cost, the aesthetics, and the belief that flood protection should be provided by the state (Kazmierczak & Bichard, 2010; Owusu et al., 2015), as well as feeling protected by collective flood mitigation (Richert, Boisgontier, & Grelot, 2019; Richert, Erdlenbruch, & Grelot, 2019). Whether there is a general demand for more individual adaptation measures and for policies to broaden their implementation (Grothmann & Reusswig, 2006; Owusu et al., 2015) can be tested through stated preference methods.

Stated preference methods, particularly contingent valuation (Carson, 2012; Johnston et al., 2017), have been used to assess a variety of collective flood-mitigation policy approaches (Champonnois, 2018; Champonnois & Chanel, 2016; Chanel, Chichilnisky, Massoni, & Vergnaud, 2016; Glenk & Fischer, 2010; Kuo, 2016). Indeed, WTP may express a monetary benefit (increased land-use value) or other benefit (reduced anxiety and community disruption), as discussed in Thunberg and Shabman (1991). For example, Champonnois and Chanel (2016) used contingent valuation to estimate French households' WTP for a collective flood-protection scenario and an insurance scenario. They found mean a WTP of 93 euros for the collective scenario and 100 euros for the insurance scenario (with maximum values at 1,500 and 1,300 euros, respectively).

Valuation studies of the benefits of individual adaptation are rare (Botzen et al., 2009a, 2009b; Kazmierczak & Bichard, 2010; Kuo, 2016; Owusu et al., 2015). Kazmierczak and Bichard (2010) estimated WTP for individual adaptation measures in flood-prone areas in England. They found median WTP values of less than £100 (although 10% of the respondents were willing to pay more than £1,000). Moreover, they found no significant difference in WTP between people who had already been flooded and those who had not. Owusu et al. (2015) studied WTP for individual adaptation measures in Scotland among households living in flood-prone areas. They reported slightly lower means for those who had previously been flooded (£734) than for those who had never been flooded (£834). The main determinants of a WTP for flood-mitigation policies found in the literature are income, home-ownership, objective measures of flood risks, flood experience and risk perception (see the literature review in Champonnois and Chanel (2016)).

Botzen et al. (2009a, 2009b) used a choice experiment to evaluate Dutch households' WTP for individual adaptation measures in exchange for reduced insurance premiums. They found that households would consider implementing low-cost measures: 68% were willing to buy sandbags at a cost of 20 euros in exchange for a

5-euro discount on their annual premium (the mean WTP for flood insurance was 120 euros per annum). Similarly, 24% of the sample would move central-heating boilers to a higher floor in return for a discount of 10 euros. However, such moves would only provide protection against relatively small floods. In the 2009 study by et al., sandbags were expected to prevent water from entering homes in 60% of all cases in one scenario and in 30% in another. On the other hand, Botzen, Aerts, and van den Bergh (2013) found that households were willing to make a substantial investment if the flood risk could be eliminated entirely. In their study of over 400 Dutch households 52% of homeowners were willing to spend up to 10,000 euros to elevate a new house to a safe level. They estimate the "safety premium" that individuals place on risk elimination at between 35 and 45 euros per month.

This article assesses the willingness of households in the South of France to reduce flood risk. First, we analysed the implementation of individual adaptation, that is, whether people have already implemented individual adaptation measures or whether they intend to invest in such measures in the near future, and the determinants of such decisions. We then used stated preferences to test whether people were in favour of further flood mitigation and adaptation measures. To this end, we built two scenarios. In one, we measured WTP (WTP) for collective flood mitigation measures, the case in most studies in the literature. In the second scenario, we tested whether people would be in favour of individual adaptation measures if they were set up collectively. We call the second "individual scenario" and the former "collective scenario" although both would be backed by the government's Flood Management Fund. The determinants of these three actions (implementation of individual measures, WTP for collectively implemented individual measures, WTP for collective mitigation measures) have never been compared in the literature even though this approach would disentangle whether people refrain from investing on their own, do not believe in the efficiency of individual adaptation, or generally refrain from contributing to public good "flood protection." Finally, we conducted a cost–benefit analysis, linking the WTP to reduce flood risk and the cost of structural protection measures in buildings, and show that in most cases, the WTP is too low.

This article is organised as follows: in Section 2, we describe the survey and the context in which it took place. In Section 3, we present the results in the form of descriptive statistics of the main variables and in the form of econometric regressions that identify the determinants of individual adaptation and of the WTP for individual and collective protective measures. In Section 4, we conduct a cost–benefit analysis based on our survey results and on results in the literature. In Section 5, we discuss the scope for flood mitigation and adaptation measures in France and conclude.

2 | STUDY AREA AND SURVEY

2.1 | Flood-prevention policy in France

To evaluate the scope for further adaptation and mitigation, here, we provide a brief overview of some of the existing flood-prevention measures in France.

First, the national disaster compensation scheme (the CatNat system) provides cover to the majority of citizens through a compulsory surcharge of 12% on their home insurance premium. This entitles them to compensation for damage caused by different types of natural disasters, provided that the event is officially recognised as such. The average contribution to this system is less than 20 euros per household per year (see Grislain-Letrémy & Peinturier, 2010; Richert, Boisgontier, & Grelot, 2019; Richert, Erdlenbruch, & Grelot, 2019 for further details).

Second, flood-prone areas are provided with flood risk prevention plans (PPRi in French). These comprise two parts: a map of the at-risk area (usually determined by the worst historical flood and the 100-year flood) and a regulatory document specifying the extent to which new construction is permitted and whether specific individual adaptation measures are recommended or compulsory in each area (Richert, Boisgontier, & Grelot, 2019; Richert, Erdlenbruch, & Grelot, 2019). Each municipality in both our study areas has a flood risk prevention plan. In the Haute-Garonne, the flood risk prevention plans were drawn up in 1997 and approved in 1999. The plans for the Var were drawn up in 2010 following a major flood event and were approved in 2014. In the flood risk prevention plan, certain individual adaptations are either recommended or compulsory and are subsidised by the government. Prior to 2020, 40% of the costs of the preventive measure could be recovered. However, these subsidies are rarely requested and there are no incentives from insurers to implement them (see also Thieken, Petrow, Kreibich, & Merz, 2006). As of 2020, households can recover even 80% of the costs.

