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## Article

# Introducing Nature into Cities or Preserving Existing Peri-Urban Ecosystems? Analysis of Preferences in a Rapidly Urbanizing Catchment

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**Abstract:** Nature-based solutions (NBS) are increasingly being promoted as a means to address societal and environmental challenges, especially flood risk reduction. In the context of rapidly urbanizing catchments, NBS can take part of the development of sustainable cities, either by conserving peri-urban ecosystems from urban sprawl or by developing green infrastructure in the cities. Both can provide a wide range of co-benefits (e.g., climate regulation, air quality regulation), but also generate some negative effects (e.g., mobility issues, unsafety, allergens). We develop and implement a Discrete Choice Experiment survey to analyse people's perception of co-benefits and negative effects, and associated preferences for the two types of NBS at a catchment scale. The results obtained from 400 households living in a French Mediterranean catchment highlight that people associate numerous co-benefits to NBS, but also negative effects. Our estimations reveal that resident households are ready to contribute large amounts through a tax increase for the development of NBS (from 140 to 180 EUR/year, on average). There is however a strong heterogeneity of preferences at the catchment scale influenced by income, location of the respondent along an urban–rural gradient, and perception of the importance of ecosystem services. These differences may reflect urban environmental inequalities at the catchment scale, which are important to take into account in order to avoid distributive inequalities.

**Keywords:** nature-based solution; water-related risk; co-benefits; preference heterogeneity; urban–rural gradient



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## 1. Introduction

Nature Based Solutions (NBS) are increasingly promoted as innovative solutions to address societal and environmental challenges, especially flood risk reduction [1–3]. In the European Union, the EU Floods Directive opened the way, as early as 2008, for more integrated flood management and a plurality of measures including the resort to Nature-Based-Solutions (NBS). These NBS may consist of introducing green infrastructure in cities, such as bioswales, green roofs, and vegetated open retention basins. Protecting and restoring peri-urban ecosystems, threatened by urban sprawl [4], and also contribute to reducing floods by enhancing the infiltration of rainwater. We consider here the broad definition of NBS given by the IUCN [5] that explicitly includes the “protection [ . . . ] of natural ecosystems” as a NBS. In a context of rapidly urbanizing catchments, these NBS can be part of two different approaches of sustainable urban development [6]. First, the conservation of peri-urban ecosystems by limiting urban sprawl is more in line with a “compact city” approach [7] that promotes the concentration of population in dense neighbourhoods. Second, the development of green infrastructure in the city is rather part of a “green city” model [8], which tends to make cities more liveable by introducing nature areas in the city. Our article considers these two types of NBS, placing them in the broader perspective of the sustainable urban development of a rapidly urbanising catchment.

The specificity of NBS aiming at reducing water risks, in comparison with grey solutions, is their capacity to produce a multiplicity of co-benefits [9], e.g., biodiversity conservation, climate regulation, improvement of air quality, the limitation of heat island effects, improved landscape, development of recreational activities. NBS can thus contribute to achieving several UN sustainable development goals [10]. The population benefiting from these solutions is not limited to the population exposed to the risk of flooding, but can be much wider: e.g., the population of dense urban centres, particularly concerned by heat island effects and air pollution; the population living close to preserved nature areas (landscape amenities) and practising nature activities; the global population benefiting from climate regulation. Taking this diversity of co-benefits into account is therefore fundamental to properly evaluating the opportunity for local authorities to implement NBS. An expanding literature is investigating the evaluation of co-benefits associated with NBS. In particular, stated preference methods (contingent valuation, choice experiment) have also been implemented to evaluate the value of co-benefits generated by NBS, by eliciting people's preferences [11].

However, besides co-benefits, NBS can also generate negative effects [12–14], which are much less studied in the scientific literature [15]. Some of these negative effects, called ecosystem disservices EDS (Von Döhren and Haase, 2015 for a review), are directly related to the existence of ecosystems, such as mosquitoes, allergens from the pollen, roots cracking pavement, leaves blocking stormwater drains and residents' fears of increased crime [12]. NBS can also lead to other negative effects that are not directly related to ecosystems but rather to the constraints of protecting/developing nature on territories with high demand for real estate development. For example, the conservation of peri-urban ecosystems requires limiting urban sprawl and, therefore, in a context of population growth, densifying the city. High-density neighbourhoods can, however, be perceived negatively, as they can be associated with higher cost of housing, lack of space, higher traffic congestion, noise and pollution [16]. Although poorly investigated in the literature, some authors suggest that negative effects may have more influence than ecosystem services on people's behaviour towards ecosystems [17,18]. Their evaluation is important to tailor NBS development policies: identifying and characterising these negative effects could help identifying the people most likely to suffer from them and possible strategies that can be used to mitigate the problems [19]. Lyytimäki [20] and Schaubroeck [15] call for a holistic valuation of both ecosystem services and negative effects to point out the net benefit of NBS, and to enable a more balanced assessment of nature's contributions to human well-being. To our knowledge, however, little research has been conducted with this holistic approach, with the exception of a few examples of socio-cultural assessment [18], institutional analysis [21], hedonic pricing [22] or cost-based monetary evaluation [23]. Therefore, our research brings a novel contribution, by developing a choice experiment that explicitly considers the perception of co-benefits and negative effects associated with NBS in the analysis of people's preferences, and by combining socio-cultural and monetary valuation approaches.

Lastly, citizens may have contrasting perceptions of the co-benefits and negative effects of NBS, resulting in heterogeneous preferences for NBS implementation. Some studies have provided insights on the heterogeneity of resident's preferences for green infrastructure in cities, by analysing the influence of socio-demographic and attitudinal characteristics of respondents (Section 2). Spatial heterogeneity (i.e., the influence that the spatial context has on preferences for environmental goods or services: e.g., distance to green areas, population density) in preferences for environmental amenities has also been confirmed in empirical studies [24]. Kronenberg [21] and Lyytimäki [20] strongly encourage analysing the heterogeneity of perception of negative effects by different social groups determined by factors such as gender, age, income, cultural background, or knowledge level. Therefore, an important part of our analysis is dedicated to the evaluation of the heterogeneity of preferences for NBS at the catchment scale.

Based on these findings, we implement a choice experiment that evaluates the preferences of the population for two types of NBS, primarily aiming at reducing flood risk in a French Mediterranean catchment: (1) the conservation of peri-urban ecosystems from urban sprawl and (2) the development of green infrastructure in the city. Our analysis addresses three main research questions (RQ):

- What are the main co-benefits and negative effects associated with these two types of NBS by the population (RQ1)?
- Are preferences heterogeneous within the population (RQ2)?
- What are the factors explaining this heterogeneity (RQ3)?