Third, most local flood-prevention policies are part of the so-called Flood Prevention Action Programmes, or PAPIs. These are locally designed policy packages that have been selected to receive financial support by the government following competitive bidding (see Erdlenbruch, Thoyer, Grelot, Kast, & Enjolras, 2009, for details). The local water manager can choose the strategies to be implemented, such as restoring natural flood plains, erecting dikes, or reducing individual vulnerability. In the Var study area the latest PAPI covers the period 2016–2022. A total of 96 million euros was allocated to flood-prevention measures, of which 90.5 million euros were earmarked for flood mitigation and over 1.3 million to reducing vulnerability. Recommendations for individual adaptation measures based on expert assessments of each property were included in the PAPI, although at the time of writing, these have not yet been implemented.

Finally, as part of a general reform of flood- and water-management policies in France, since 2018, greater responsibility has been granted to local authorities. According to a new law, local water managers can levy an additional tax of up to 40 euros per annum per resident for flood and water management. At the time of our study, this tax was under discussion but had not yet been introduced in our two study areas.

2.2 | Study area and survey method

Our study is based on a survey carried out in two river basins which are subject to flooding in the Var and Haute-Garonne departments in the South of France (see Figures 1 and 2). In the Var, major floods occurred on June 15 and 16, 2010, causing more than 1,000 million euros of damage, and leaving 26 dead (Vinet, Lumbroso, Defossez, & Boissier, 2012). The floods mainly occurred in the Argens and Naturby rivers, in the heart of one of our two study areas. The 2010 floods were followed by another major flood of the Argens river lasting from November 4–10, 2011, just after the initial phase of reconstruction. The two events had far-reaching consequences: a projected flood risk prevention plan was implemented by the prefect in 2012 (and approved in 2014), slowing down further urban development. A local water basin management institution was created (in 2013–2014), and a PAPI programme was established to invest roughly 100 million euros in flood management over a four-year period. These institutional changes were accompanied by many public meetings and discussions about flood risk management. Voluntary programmes were set up to help people evaluate the vulnerabilities of their homes and businesses. The government purchased and destroyed around 50 at-risk homes.

We conducted several semi-structured interviews in the study area, which showed that most people had vivid memories of the 2010 and 2011 events. In particular, they highlighted the close sequence of the two events, which occurred after a lengthy period with no floods (since 1999). The most recent flood comparable in intensity to the 2010 event occurred in 1827 (Vinet et al., 2012). In 2014, a severe flood affected several nearby coastal municipalities but had almost no impact in our study area. There was another major flood on November 23 and 24, 2019), which left nine dead, but this flood occurred a few months after our survey and is consequently not included in this article.