In Section 2, the paper presents a state of the art on the preference heterogeneity for NBS. Section 3 describes the implementation of the choice experiment in the case study and our modelling approach. Section 4 describes the results, followed by a discussion (Section 5) and concluding remarks (Section 6).

## 2. Heterogeneity of Preferences for NBS: State of the Art

Choice experiment studies on NBS have provided insights into the heterogeneity of resident's preferences for green infrastructure in cities, and the influence of individual socio-demographic, attitudinal and spatial location characteristics. Several studies show that age, income, education and having a child in the household influence preferences. For instance, Giergiczny and Kronenberg [25] find that residents with higher income, higher education, who are younger or do not own a car have a higher willingness to pay (WTP) for the development of street trees. Other studies have focused more on attitudinal characteristics. Collins et al. [26] reveals for instance that WTP for green façade is influenced by knowledge on biodiversity and aesthetic opinion. An expanding literature also addresses spatial issues in stated preference welfare measures [27]. Several authors investigated the spatial heterogeneity of preferences for forest management [28–31], conversion of forest plantations into higher value nature [32], water quality improvement [33–37], and benefits associated to agri-environmental schemes [38,39]. In this paper, we argue that socio-demographic, attitudinal and spatial characteristics can influence the types of (perceived or actual) ES and negative effects associated to NBS, and ultimately individuals' preferences for NBS, in line with the conceptual framework proposed by Venkataramanan et al. [40] to analyse green infrastructure for flood management.

On the one hand, preferences are expected to be heterogeneous due to contrasting perceptions of co-benefits. For instance, the demand for some co-benefits may vary along a urban–rural gradient [41,42], with a higher demand from the urban population for temperature regulation and air quality, or a higher demand for nature areas for those living in apartments. Tu et al. [31] determine that people with private gardens, more likely to live outside city centres, are willing to pay a smaller price premium for housing near urban parks.

On the other hand, although little investigated in the literature, differences in the perception of negative NBS effects are highlighted in particular by Escobedo et al. [43] for urban forests. He shows that the negative effects of urban forests (source of allergens, leaf litter, and obstructed views) differ between individuals with different lifestyles, cultures, ages, education. For instance, young and fit people are not as prone to environmental diseases and sicknesses as are the elderly or newborns. In addition, we expect that indirect negative effects of NBS, such as a reduction in car space in the city, will also be perceived differently according to the position along the urban–rural gradient because of the greater dependence on cars of the population living in low-density areas. Densifying the city, to conserve peri-urban ecosystems, one of the NBS we evaluate in this paper, may also be perceived very differently among the population. Several studies show that residents acceptability for more compact forms of housing remains relatively limited, with a strong preference for single family detached house on a large lot [44–46]. Talen (2001) suggests that two-parent families with children present the greatest preference for low-density, suburban living. The principal justification advanced for this preference include: an association with

a certain social status, the perception of safety, privacy, the access to space and greenery and the ease of automobile use [47]. On the other hand, compact neighbourhoods may be favoured by childless young-adults, lower-income groups, and families with children that have left home [46,48,49].

Based on these findings, we formulate three hypotheses in our analysis of the factors influencing preferences heterogeneity (RQ3): preferences for NBS vary along an urban–rural gradient (H1), according to socio-demographic (H2) and attitudinal (H3) characteristics.

### 3. Materials and Methods

#### 3.1. Study Design and Survey

##### 3.1.1. The Lez Catchment

The Lez catchment (64,000 ha, total population of 466,000 inhabitants), located in the south of France along the Mediterranean Sea and covers 43 municipalities, including the city of Montpellier. The catchment is as a typical Mediterranean catchment with the prevalence of generally dry climate with violent storms generating flash floods in autumn [50,51]. Although investments have been carried out in order to prevent overflow of the Lez and its tributaries, urban runoff flood risk remain a challenge. In 2014 only, three successive major flood events led to 65 million euros of damages for insured private housing and businesses, 78% of which was due to urban runoff (CCR). The estimated present value of damages for insured private housing and businesses is estimated to be 124 million euros for the Lez catchment in current climate [52]. The strong attractiveness of the city of Montpellier (282,000 inhabitants, 4th largest commune in France in terms of population gain over the 2012–2017 period) has led to a rapid urbanization of the catchment resulting in the loss of 3000 ha of natural and agricultural areas over the period 1990–2012. The catchment is composed of very contrasting types of urban areas, from the dense urban centre of Montpellier (14,000 inh/km<sup>2</sup>) to low-density residential areas of municipalities furthest from the centre (less than 50 inh/km<sup>2</sup>), according to an urban–rural gradient. Large investments have been carried out to manage overflow risk but runoff risk, accentuated by the recent urbanization, remains a major challenge. Urban areas are also facing several other challenges typical of large Mediterranean cities. Air pollution mainly due to the commuting of an increasing number of urban workers living in individual housing outside the main city centre remains a large issue. Heat island effect is also a growing challenge with the increase of temperature peaks due to climate change, with a historical record of more than 45 °C in 2019. The preservation of local agricultural production is also a very strong issue in the basin [53], as is the preservation of landscape and biodiversity. Outdoor recreational activities are a major asset for the attractiveness of this area and the well-being of its inhabitants.

##### 3.1.2. NBS Selection

In order to address these challenges and identify potential NBS aiming at reducing flood risk, we organised a participatory process with two stakeholders workshops gathering state, regional, water basin and city authorities, residents association and private and public developers. The first workshop (six stakeholders in June 2018) aimed to (i) build plausible future scenarios describing the evolution of the catchment by 2040 (population growth, urban development, resulting flood risk level), (ii) identify the main types of NBS that could be used to manage flood risk in the future, and (iii) discuss their main benefits, negative effects, potential barriers and implementation areas. The second workshop (11 stakeholders in February 2019) made it possible to finalize the description of the types of NBS studied and their implementation by 2040 at the catchment scale, as well as to present the choice experiment method. Finally, we selected two types of NBS aiming at reducing flood risk, by favouring the retention and infiltration of rainwater: (1) the conservation of peri-urban ecosystems from urban sprawl and (2) the development of green infrastructure in the city. We anticipate that, in addition to reducing flood risk, these solutions will generate a

variety of co-benefits, by addressing several major challenges of the Lez catchment, but also potentially negative effects.

### 3.1.3. The Survey

We carry out a choice experiment (CE) for assessing the preferences of the population of the Lez catchment for different flood management strategies combining different levels of these two types of NBS. For this, we constructed a four-part questionnaire that first addresses respondents' perception of co-benefits and negative effects associated to NBS before eliciting their preferences for NBS strategies.