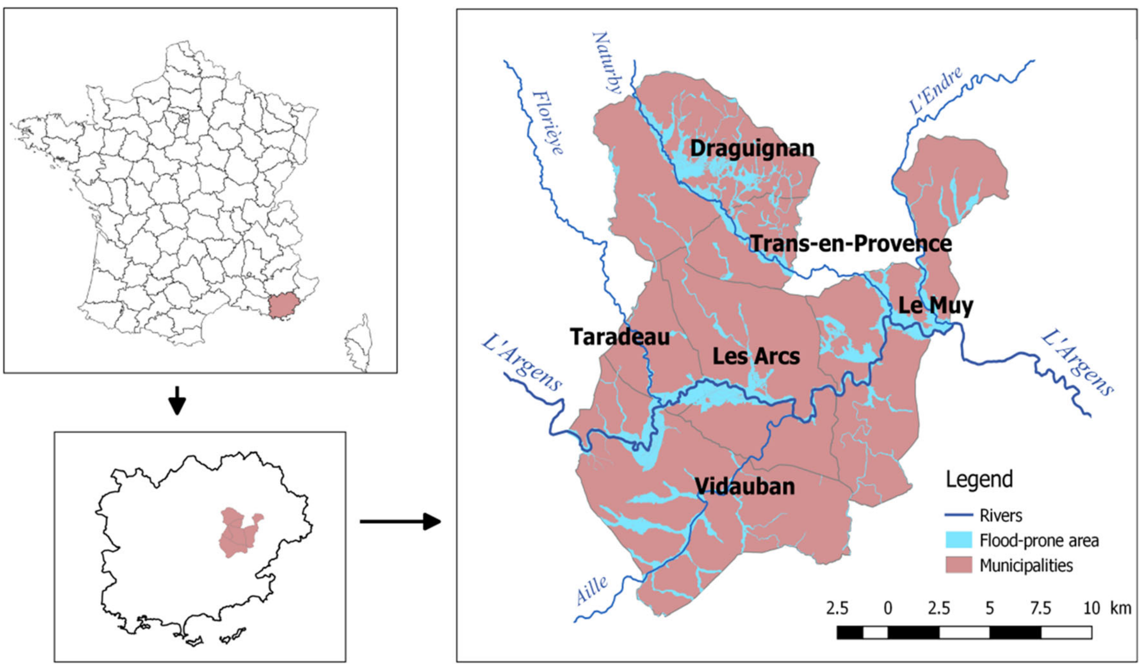

FIGURE 1 Municipalities surveyed in the Var

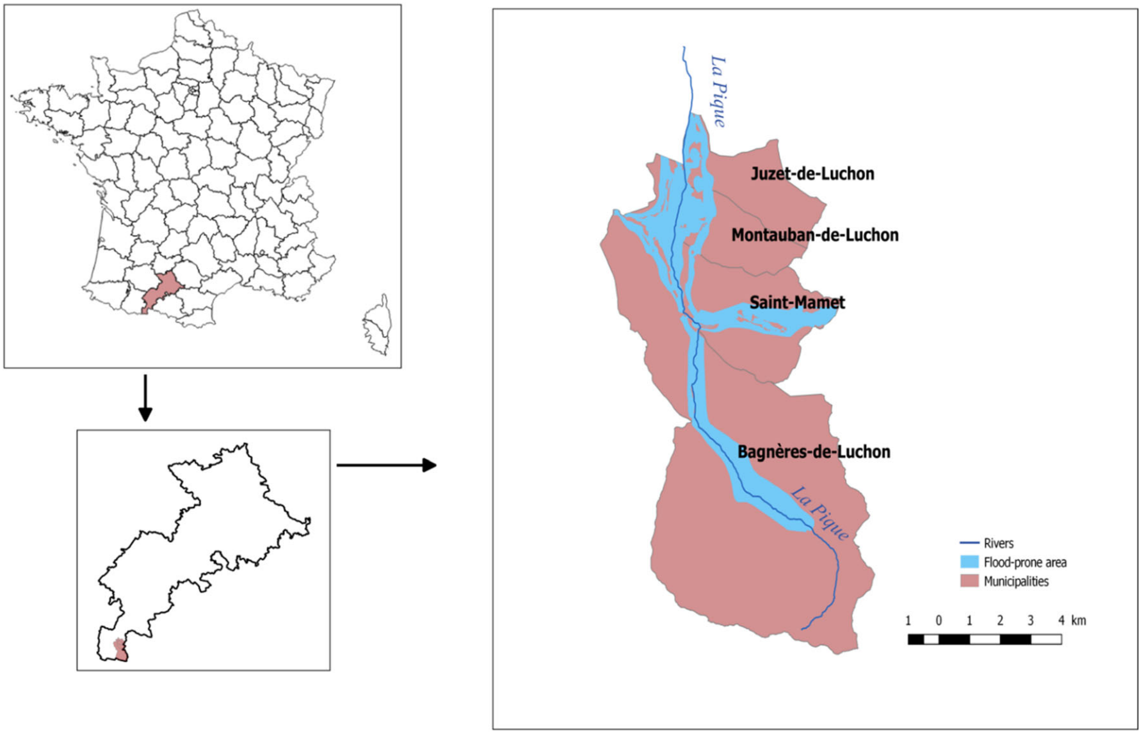

FIGURE 2 Municipalities surveyed in the Haute-Garonne

Bagnères-de-Luchon and the surrounding areas in the Haute-Garonne, suffered a flash flood of the La Pique river that lasted from June 17–20, 2013 and caused serious damage. Smaller flood events occurred in 1995, 1999, 2009, and 2018. However, the most recent significant floods comparable in intensity to the 2013 reference event we studied in the Var—occurred back in 1925. The situation in this river basin is consequently quite different from that in the Var, thereby ensuring our dataset was sufficiently diverse. In the semi-structured interviews, respondents mainly referred to the 2013 event but were less impressed by the severity of the flood than respondents in the Var.

A total of 418 interviews were carried out in spring 2019 in 10 municipalities, of which six—Draguignan, Le Muy, Les Arcs, Trans-en-Provence, Taradeau, and Vidauban—are located in the Var, and four—Bagnères de Luchon, Montauban de Luchon, Saint-Mamet, and Juzet de Luchon—are located in Haute-Garonne. Face-to-face interviews took place in the respondent's home. The respondents were selected by random walk sampling.

The questionnaire was divided into seven sections as follows: the sociodemographic features of the household, the type of property, flood experience, attitudes to risk and time, flood-risk perception, individual adaptations, and the WTP for individual adaptation and collective protection measures. In this article, we focus on the level of individual adaptation today, and its determinants, and on the WTP for future individual and collective adaptations. The main variables used in the following analysis are summarised in Table 1.

2.3 | Measures of households' willingness to reduce risk

2.3.1 | Individual adaptation measures

We asked respondents about specific individual adaptation measures: slot-in flood barriers, sewer non-return valves, main rooms upstairs and valuables placed upstairs, and electrical fittings set higher up the walls. According to previous surveys by Richert et al. (2017), these are the most common measures taken. We also asked respondents if they had taken any other measures. Efforts to improve water flow, pumps and manholes were each mentioned several times.

2.3.2 | WTP for individual and collective measures

We asked respondents about their WTP for individual and collective adaptations. The scenarios are described in the Appendix. Both scenarios call for willingness to contribute to a fictitious Flood Management Fund created by the government. In Scenario 1, the fund would be used

TABLE 1 Description of the variables

Variable	Description
Age	Age of the respondent
Household size	Number of persons in the household
Owner	Householder is the owner of the property (yes/no)
Years since installation	Number of years since installation
Risk perception	"What is the likelihood of flooding less than 1 m in depth in your street in the next 10 years?" (0 "no risk" to 5 "very high risk")
Flood experience	"Have you ever experienced a flood?"
Within flood risk prevention plan area	Property located in an area with a flood risk prevention plan
Damage perception	"If your home were flooded, would there be serious damage?"
Responsibility	Responsibility for flood protection (state authority, individuals, everyone)
Living in an at-risk area	"Do you live in a flood-prone area?" (yes/no/do not know)
Var	Property in the Var department
Income	Respondent's individual income
Education	Respondent's level of education
Order of scenarios	The collective scenario is presented before the individual scenario
WTP (individual)	WTP for the individual scenario
WTP (collective)	WTP for the collective scenario
Measures already taken	At least one individual adaptation measure already taken by the household

Abbreviation: WTP, willingness to pay.

for collective flood protection works, such as dikes, retention basins or for the improvement of existing rainwater drainage networks. We call this the "collective" scenario. In Scenario 2, the fund would finance expert assessments and implement protective measures in individual homes in high-risk areas. We call this the "individual" scenario, even though it is also collectively managed. The measures that would be implemented by the experts would be "individual." Indeed, a programme similar to the individual scenario was being introduced by the water basin manager in the Var at the time of our survey.