Part I presents the Lez catchment and the flood risk at present; it is followed by a series of questions aiming at assessing the importance respondents give to eight ecosystem services on the Lez catchment: flood risk reduction, air quality improvement, local temperature regulation, climate change mitigation, landscape conservation, recreation activities, local agriculture and food production and biodiversity conservation.

Part II presents the projected population growth by 2040, natural and agricultural areas that will be made impervious if the process of urban sprawl observed in the past continues, and future flood risk (Appendix A). The diversity of benefits associated with NBS is described in a short video, in terms of ecosystem services (ES). Each NBS is then described individually with text and visual aids in the form of photographs and diagrams (Appendix A). Respondents were invited to express both significant benefits (among the eight ES) and negative effects (from a list of options) they associate with each NBS, and to choose whether or not they are in favour of their implementation. The negative effects listed were selected based on the pre-test survey to cover at least the diversity of ESD highlighted by Lyytimäki [13] and Von Döhren and Haase [14]: aesthetic, safety, health, economic, mobility, and psychology issues. This part specifically addresses RQ1.

Part III is the Choice experiment component of the survey described in Sections 3.1.4 and 3.1.5 (Appendix A). Respondents chose between hypothetical flood management strategies. The responses obtained in this part provide data to study the heterogeneity of preferences (RQ2).

Part IV deals with socio-demographic characteristics of the respondents (e.g., gender, age, employment, education, size of the household, income). This part, in addition to part I, allows us to collect the data needed to investigate the factors influencing heterogeneity (RQ3).

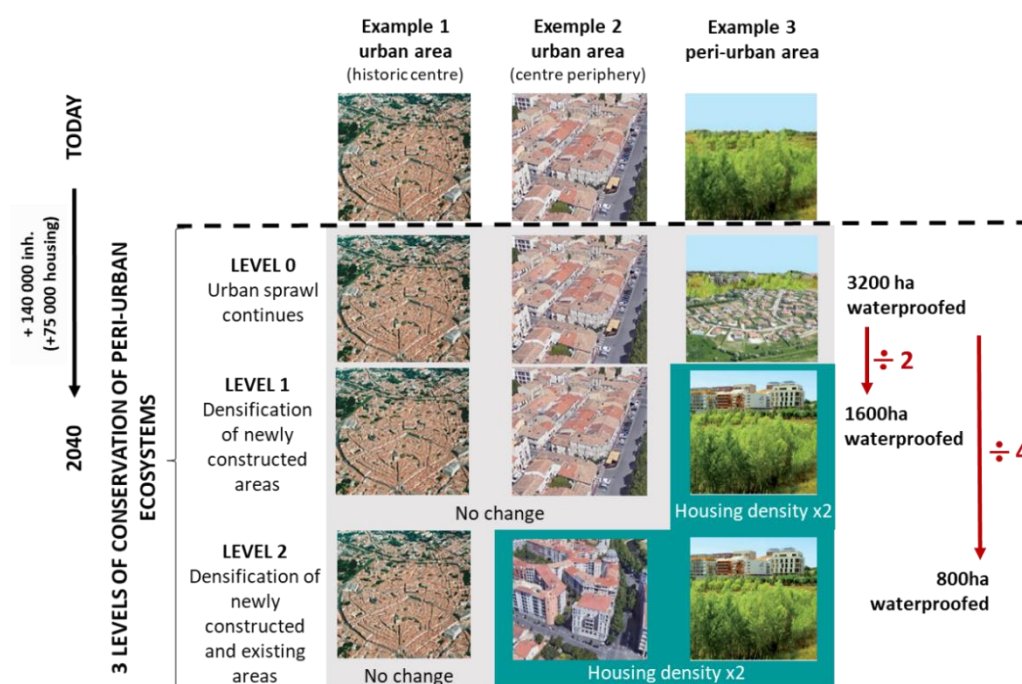
We first pre-tested the questionnaire during 29 face-to-face interviews with inhabitants of the Lez catchment recruited randomly in two outside market places and a shopping mall. This pre-test helped to improve the questionnaire to ensure that it is easily understood and not too long, while providing a sufficient level of information. We then administered the questionnaire on-line by distributing it by email to residents of the Lez catchment recruited via a polling company specialized in the implementation of market study. The company manages a sample of registered respondents that can be invited to participate on-line in surveys through an ad-hoc portal. The participation to a survey is incentivized with "points" that can be used to have discounts on certain products. The survey was completed online during two weeks in September 2019.

### 3.1.4. The Choice Experiment Attributes

We carried out a choice experiment (CE) for assessing the preferences of the population of the Lez catchment for different flood management strategies combining different levels of these two types of NBS. The CE methodology was based on discrete choice models, the objective of which is to analyse the factors that influence the choices of individuals (in our case the choice of flood risk management strategies based on NBS). The factors can be both the characteristics of the proposed strategies ("attributes") and the respondents' individual characteristics.

Flood management strategies differ according to three attributes validated during the two workshops with local stakeholders.

The first attribute corresponds to the level of conservation of peri-urban ecosystems resulting from the limitation of urban sprawl. We define three levels of implementation (Figure 1). In Level 0, we consider that urban sprawl observed in the past will continue, leading to the additional loss of 3200 ha of peri-urban ecosystems by 2040. In Level 1, we consider that urban sprawl will be limited with the densification (housing density x2) of newly constructed areas, allowing protecting 1600 ha from urbanisation. In Level 2, we consider that urban sprawl will be strongly limited, with the densification (housing density x2) of newly constructed areas and some existing urban areas (urban regeneration), allowing to protect 800 ha from urbanisation.

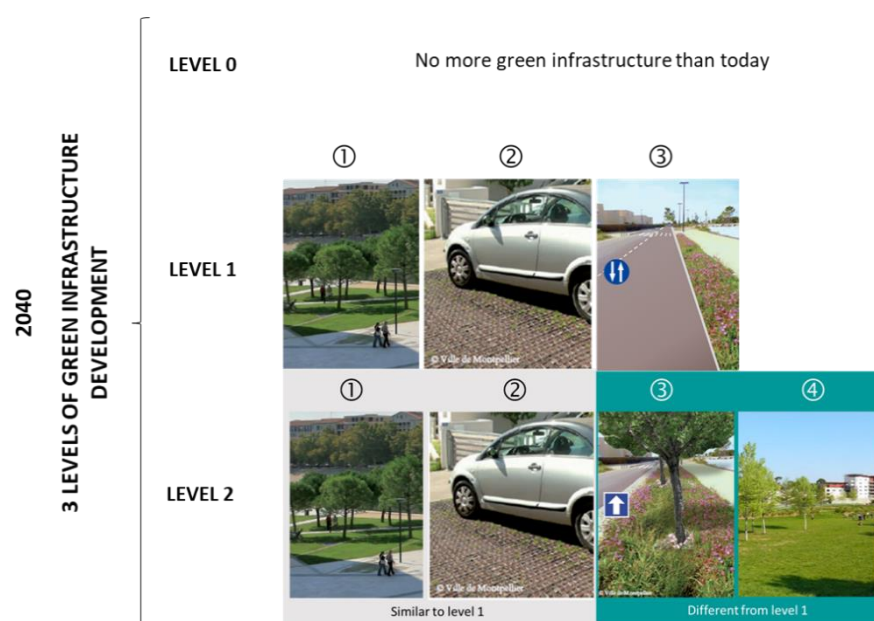


**Figure 1.** Description of the effects of three levels of conservation of peri-urban ecosystems on housing density and peri-urban ecosystems conservation for three typical areas of the catchment.