The scenarios are equally efficient in avoiding damage to the property: both would prevent any damage if the flood water in the street remained less than 1 m in depth. The main difference between the two scenarios is that the individual scenario would prevent water from entering properties while the collective scenario would prevent water from flooding the streets at all (including individual properties). The same payment vehicle would be used, a compulsory local tax. Therefore, both WTP amounts should be comparable and inform the relative preference for individual or collective adaptation.

To design the WTP question, we followed the most recent guidelines in stated preference surveys (Johnston et al., 2017). The elicitation format is a dichotomous choice with bids randomly chosen among the following values: 10, 30, 50, 80, 100, and 130 euros (there is one draw per scenario). This format is recommended because it is incentive compatible. The payment vehicle considered is a compulsory local tax, as is also required for incentive compatibility and to prevent free riding. The availability bias was reduced because the scenario was close to the real policy context, in which the introduction of a local tax for flood mitigation was underway.

The stated-preference literature reports that respondents do not always state their true value for the good or service in question. It is therefore usual to check whether respondents gave a protest answer, that is, that they reject (protest against) some aspect of the proposed scenario. We asked what motivated the answer with an open question in order to avoid influencing the response by the choice of proposed answers. Following the literature, we grouped responses, such as "I don't trust the institutions," "it's not me who should pay," "I don't have enough information," "I pay too much tax," and classify them as protest responses.

3 | RESULTS

3.1 | The dataset

Table 2 lists the summary statistics of our main variables. We focused on respondents who have houses with a ground floor, which resulted in a dataset comprising 343 individuals.[3] The average age of the respondent was 60, the household comprised 2 or 3 people, the respondent owned their property and had lived on their property for 17 years on average. Seventy-four percent of the respondents had already experienced flooding,[4] although only a third live in an area with a flood risk prevention plan. On a scale from 0 ("no risk") to 5 ("very high risk"), the average respondent believed the likelihood of a one-metre flood occurring in their street in the next 10 years was small (with the mean risk perception variable at 1.36). Only 24% of respondents thought that damage would be severe if their home were flooded. Forty-three percent of the respondents considered flood management to be mainly the responsibility of the state, only 8% considered it to be mainly down to the individual. Income distribution showed the study areas to be relatively wealthy: only 27% of the respondents earned less than 1,700 euros per month, which is the median income in

France. The distribution of education levels was balanced: 45% did not have their GCE Advanced level (education Levels 1 and 2), while 55% has at least GCE A-level, and one third of the respondents (33%) also had a university degree. Finally, in the WTP treatment, the collective scenario was presented first to 46% of the respondents, and the individual scenario was presented first to the remaining 54% of the respondents.

TABLE 2 Descriptive statistics (mean and standard deviation) of the main variables

	Mean	*SD*
Age	59.40	18.28
Household size	2.34	1.14
Owner	0.80	0.40
Years since installation installation	17.11	16.53
Risk perception	1.36	1.54
Flood experience	0.74	0.44
In a flood risk prevention plan area	0.32	0.47
Damage perception	0.24	0.43
Resp. of the state authority	0.43	0.50
Resp. of individuals	0.08	0.27
Resp. of everyone	0.49	0.50
Income <1,000	0.08	0.27
Income 1,000–1,699	0.19	0.39
Income 1,700–2,499	0.15	0.36
Income 2,500–3,999	0.05	0.22
Income 4,000+	0.03	0.16
Education Level 1	0.23	0.42
Education Level 2	0.22	0.42
Education Level 3	0.22	0.41
Education Level 4	0.33	0.47
Order of scenarios	0.46	0.50

Note: N = 343.

3.2 | Households' willingness to reduce the risk of flooding

3.2.1 | Individual adaptation measures

Fifty percent of the respondents live in elevated accommodation (with a raised floor or crawl space) and are therefore better protected against flooding. However, this does not seem to have been an active choice, since respondents rarely took flood risk into account when choosing their property. The results of our survey showed that flood risk had a greater influence on property choice prior to 1960, receded in the period from 1960 to 2000, and only reappeared in 2010.

As shown in Table 3, only a few individual adaptation measures had been taken by the households surveyed. In all, 16% of the respondents had implemented individual adaptation measures to reduce their vulnerability at home, of which most common is having placed electrical fittings higher up the walls (done by 25 respondents, i.e., 7% of our sample). Table A1 shows that this was the most common adaptation measure taken by the respondent's household. In all, 11% of respondents implemented the measures themselves. Almost none of the respondents planned further actions. This is perhaps because the last major floods took place several years ago, that is, 2010 in Var and 2013 in Haute-Garonne. Indeed, the survey results revealed a peak in the implementation of new measures in the Var immediately after the 2010 flood followed by a rapid decrease to very low levels.

Two main factors explain why the respondents do not take protective measures. First, they think their accommodation is not at risk and/or that floods are rare.

TABLE 3 Individual adaptation measures

	Present		Planned		Neither present nor planned		Do not know	
	N	%	*N*	%	*N*	%	*N*	%
Storing valuables upstairs	10	0.03	0	0.00	329	0.96	4	0.01
Install flood barriers	10	0.03	1	0.00	298	0.87	34	0.10
Sewer non-return valves	10	0.03	1	0.00	289	0.84	43	0.13
Improve water flow	4	0.01	0	0.00	339	0.99	0	0.00
Install electrical fittings higher up the walls	25	0.07	0	0.00	314	0.92	4	0.01
Install pumps	7	0.02	0	0.00	336	0.98	0	0.00
Install a manhole	3	0.01	0	0.00	340	0.99	0	0.00
Others	9	0.03	2	0.00	332	0.97	0	0.00

Note: N = 343.

However, a third of respondents stated that their accommodation was in a flood-prone area (Table 4). Moreover, Table A2 shows that even among those who actually live in a flood-prone area (defined here as living in a flood risk area) reasons such as “floods are rare” or “my property is not at risk” were still the most widely cited. This suggests a discrepancy between flood-risk perception and official information about flood risks.

3.2.2 | WTP for individual and collective measures

As often reported in the relevant literature, a high proportion of respondents refuse to participate in the WTP scenario: a total of 45 and 47% of protest respondents were identified in the individual and collective scenarios, respectively. Table 5 shows the proportion of respondents who would be willing to pay the proposed amount for the individual and collective scenarios, respectively. As expected, the share decreased monotonically with an increase in the amount.

TABLE 4 Reasons for not taking adaptation measures (whole sample)

	N	%
Because it is up to the authorities to protect people from flooding	4	0.01
Because it is too expensive	5	0.01
Because floods are rare	63	0.18
Because your property is already well protected	7	0.02
Because you are a tenant and it is not your responsibility	39	0.11
Because you do not have time	2	0.01
Because you are not exposed to flood risk	134	0.39
Because you feel not adequately informed about protection measures	10	0.03
Because you are thinking of moving soon	4	0.01
Because you think it would be ineffective in the event of a flood	10	0.03
Because you think it would not help much in the event of a flood	10	0.03

As can be seen in Table 6, the mean WTP for the whole sample was 35 euros for the individual scenario and 46 euros for the collective scenario. When we removed the respondents with a protest stance from the calculation, the mean WTP increased to 95 euros for the individual scenario and to 91 euros for the collective scenario (Table 6). It will be recalled that the main difference between the two scenarios is that the individual scenario prevents water from entering the home, while the collective scenario prevents water from flooding the streets at all (including homes). The impact on the respondent's home is the same in the two scenarios, and the number of protest responses was also similar (around 45%).

Table A3 shows that the WTP increased when we focused only on respondents who live in the flood risk area, albeit not to a great extent. This increase applied only to non-protest respondents and even decreased slightly for the sample as a whole. This is because the proportion of protest respondents was higher in the flood risk area (e.g., for the individual scenario, there are 60% of protests among the respondents living in the flood risk prevention plan area but only 46% outside the area). This is a surprising result given that respondents whose homes are at greater risk have more to gain from adaptation.

3.3 | Determinants of household willingness to reduce flood risk

We estimated probit models to analyse the determinants of the implementation of individual adaptation measures and the determinants of the WTP for the individual and collective scenarios. The results are listed in Table 7. The analysis shows that the main determinants of adaptation are having already experienced a flood and the perception of risk, both of which have a positive effect on individual adaptation. Living in a flood risk area did not

TABLE 5 Proportion of respondents willing to pay the proposed amount

	Individual scenario			Collective scenario		
Amount	No	Yes	No response	No	Yes	No response
10	0.15	0.77	0.08	0.24	0.71	0.05
30	0.63	0.31	0.06	0.37	0.56	0.07
50	0.58	0.34	0.08	0.50	0.41	0.09
80	0.69	0.25	0.06	0.67	0.25	0.08
100	0.72	0.25	0.04	0.75	0.16	0.10
130	0.81	0.16	0.03	0.82	0.13	0.05

increase investment in adaptation. Being a homeowner had a slight positive effect on investment. Although not shown here, when we used the discrete specification of the risk-perception variable, only residents with a very acute perception of risk adopt further measures.

Concerning WTP, regression analysis showed that education, individual income and the perception of the potential damage all had a positive effect on the WTP for the collective scenario.[5] Perception of damage was the main positive determinant of the WTP in the individual scenario. It was clear that the respondents took the amount offered to them into account, because the proportion of positive responses decreased with an increase in the amount.[6] We also tested whether having implemented an adaptation measure in the past had an impact on our explanatory variables, but the impact was not significant (data not shown). The effect of coping

TABLE 6 Mean WTP

	Individual scenario	Collective scenario
Whole sample	34.89	45.92
Without protests	94.28	90.85
Without protests who refuse to contribute	99.93	95.09

Abbreviation: WTP, willingness to pay.

TABLE 7 Probit model

	Implementation	WTP individual scenario	WTP collective scenario
	Coefficient (*SD*)	Coefficient (*SD*)	Coefficient (*SD*)
Intercept	−4.34 (1.10)***	−0.45 (0.76)	−0.21 (0.85)
Age	0.01 (0.01)	−0.00 (0.01)	−0.00 (0.01)
Household size	0.14 (0.12)	0.12 (0.09)	−0.01 (0.10)
Education Level 2	0.08 (0.36)	0.17 (0.28)	0.73 (0.32)**
Education Level 3	−0.15 (0.39)	0.32 (0.29)	0.85 (0.32)***
Education Level 4	0.21 (0.35)	0.42 (0.28)	0.84 (0.31)***
Income 1,000–1,699	−0.13 (0.48)	0.06 (0.35)	0.29 (0.39)
Income 1,700–2,499	−0.00 (0.49)	0.33 (0.38)	0.49 (0.42)
Income 2,500–3,999	0.58 (0.59)	0.33 (0.48)	1.09 (0.51)**
Income 4,000+	−0.18 (0.78)	0.61 (0.55)	1.18 (0.61)
Income n.a.	0.11 (0.43)	−0.07 (0.33)	0.38 (0.38)
Owner	0.77 (0.44)*	0.06 (0.25)	−0.33 (0.27)
Risk perception	0.20 (0.08)**	−0.01 (0.06)	−0.06 (0.07)
Damage perception	0.12 (0.30)	0.60 (0.24)***	0.48 (0.25)*
In a flood risk prevention plan area	−0.59 (0.29)**	−0.06 (0.21)	−0.12 (0.22)
Resp. of the state authority	0.27 (0.56)	0.23 (0.38)	0.23 (0.42)
Resp. of everyone	0.44 (0.54)	0.53 (0.38)	0.37 (0.40)
Experience of flooding	1.03 (0.49)**	0.05 (0.23)	0.26 (0.25)
Years since installation	−0.01 (0.01)	−0.00 (0.01)	−0.00 (0.01)
Order scenario	−0.08 (0.23)	−0.34 (0.18)	0.27 (0.19)
Bid individual scenario		−0.01 (0.00)***	
Bid collective scenario			−0.02 (0.00)***
AIC	200.94	335.00	295.89
BIC	272.69	409.36	369.92
Log likelihood	−80.47	−146.50	−126.94
Deviance	160.94	293.00	253.89
No. observations	267	255	251