The second attribute describes different levels of development of green infrastructure in existing and new urban areas. Four NBS are combined in this attribute: (i) deproofing and greening of available public space, (ii) replacement of waterproof parking areas with permeable pavements, (iii) creation of bioswales along the streets, and (iv) transformation of 25% of parking areas in vegetated multifunctional retention basins (Figure 2). We define three levels of implementation. In Level 0, we consider that no more green infrastructure will be implemented by 2040 than the ones existing at present. Level 1 consists of implementing the first three solutions, with narrow 50-cm-wide bioswales that do not change the direction of street traffic. Level 2 consists in implementing the four solutions, with 2-m-wide bioswales, involving a shift to one-way traffic on some streets.

These two attributes therefore correspond to levels of implementation of the two NBS types. Implementing Level 2 of the two attributes potentially involves greater constraints than Level 1, i.e., densification of existing urban areas for the first attribute, changing traffic directions and reducing the number of parking spaces for the second attribute.

The third attribute is the monetary contribution that respondents are willing to pay for financing the flood management strategy, through a 10-year yearly increase in local taxes. It is either 20, 40, 60, 80, 100 or 120 EUR/household/year. These amounts were adjusted after a pre-test survey with 29 respondents (face-to-face interviews with residents of the Lez catchment in August 2019).



**Figure 2.** Description of the three levels of green infrastructure development.

### 3.1.5. Experimental Design

Respondents were asked to compare two hypothetical flood management strategies (strategy A and strategy B) that make it possible to achieve the same level of flood risk management and choose their preferred one. Strategy A and strategy B differ in terms of NBS implementation levels (from Level 0 to Level 2) and monetary contribution: we present grey solutions (e.g., rainwater network, dikes) as the adjustment variable to achieve the same level of flood risk control. An opt-out option of “neither of the two strategies” is also proposed, which is explicitly defined as not allowing to control the level of flood risk. Consequently, the preferences expressed for Level 1 and Level 2 will be analysed relatively to Level 0 (i.e., for the same level of flood risk control), and not to the opt-out option. We offer this possibility in order to make sure that the preference for the attributes is not driven by the flood reduction benefit but only by the associated ES and negative effects. This is key in this study, to avoid the double counting of flood mitigation benefit that is evaluated through another methodology [52]. The implication of this difference between the opt-out and the alternatives is discussed in Section 3.2.2. An example of choice set is presented in Figure 3.

A full factorial design with two alternatives would require  $(3 \times 3 \times 6) \times (3 \times 3 \times 6 - 1) = 2862$  possible choice situations. We therefore used a fractional factorial design (D-efficient) elaborated with the NGENE software, based on prior knowledge on peoples’ preferences collected during the pre-test survey. We generated a two-block design with six choice sets each (Appendix B). Each respondent was randomly assigned to one of the blocks, and therefore was confronted with six choice sets.

Conservation of peri-urban ecosystems	<b>Strategy A</b> <b>LEVEL 2</b> 2,400 ha of preserved peri-urban ecosystems 		<b>Strategy B</b> <b>LEVEL 1</b> 1,600 ha of preserved peri-urban ecosystems 		None of the 2 strategies
	<b>LEVEL 1</b> 		<b>LEVEL 2</b> 		
	Green infrastructure		Green infrastructure		
Contribution to local taxes	60€/household/year		60 €/household/year		

Tick your preferred option ☐ ☐ ☐

Figure 3. Example of a choice set.

### 3.2. Modelling Approach

#### 3.2.1. Model Specification

The econometric modelling is based on the random utility theory. We assume that individual preferences for a strategy is guided by the relative level of utility the individual can gain by choosing one strategy (identified by its  $k$  attributes). Each individual  $n$  make  $T$  successive choices during the survey. The random utility theory assumes that the utility  $U_{int}$  of the strategy  $i$  to an individual  $n$  facing choice situation  $C_t (t = 1, \dots, T)$ , is composed of a deterministic and observable part  $V_{int}$ , and an unobservable random part  $\varepsilon_{int}$ :

$$U_{int} = V_{int} + \varepsilon_{int} = \sum_{k=1}^K \beta_{nk} x_{itk} + \sum_{a=1}^A \alpha_a z_{an} + \varepsilon_{in}$$

where  $x_{intk}$  is the value of attribute  $k$  for strategy  $i$  facing an individual  $n$  during choice situation  $C_t$ ;  $\beta_{nk}$  represents individual  $n$  specific utility weight for this attribute;  $z_{an}$  are the individual-specific characteristics;  $\alpha_a$  are their weights in the utility function.

According to the Conditional Logit (CL) model as developed by [54], the probability that an individual  $n$  chooses strategy  $i$  in choice situation  $C_t (t = 1, \dots, T)$  corresponds to the probability that this strategy  $i$  is the one that gives him the greatest utility ( $P_{int} = P[V_{int} + \varepsilon_{int} > V_{jnt} + \varepsilon_{jnt}, \forall j \in C_t, j \neq i]$ ,  $P_{int} = P[\varepsilon_{jnt} < V_{int} - V_{jnt} + \varepsilon_{int}, \forall j \in C_t, j \neq i]$ ). With the assumption that the unobservable error terms are independently and identically distributed (IID) among the alternatives and across the population and follow a Gumbel distribution, then the probability that respondent  $n$  chooses strategy  $i$  in choice situation  $C_t$  is:

$$P_{int} = \frac{\exp(\beta X_{it})}{\sum_{j \in C_t} \exp(\beta X_{jt})}$$

where  $\beta$  is the vector of  $k$  preference parameters, representing the average “weight” of each attribute. This model requires two strong assumptions: the Independence of Irrelevant Alternatives (IIA), and the homogeneity of preferences among respondents [55]. This model assumes the equality of the utility functions across the respondents: the vector  $\beta$  is the same for all individuals. As the analysis of the heterogeneity of preferences within the population is of particular interest in our study, we directly use two alternative models: the mixed logit model and the latent class model. These models introduce individual preference variation, and do not require the IIA property.