Note: ***$p < .01$, **$p < .05$, * $p < .1$.
Abbreviation: WTP, willingness to pay.

appraisal, which is often found to be an important determinant of the adoption of adaptation in the literature, was not found to be significant here and is therefore not included in our results.

Analysis of marginal effects showed that the strongest determinant for the collective scenario was the level of education, followed by income and damage perception, while the strongest determinant of the individual scenario was damage perception. The strongest determinant for the implementation of individual adaptations was previous experience of flooding, followed by not living in a flood risk prevention plan area and risk perception.[7] It is interesting to note that hazard, as measured by risk perception, was a determinant of implementing the adaptation, and vulnerability, which is measured by potential damage to the home, was a determinant of WTP.

Overall, since the WTP was positive, we can conclude that people are willing to contribute to the public good "flood prevention." They are willing to contribute even more if the prevention is designed as a collective mitigation investment than if it reduces the vulnerability of individual homes. However, as we will see in the following section, the sum of WTP is small and is not sufficient to cover the cost of structural building protection measures.

4 | COST–BENEFIT ANALYSIS

Here we compare the results of WTP with measures of cost and damage avoided by dry-proofing a home according to descriptions in the literature.

4.1 | Benefits and costs at the household level

4.1.1 | Benefits

According to our scenario, the average annual WTP for individual adaptation to prevent water from entering a property—if the water remains less than 1 m deep—is 35 euros.

With a discount rate δ of 2.5% (as in Richert, Boisgontier, & Grelot, 2019; Richert, Erdlenbruch, & Grelot, 2019), and a time horizon of 30 years, the discounted benefits in euros are:

$$\sum_{i=1}^{30} \frac{\text{WTP}^i}{1+\delta} = \sum_{i=1}^{30} \frac{35}{1+0.025}^i = 733.$$

On the other hand, we can use the WTP of non-protesters, which is 100 euros:

$$\sum_{i=1}^{30} \frac{\text{WTP}^i}{1+\delta} = \sum_{i=1}^{30} \frac{100}{1+0.025}^i = 2{,}093.$$

Other discounted benefits for different time horizons, discount rates, and WTP subsets are given in Table 8.

Our results can be compared with average values of avoided damage. Richert, Boisgontier, and Grelot (2019) and Richert, Erdlenbruch, and Grelot (2019) calculated the costs and benefits of dry-proofing based on expert assessments and numerical models of properties. One of the options they investigated was dry-proofing techniques that prevent water from entering the building if the water is less than 1 m deep, which corresponds to our WTP scenarios. They found the mean annual benefits of dry-proofing to be 1,600; 1,100; and 1,100 euros for a bungalow, two-storey house and a flat, respectively. This was the order of magnitude of the WTP estimations when protest answers were excluded. It was lower than the estimations for the whole sample.

4.1.2 | Costs

Richert, Boisgontier, and Grelot (2019) and Richert, Erdlenbruch, and Grelot (2019) found that the average

TABLE 8 Total discounted benefits depending on the time horizon, discount rate, and WTP sample

Time horizon (years)	Discount rate (unitless)	Discounted benefits (euros)	
		WTP = 35	WTP = 100
50	0.010	1,372	3,920
30	0.010	903	2,581
50	0.025	993	2,836
30	0.025	733	2,093
50	0.050	639	1,826
30	0.050	538	1,537

Abbreviation: WTP, willingness to pay.

TABLE 9 Net present value depending on the time horizon, discount rate, and WTP sample

Time horizon (years)	Discount rate (unitless)	Net present value for the study area (euros)	
		WTP = 35	WTP = 100
50	0.010	−8,676,967	97,476
30	0.010	−10,290,806	−4,513,492
50	0.025	−9,982,874	−3,633,687
30	0.025	−10,878,730	−6,193,274
50	0.050	−11,201,098	−7,114,326
30	0.050	−11,548,672	−8,107,395

Abbreviation: WTP, willingness to pay.

TABLE 10 WTP needed to reach positive NPV for costs of 13.4 million euros in an at-risk area

Time horizon (years)	Discount rate (unitless)	WTP needed (euros)
50	0.010	99
30	0.010	151
50	0.025	137
30	0.025	186
50	0.050	213
30	0.050	253

Abbreviation: NPV, net present value; WTP, willingness to pay.

cost of dry-proofing a home up to 1 m above the ground was 10,400 euros for a bungalow, 7,700 euros for a two-storey house and 9,400 euros for a flat. The international literature proposed similar average costs for dry-proofing: 6100 euros for an average house in Germany and 8,000 euros for a one-family house in the Netherlands (Richert, Boisgontier, & Grelot, 2019; Richert, Erdlenbruch, & Grelot, 2019). At the individual level, these amounts exceed the individual discounted benefits calculated above. However, to determine the efficiency, or otherwise, of the proposed policies we need a more complete cost–benefit approach at the scale of the study area.

4.2 | Balancing costs and benefits at the scale of the study area

4.2.1 | Net present value

In a more complete cost–benefit analysis, we compared the total cost of dry-proofing homes in the risk area with the total benefits estimated through WTP. To this end, we first estimated the average number of households at risk (see Table A4). Next, we calculated the total costs by multiplying individual costs of dry-proofing by the total number of households at risk for each type of home. We assumed an equal distribution of flats, bungalows, and two-story dwellings, which gives a total cost of C = 13,401,667 euros. We calculated the average benefits by multiplying the individual WTP by the total number of households, which gives a benefit of B = 120,540 euros when assuming an individual WTP of 35 euros (and 344,400 euros when assuming an individual WTP of 100 euros). With a discount rate of $\delta = 2.5\%$ and a time horizon of n = 30 years, the net present value (NPV) is:

$$NPV = -C + \sum_{i=1}^{30} \frac{WTP^i}{1+\delta} = -13,401,667 + \sum_{i=1}^{30} 120,540/(1+0.025)^i = -10,878,730.$$

Table 9 shows the results of NPVs at different time horizons, for different discount rates, and for WTP subsets. NPVs are clearly nearly always negative. Only with high WTP, low discount rates and longtime horizons does investment in complete individual dry-proofing prove to be efficient. This is the case for example for the sample of non-protesters, a discount rate of 1% and a time horizon of 50 years.

4.2.2 | Level of WTP required for dry-proofing to be efficient

We then calculated the WTP needed to make complete dry-proofing efficient. For example, for the NPV to be greater than zero when investing in the flood-proofing of a two-storey house, given a discount rate of 2.5% and a time horizon of 30 years, one would need a WTP of 186 euros (see Table 10). More generally, for an NPV greater than zero, the WTP would need to be several hundreds of euros. This exceeds the values we found in our survey.

5 | DISCUSSION AND CONCLUSION

In our study, we analysed three types of action: investment in individual adaptation measures, WTP for collectively implemented individual measures, and WTP for collective flood protection works (dikes, retention basins, improvement of existing rainwater drainage networks). The results were a low implementation rate of individual adaptation measures and low WTP for further flood prevention measures.

Yet, respondents are willing to contribute positive amounts to the public good "flood prevention." In particular, willingness to contribute was greater for the collective scenario than for the individual scenario. Hence, people are more in favour of collective mitigation measures than of individual adaptations. However, the overall levels of WTP are low, especially compared to those found by expert assessment (Richert, Boisgontier, & Grelot, 2019; Richert, Erdlenbruch, & Grelot, 2019). This is surprising since expert assessments only value tangible benefits, whereas WTP includes intangible values. One explanation could be the cap that we placed on the proposed contributions (a maximum of 130 euros). However, our mean values are close to those found by Champonnois and Chanel (2016), who valued collective mitigation measures. The analysis of the determinants of people's actions helped shed further light on the reasons for the low levels of adaptation and the low WTP.

Our analysis identified differentiated effects of risk perception, damage perception and experience on people's willingness to act. While experience and risk perception influenced the implementation of individual adaptations, damage perception explained the WTP. As shown by our study, many people perceive the risk to be low, or believe that they personally are not exposed, which limits the number of real adaptations that are made. Experience of flooding remains a major determinant of implementing individual adaptations, but investment in such measures is high for only a few years following a major flood event. Similarly, many people have low perception of the potential damage caused by a flood, and this may explain the low WTP for the individual scenario. Only more highly educated and wealthier people contribute sufficiently and then only to collective flood prevention policies. It should be noted that in our study, in contrast to the literature, the coping variable had no significant effect on the willingness to take measures. Anyway, it should not play a role in the WTP scenarios, as the respondents are not responsible for the assessment, purchase and implementation of adaptation measures.

Our study also revealed the low cost-efficiency of individual adaptation, which may be one reason for the low rate of implementation . Even when respondents showed a positive WTP for dry-proofing their house, it seemed fairly low compared to the actual cost. Indeed, given a time horizon of 30 years and a discount rate of 0.25, our highest WTP estimates (without protesters) is a third of the amount needed to cover the lowest cost estimate. This result suggests that dry-proofing might not be economically sound for residents in the areas we surveyed, which contrasts with many findings in the literature (Bubeck, Botzen, & Aerts, 2012; Bubeck, Botzen, Kreibich, & Aerts, 2012; Bubeck, Botzen, Suu, & Aerts, 2012; Kreibich et al. (2015, 2011, 2005); Owusu et al., 2015; Poussin et al. (2012, 2015); Richert, Boisgontier, & Grelot, 2019; Richert, Erdlenbruch, & Grelot, 2019; Sairam et al., 2019).[8] However, fully dry-proofing a property is only one adaptation measure among many. Some inexpensive adaptations, such as installing sandbag barriers, as described in Botzen et al. (2009a, 2009b), could be economically viable, but such low-cost measures are currently not promoted in French public policies.

One reason for the overall limited willingness to reduce flood risk could be the specificity of the French flood prevention policy: the CatNat system provides a significant safety-net by compensating people for most of any material damage resulting from a natural disaster. If this is perceived to be a sufficiently protective system, it could explain the low WTP for other public measures and the high protest behaviour in our scenarios. This may in turn be an indicator of the CatNat system possibly crowding out individual adaptation (Raschky, Schwarze, Schwindt, & Zahn, 2013), at least in periods with no flooding.