The mixed logit (MXL) model (or random parameters logit model) addresses random heterogeneity by assuming, for each individual's preferences, a continuous distribution of the coefficients  $\beta_k$  specific to each individual and randomly distributed across the population, with a density function  $f(\beta)$  [56]. We consider an MXL model with independent random coefficients for all the attributes except the monetary attribute. The probability that respondent  $n$  make the sequence of  $T$  choices is:

$$P_{nT} = \int \left( \prod_{t=1}^T \frac{\exp(\beta_n X_{it})}{\sum_{j \in C} \exp(\beta_n X_{jt})} \right) f(\beta) d\beta$$

We specify  $(\beta)$  to be normal:  $\sim(b, s)$ . The parameters  $b$  and  $s$  are, respectively, the mean and the variance of these distributions and are to be estimated by simulation. In our estimations, we use 500 Halton draws to carry out this simulation.

The latent class model (LCL) [57] addresses parameter heterogeneity across individuals with a discrete distribution, which is a function of individual characteristics. The population is partitioned into  $S$  latent classes within which preferences are homogeneous (members of the same class  $s \in S$  have a vector of  $\beta_s$  parameters) and errors are IIA, but between which preferences are heterogeneous. Each respondent can be probabilistically assigned to any class, given personal characteristics, and the final result is a set of preference parameters for each class. The probability that respondent  $n$  makes the sequence of  $T$  choices becomes:

$$P_{nT} = \sum_{s=1}^S M_{n,s} \left( \prod_{t=1}^T \frac{\exp(\beta_s X_{it})}{\sum_{j \in C} \exp(\beta_s X_{jt})} \right)$$

with  $M_{n,s}$  the Probability of  $n$  belonging to class  $s$ .

We analyse preferences heterogeneity by introducing individual characteristics of respondents as covariates in the LCL [32,39].

### 3.2.2. Data Coding and Statistical Analysis

As recommended by Haaijer et al. [58] for CE with an opt-out option, we use effect coding for the two first attributes. Each attribute is coded with an additional level set to 0 for the opt-out option. For three-level attributes, the first, second and third levels are then represented by the vectors  $[-1, -1]$ ,  $[1, 0]$ ,  $[0, 1]$ ; and  $[0, 0]$  for the opt-out option. An additional dummy variable BAU is added in the model. It takes value 0 for the two strategies and value 1 for the opt-out alternative. This dummy variable can be interpreted as the respondent's difference in utility when choosing the opt-out option rather than enrolling in any flood mitigation strategy. In the estimation, if the coefficient for the opt-out is negative, it captures a preference for the implementation of any flood mitigation strategies (NBS or not). The coding is presented in Table 1. Statistical analysis was performed using STATA version 14.2.

**Table 1.** Attributes, levels used and their coding.

Attribute	Levels	Coding
Conservation	Level 0	$[-1, -1]$
	Level 1	$[1, 0]$
	Level 2	$[0, 1]$
	Opt-out	$[0, 0]$
Green infrastructure	Level 0	$[-1, -1]$
	Level 1	$[1, 0]$
	Level 2	$[0, 1]$
	Opt-out	$[0, 0]$
BAU	Strategy A or B	0
	Opt-out	1

## 4. Results

### 4.1. Sample Description

We obtained 436 answers from people living in the Lez catchment. From this initial sample, we exclude those who spent less than five minutes to complete the questionnaire (24 respondents), considering that they might have filled the questionnaire without the required care needed, and those who are identified as protest answers (12 respondents) thanks to a standard series of questions [59] added at the end of the CE. Overall, the representativeness of the 400 remaining respondents is quite good regarding age, household size and employment rate (Table 2), despite the under-representation of students, which can be explained by the fact that the survey targeted household representatives, over-representation of women and of high education levels. These socio-demographic variables will be used to test H2 (preferences for NBS vary according to socio-demographic characteristics).

Each respondent indicated his or her municipality and street in the questionnaire. This information then enables us, using the French national ADDRESS database (IGN), to locate each respondent at the centroid of his or her street, and to measure the Euclidian distance to the city centre of Montpellier (DISTANCE). This location is then used to link each respondent to the infra-municipal IRIS unit where he lives, and thus to characterize at a finer scale than that of the municipality, the type of respondent's living neighbourhood. The respondents are located in 126 of the 163 IRIS units of the basin. Figure 4 shows that these IRIS units are diversified in terms of housing density, proportion of houses, and percentage of inhabitants having a car. The representation of this data according to the distance of the centroid of each IRIS unit from the Montpellier city centre confirms the spatial organization of the urban areas of the catchment according to an urban–rural gradient, from the highest housing densities in the city centre to the lowest densities in municipalities further away. Figure 4 also shows a good representativeness of the different types of IRIS units in the survey answers, as well as an average distance to the city centre representative of the basin's population. The DISTANCE variable will be used to test the hypothesis H1 (preferences for NBS vary along an urban–rural gradient).

In terms of attitudinal variables, respondents have different perceptions of the three most important challenges at the catchment scale (based on a list of eight ES). Climate change mitigation is selected by 67% of the respondents, followed by flood risk reduction (58%) and biodiversity conservation (45%). The diversity of the selected bundles of ES shows different concerns among the respondents (Table 2). The realization of a hierarchical ascending classification from the selected ES allows us to group the respondents into five categories with similar ES bundles. The AIR category (N = 120) is characterised by a very high importance given to air quality, TEMP (N = 59) by a predominance of the issue of temperature regulation in cities, BIODIV (N = 78) by concerns oriented towards the conservation of biodiversity and climate change mitigation, LANDSCAPE (N = 96) by the importance given to landscape preservation, and RECREATION (N = 47) by the selection of maintaining recreational activities as one of the three main issues. These classification-derived variables will be used to test the H3 hypothesis (preferences for NBS vary according to attitudinal characteristics).

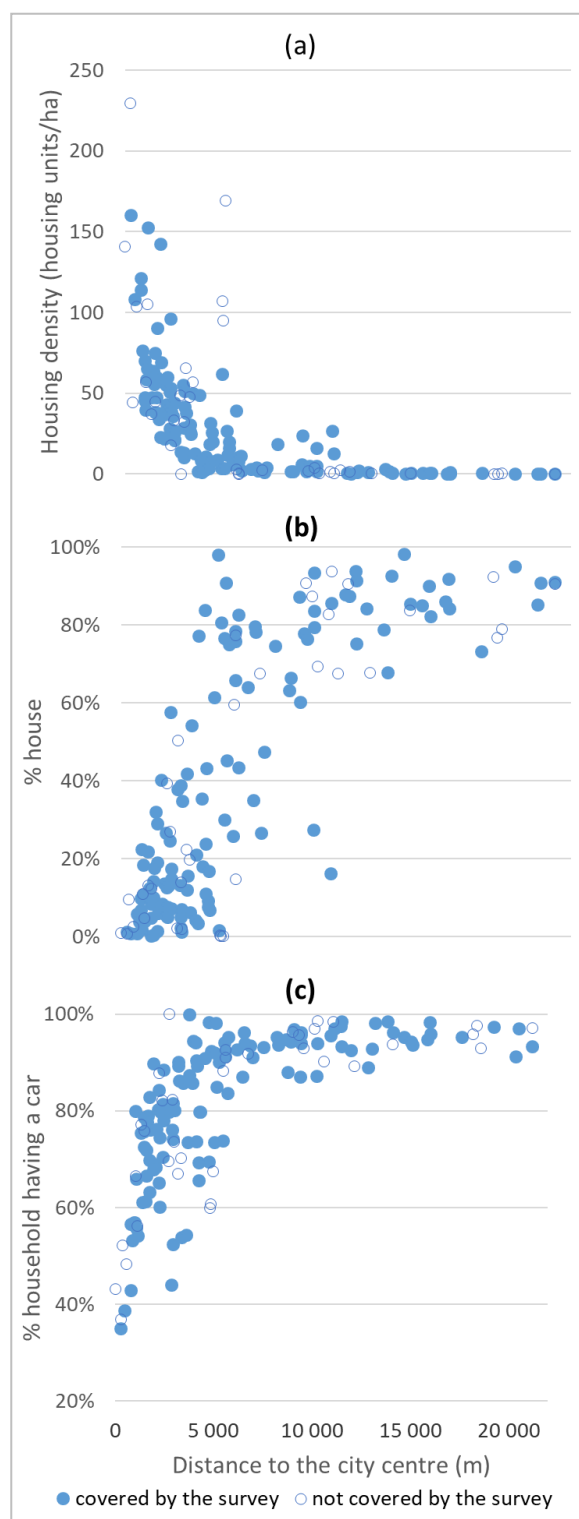
Table 2 also shows that the vast majority of respondents (85.3%) consider that the level of information provided by the questionnaire is sufficient or largely sufficient to make their choice of strategies. This percentage validates our choices during the pre-test survey in terms of the amount of information provided in the questionnaire, which must be sufficient to make the strategies understandable to individuals with different backgrounds, interests, experiences, and knowledge levels, without being too complex to avoid respondent fatigue from the provision of unnecessary details [59]. However, 14.7% of respondents consider the level of information to be insufficient: this may reflect an initially low level of knowledge of respondents about NBS and flood risk at basin level, but also a need for more detail on the attributes in order to make their choice of strategies in the questionnaire. For the robustness check, we have evaluated the impact on average preferences of withdrawing from the

sample respondents who consider the level of information to be insufficient (Appendix A). This impact being extremely limited, we have kept these respondents in the sample.

**Table 2.** Descriptive statistics of the sample.

	Sample Average	Lez Catchment <sup>1</sup>
Sample size (households)	400	225,250
<b>Socio-demographic data</b>		
Age, mean (SD) [AGE]	47.3 (15.7)	
<25 (%)	5.8	17.8
25–39 (%)	29.8	26.5
40–54 (%)	29.0	22.2
55–64 (%)	16.8	13.2
65–79 (%)	18.5	14.1
>80 (%)	0.3	6.1
Gender (% of female)	66.5	52.4
Household size	2.26	2.07
Dependent children in the household (% with)	27.3	-
Education level (%)		
Primary	1.5	22.1
Lower secondary	16.5	16.0
Upper secondary	17.0	18.1
Tertiary	65.2	43.8
Unemployed (%)	7.0	10.4
Student (%)	2.5	12.0
Retired (%)	22	23.4
Mean household income/family quotient (kEUR/month) (SD) [INCOME]	1.47 (0.78)	-
<b>Residence location data</b>		
Mean distance to city centre (km) (SD) [DISTANCE]	5.09 (4.39)	5.18 <sup>3</sup>
Living in a house (%)	40.8	32.5 <sup>4</sup>
Commuting with car (%; N = 246)	56.9	-
<b>Attitudinal data</b>		
Importance associated to ecosystem services <sup>2</sup> (%)		
Climate change mitigation	67.0	-
Flood risk reduction	57.8	-
Biodiversity conservation	42.5	-
Landscape conservation	38.0	-
Air quality improvement	28.0	-
Local agriculture and food production	25.8	-
Local urban temperature regulation	19.0	-
Recreation activities	15.3	-
Other	1.8	-
<b>Perception of the level of information provided by the questionnaire (%)</b>		
Totally inadequate	0.7	-
Inadequate	14.0	-
Adequate	67.5	-
Totally adequate	17.8	-

<sup>1</sup> Data from the Lez catchment are an aggregation of 2016 INSEE data by IRIS unit, except for employment data (by municipality). <sup>2</sup> % respondents considering the ecosystem services (ES) as one of the 3 most important ES at the Lez catchment scale, from a list of choices. <sup>3</sup> Average distance of IRIS units located in the catchment to city centre weighted by their population. <sup>4</sup> Number of houses in primary residences/total number of primary residences in the IRIS units located in the catchment.



**Figure 4.** Average housing density (a), percentage of houses (b) and percentage of household having a car (c) per IRIS unit as a function of the distance its centroid to city centre. (In French, IRIS is an acronym of “aggregated units for statistical information”. The IRIS unit is the fundamental unit for dissemination of infra-municipal statistical data).

#### 4.2. NBS Perception: Benefits and Negative Effects

The questionnaire provides elements of respondents’ perception of the benefits of ES and negative effects of NBS (RQ1). Table 3 displays the percentage of respondents

who consider that NBS present significant ES and/or negative effects, by NBS type and implementation level as well as the average number of ES and negative effects they associate with each NBS. Most residents perceive that green infrastructure presents significant benefits and few consider that they present negative effects, although more residents perceive negative effects for the most ambitious level of introduction of green infrastructure. The conservation of peri-urban ecosystems is also largely perceived to generate ES but to a lesser extent and to provide negative effects by more respondents especially for the Level 2. We introduce here a net co-benefits indicator (number of ES excluding flood risk reduction—number of negative effects) that captures both positive and negative effects of each NBS type and level, and is a proxy of the net benefit to human well-being, as recommended by Schaubroeck [15]. This indicator shows that, on average, the most ambitious level of conservation of peri-urban ecosystems may face the highest opposition.