To conclude, we can derive some policy implications from our study. If French flood managers wish to continue to promote the implementation of individual adaptation measures, they should target their information, and their subsidies, towards low-cost adaptation measures, such as sandbags or adapted use of buildings, rather than the costly complete dry-proofing of buildings. On the other hand, if they believe that individual adaptation measures, including dry-proofing, should complement current flood prevention policies, they should focus on raising public awareness both of the hazard and the damage that future flooding could cause, since these are the main determinants of willingness to reduce flood risk, whether through individual investment or a contribution to the public good. Our results suggest that people who live in flood risk areas are not willing to reduce risk, even though these areas specifically target households at risk, and flood risk prevention plan policies include specific subsidy programmes and information sessions. This may indicate insufficient communication concerning risk. Another option for flood policymakers could be to make structural building measures compulsory when carrying out restoration works or to make them a condition for receiving CatNat compensation.

More generally, our study underlines the difficulty in motivating people to take private action when public disaster relief programmes are robust. This may also hold in other countries. Our results highlight the importance of the promoting cheaper and potentially more cost-efficient individual adaptation measures, such as better use of buildings in risk prone areas or using sandbags. Many countries currently lack effective programmes to promote such actions.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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ENDNOTES

[1] Alternative names found in the literature are precautionary measures (Grothmann & Reusswig, 2006; Kreibich et al., 2015), (damage) mitigation measures (Botzen, Aerts, & van den Bergh, 2009a, 2009b; Bubeck, Botzen, & Aerts, 2012) and property-level flood protection (Owusu, Wright, & Arthur, 2015).

[2] Coping appraisal is defined in protection motivation theory as whether individuals believe the recommended behaviour to be efficient ("response efficacy") and that they can individually successfully enact this behaviour ("self-efficacy"). For our purposes, coping appraisal means selecting appropriate adaptation measures and implementing them in the home.

[3] We needed to make this assumption to target places where individual adaptation is appropriate.

[4] More precisely, 71% of the respondents experienced either the 2010 flood in the Var or the 2013 flood in the Haute-Garonne, 3% of the respondents experienced other floods.

[5] We also estimated a model with the perception variables treated discretely to capture possible non-linearities, but the results were almost the same.

[6] The variable "Order of scenarios" is equal to one when the collective scenario is posed first. It has a negative impact on the WTP for the individual scenario, which means that the WTP for this scenario is weaker when it is posed second.

[7] Results available upon request.

[8] Note that 40% (80% since 2020) of the cost of adopting individual adaptation measures is subsidised in flood risk prevention plan areas. Yet, even with the subsidy, the lowest estimated net cost is 3,660 euros, which is still above many of the total discounted benefits calculated in Table 8.

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APPENDIX

A WTP scenario

The description of Scenario 1 was "Let's imagine that the government created a Flood Management Fund to finance the construction of collective flood protection works (dikes, retention basins, improvement of existing rainwater drainage networks). The works would protect you from floods up to a depth of one metre in your street. The fund would be financed by an additional local tax payable by all households in the commune."

The description of Scenario 2 was "Let's imagine that the government created a Flood Management Fund to finance expert assessments and implement protective measures in high-risk areas. These would prevent water from entering homes provided the flood water in your street was no more than one metre deep. The fund would be financed by an additional local tax payable by all households in the commune."

Descriptive statistics

TABLE A1 Who took the decision to implement the measures listed below?

	Someone else before you moved in		Your household		Do not know (or no response)	
	N	%	*N*	%	*N*	%
Storing valuables upstairs	1	0.10	9	0.90	0	0.00
Install flood barriers	0	0.00	9	0.90	1	0.10
Sewer non-return valves	5	0.50	5	0.50	0	0.00
Improve water flow	0	0.00	4	1.00	0	0.00
Install electrical fittings higher up the walls	12	0.48	12	0.48	1	0.04
Install pumps	1	0.14	6	0.86	0	0.00
Install a manhole	1	0.33	2	0.67	0	0.00
Others	1	0.11	6	0.67	2	0.22

Note: N = number of respondents with existing adaptation measures cf. Table 3.

TABLE A2 Reasons for not implementing adaptation measures (respondents living in a flood risk prevention plan area)

	N	%
Because it is up to the authorities to protect people from flooding	1	0.01
Because it is too expensive	3	0.03
Because floods are rare	23	0.22
Because your property is already well protected	5	0.05
Because you are a tenant and it is not your responsibility	6	0.06
Because you do not have time	1	0.01
Because you are not exposed to flood risk	37	0.35
Because you feel inadequately informed about protection measures	5	0.05
Because you are thinking of moving soon	1	0.01
Because you think it would be ineffective in the event of a flood	5	0.02
Because you think it would not do much good in the event of a flood	4	0.03

TABLE A3 Mean WTP, respondents living in a flood risk prevention plan area

	Individual scenario	Collective scenario
Whole sample	32.54	42.03
Without protests	113.97	98.23
Without protests who refuse to contribute	120.23	105.84

Abbreviation: WTP, willingness to pay.

Data used for the cost–benefit analysis

To implement the cost–benefit analysis at the scale of the municipalities we surveyed, we estimated the average number of households at risk. We used data from a nation-wide natural risk observatory—the "*Observatoire National des Risques Naturels*"—which provides the number of residents in flood-prone areas, referring to the so-called "EAIP" envelope area. Note that this area is slightly larger than the flood risk area to which we refer in the text. We then divided the number of residents by the average household size reported in our survey to estimate the total number of households in the area, as shown in the following table.

TABLE A4 Estimated number of households per municipality

Municipality	Number of households at risk	Total number of households	%
Bagnères-de-Luchon	925	1,049	0.88
Juzet-de-Luchon	129	165	0.78
Montauban-de-Luchon	165	215	0.77
Saint-Mamet	130	246	0.53
Les Arcs	1,532	3,093	0.50
Draguignan	7,018	17,194	0.41
Le Muy	1,341	4,009	0.33
Taradeau	227	785	0.29
Trans-en-Provence	834	2,557	0.33
Vidauban	2,324	5,133	0.45
Average	1,462	3,444	0.53