**Table 3.** Respondents' perceptions of different types and levels of nature based solutions (NBS).

		Conservation		GI	
		Level 1	Level 2	Level 1	Level 2
The NBS bring significant benefits <sup>1</sup>		86.3	76.8	94.0	92.3
Average number of significant ES		3.8	3.1	4.1	3.9
Average number of significant co-benefits <sup>2</sup>		3.2	2.6	3.4	3.2
ES perceived as significant <sup>1</sup>					
Regulating	Flood risk reduction	63.3	53.0	69.8	68.5
	Air quality improvement	53.3	44.0	58.3	57.0
	Local temperature regulation	46.0	36.8	53.0	54.0
	Climate change mitigation	55.5	44.8	53.3	52.8
Cultural	Landscape conservation	54.5	45.0	66.3	62.3
	Recreation activities	30.3	27.3	34.5	34.0
Provisioning	Local agriculture and food	27.8	25.0	20.5	19.0
Support	Biodiversity conservation	46.8	37.3	52.8	45.5
The NBS bring significant negative effects <sup>1</sup>		31.8	47.0	18.8	32.8
Average number of negative effects		0.9	1.7	0.4	0.7
Negative effects perceived as significant <sup>1</sup>					
Aesthetic	Landscape deterioration	12.5	22.5	n.a.	n.a.
	Poorly maintained green spaces	n.a.	n.a.	10.3	14.8
Safety	Unsafety	7.0	15.3	3.8	4.3
Health	Mosquitoes, allergens, . . .	7.3	11.0	6.0	6.5
Economic	High implementation cost	9.3	18.6	6.0	10.3
	Increase in house prices	10.5	18.0	n.a.	n.a.
Mobility	Traffic and car park problems	14.3	21.8	4.5	18.0
Psychology	Limited space, individualism . . .	18.3	31.8	n.a.	n.a.
Socio-cultural	Loss of cultural heritage	4.3	16.0	n.a.	n.a.
	Barrier to village development	3.3	7.0	n.a.	n.a.
Effectiveness	Little effect on flooding	6.0	9.8	2.0	1.8
Sustainability	Low resistance to drought and urban pollution	n.a.	n.a.	7.8	10.3
Average net co-benefits indicator <sup>3</sup>		2.2	0.9	3.0	2.6
In favour of NBS implementation (0 = Not at all favourable, 3 = strongly favourable)		2.2	1.9	2.5	2.4

<sup>1</sup> Percentage of respondents (N = 400). <sup>2</sup> ES excluding flood risk reduction. <sup>3</sup> Number of ES excluding flood risk reduction—number of negative effects. n.a.: not assessed (negative effect not proposed for this type of NBS).

The main ES identified by respondents for each NBS type and level are detailed in Table 3. Flood risk reduction is always quoted as the main ES associated with the proposed NBS, but other ES account for an average of 83% of the ES cited, with regulating services being by far the most frequently cited. The number of co-benefits (ES excluding flood risk reduction) is rather similar between NBS types and levels, with between 2.6 and 3.4 co-benefits quoted on average.

The number of negative effects cited is on average much lower than the number of ES: from 0.4 to 1.7 (Table 3). To improve readability, we group disadvantages into nine categories by adapting the ecosystem disservices typology proposed by Lyytimäki et al. [13] and Von Döhren and Haase [14]: aesthetic, safety, health, economic, mobility, psychological, socio-cultural, effectiveness (Table 3). Psychology, mobility and aesthetic issues are the three most cited disadvantages for the conservation of natural and agricultural areas. Aesthetic, sustainability, mobility, and economic issues are the most quoted for green infrastructure, with mobility issues being by far the most frequently quoted disadvantage for Level 2.

#### 4.3. Average Preferences

The results of the MXL model reveal that the coefficients of the different attributes of NBS strategies are positive and statistically significant. On average, respondents prefer the Level 2 of implementation of the two NBS types (Conserv\_L2 and GI\_L2) over the Level 1 (Conserv\_L1 and GI\_L1), and the Level 1 over the Level 0. The negative sign of the Payment coefficient is as expected. The coefficients are very similar between the two types of NBS, and do not show a difference in utility between the conservation of peri-urban ecosystems and the development of green infrastructure. These results are surprising compared to the previous analysis of benefits and negative effects (5.2), which shows a relative preference for green infrastructure and stronger opposition to the implementation of Level 2. The analysis also reveals a negative preference for the opt-out option (BAU), i.e., a strong preference for implementing flood mitigation strategies.

The MXL results also show that the coefficients for the SD are almost all significant, except for the Level 1 of green infrastructure (Table 4), highlighting that there is a significant preference heterogeneity for the attributes in our sample (RQ2). These levels have a large magnitude and suggest potential strong difference of preferences among respondents, especially for the most ambitious level of NBS implementation.

**Table 4.** Mixed logit (MXL) model estimation of choice experiment data.

	MXL
Mean	
Conserv_L1	0.542 ***
Conserv_L2	1.141 ***
GI_L1	0.553 ***
GI_L2	1.149 ***
BAU	−2.198 ***
Payment	−0.016 ***
SD	
Conserv_L1	−0.158
Conserv_L2	−0.727 ***
GI_L1	−0.495 ***
GI_L2	−0.780 ***
BAU	2.443 ***
Log likelihood	−2038.8967
LR chi <sup>2</sup>	
Pseudo R <sup>2</sup>	
AIC	4099.793
BIC	4175.494

The sign of SD is irrelevant, must be interpreted as positive. \*\*\*: significance at 1%.

#### 4.4. Preference Heterogeneity

We explore this heterogeneity of preferences through the LCL model. The optimal number of classes is identified by testing different models with an increasing number of classes from 2 to 7 (Table 5). The Bayesian Information Criterion (BIC) would rather lead us towards the 3-class model. The log likelihood, instead, suggests the 5-class model. The Akaike information criteria (AIC) presents improvement as the number of classes increased.

Finally, we choose the 5-class model, which provides the greatest improvement in AIC and log likelihood. The mean highest posterior probability of the model is 0.83, which suggests that most of the underlying taste heterogeneity patterns are captured.

**Table 5.** Criteria for selecting the optimal number of classes.

Number of Classes	2	3	4	5	6	7
Log likelihood	−2086.885	−2044.416	−2016.126	−1971.098	−1979.826	−1969.311
AIC	4199.769	4128.831	4086.252	4042.195	4041.652	4034.623
BIC	4289.233	4266.468	4272.062	4386.162	4323.808	4364.951
Correct predictions	0.93	0.89	0.85	0.83	0.81	0.80

AIC: Akaike Information Criterion. BIC: Bayesian Information Criterion.

From the set of individual characteristics of the respondents presented in Table 2, we select four variables to be included in the latent class model as covariates: DISTANCE to test H1 (preferences for NBS vary along an urban–rural gradient), AGE and INCOME to test H2 (preferences for NBS vary according to socio-demographic characteristics), and RECREATION to test H3 (preferences for NBS vary according to attitudinal characteristics). For each group of variables, we select those that have the highest significant influence on class membership from a 5-class LCL model without covariates.

The results of the 5-class LCL model with covariates confirm the existence of preference heterogeneity in the sample (RQ2), with five classes of respondents with contrasting coefficients (Table 6). The coefficients of the payment attribute are significant and negative for classes 2 to 5 (77% of the respondents), with a higher marginal utility of income for class 4. On the contrary, the choices of the respondents of the first class, the “Whatever price” class (23% of the respondents), are only affected by NBS attributes of the strategy and the payment attribute is insignificant. The coefficient for the BAU variable is significant and negative for classes 1, 3 and 4, indicating a preference for flood mitigation strategies, but positive for class 2. The coefficients for NBS attributes are mostly positive and significant, indicating a preference for NBS in comparison to grey solutions. This is, however, not the case for classes 2 and 4, for which conservation and green infrastructure attributes, respectively, do not significantly affect the choice. We subsequently refer to class 2 as “Green infrastructure only” (12% of the respondents) and to class 4 as “Conservation only” (13% of the respondents).

The NBS attribute coefficients show contrasting preferences for the two types of NBS in classes 1 to 4: respondents in classes 1 and 4 (36% of respondents) have a strong preference for conservation, while respondents in classes 2 and 3 (34% of respondents) express a clear preference for the introduction of nature in the city. Class 5 respondents (30% of respondents) have less pronounced differences in the coefficients between the two types of NBS. Classes 2, 3 and 4 differ from classes 1 and 5 in that they have low or even negative utility in moving from Level 1 to Level 2 of the two NBS attributes (the coefficients associated with Level 2 are of the same order of magnitude or even lower than those of Level 1). The members of class 2 to 4 (47% of the respondents) do not place additional value on the most ambitious NBS. On the contrary, classes 1 and 5 (53% of the respondents) clearly express a preference for the most ambitious levels of NBS implementation, with significantly higher coefficients for Level 2 NBS attributes.

Table 6. Latent class (LCL) model results.

	Class 1	Class 2	Class 3	Class 4	Class 5
	“Whatever price”	“GI only”	“Pro-Level 1”	“Conservation only”	“Pro-Level 2”
Class Share	0.23	0.12	0.22	0.13	0.30
<b>Utility function</b>					
Payment	−0.006 (0.005)	−0.019 *** (0.006)	−0.010 *** (0.003)	−0.038 *** (0.006)	−0.013 *** (0.003)
Conserv_L1	0.699 *** (0.191)	−0.186 (0.272)	0.583 *** (0.131)	0.734 *** (0.204)	0.494 *** (0.117)
Conserv_L2	2.330 *** (0.594)	0.444 (0.299)	0.484 *** (0.160)	0.624 *** (0.135)	1.178 *** (0.137)
GI_L1	0.372 ** (0.168)	0.933 *** (0.278)	0.974 *** (0.180)	−0.099 (0.213)	0.414 *** (0.118)
GI_L2	1.414 *** (0.447)	0.767 ** (0.335)	1.162 *** (0.178)	0.135 (0.240)	1.322 *** (0.164)
BAU	−3.841 *** (0.678)	0.883 ** (0.407)	−3.244 *** (0.455)	−3.227 *** (0.489)	−0.365 (0.242)
<b>Class membership model</b>					
AGE	0.009 (0.013)	0.001 (0.017)	−0.020 (0.016)	0.017 (0.016)	REF
INCOME	−0.195 (0.242)	−0.980 *** (0.368)	−0.642 ** (0.295)	−0.835 ** (0.351)	REF
DISTANCE	0.124 ** (0.049)	0.166 *** (0.054)	−0.088 * (0.052)	0.120 ** (0.056)	REF
RECREATION	−0.146 (0.810)	1.265 * (0.788)	0.677 (0.793)	1.199 * (0.696)	REF
Constant	−1.027 (0.821)	0.562 (0.853)	1.127 * (0.686)	−1.012 (0.813)	REF
Number of observations	7182				
Number of respondents	399				

Standard errors are in parentheses. \*, \*\* and \*\*\*: significance at 10%, 5% and 1%.

#### 4.5. Factors Influencing Preference Heterogeneity

The LCL model shows significant influence of DISTANCE, INCOME and RECREATION on class membership probabilities (Table 6) which confirms respectively H1, H2 and H3 (RQ3). Post-estimation of covariates (Table 7) helps to further analyse differences across classes.

There is a significant influence of distance from the city centre (DISTANCE) on class membership (Table 6). Figure 5 illustrates this influence of the location along an urban–rural gradient on class membership, and highlights in particular an opposite influence of distance from the city centre on the probability of belonging to classes 2 and 5. Respondents in classes 2, 3 and 4 differ from those in classes 1 and 5 in their lower average income quotient (INCOME). Here we find again the distinction between respondents in favour of NBS Level 1 only (classes 2 to 4), and those in favour of the most ambitious levels of implementation (classes 1 and 5). Although the coefficient for AGE does not appear significant in the LCL model, respondents in class 3 are younger than average. Respondents in classes 2 and 4 differ from others in the higher importance placed on recreational services (RECREATION).

Table 7. Post-estimation of the LCL covariates.

	Class 1	Class 2	Class 3	Class 4	Class 5
	“Whatever the Price”	“GI Only”	“Pro-Level 1”	“Conservation Only”	“Pro-Level 2”
Number of respondents	91	46	89	53	120
AGE: Mean age	51 (16)	45 (15)	41 (16)	50 (14)	49 (15)
INCOME: Mean household income/family quotient (kEUR/month)	1.6 (0.8)	1.2 (0.6)	1.2 (0.7)	1.3 (0.7)	1.8 (0.9)
DISTANCE: Mean distance to city centre (km)	5.8 (4.7)	6.8 (5.4)	4.8 (4.0)	5.7 (4.9)	3.9 (3.2)
RECREATION: proportion of people considering recreational activities as one of the three most important issues at the catchment scale	0.05	0.22	0.13	0.23	0.07

Standard errors are in parentheses.

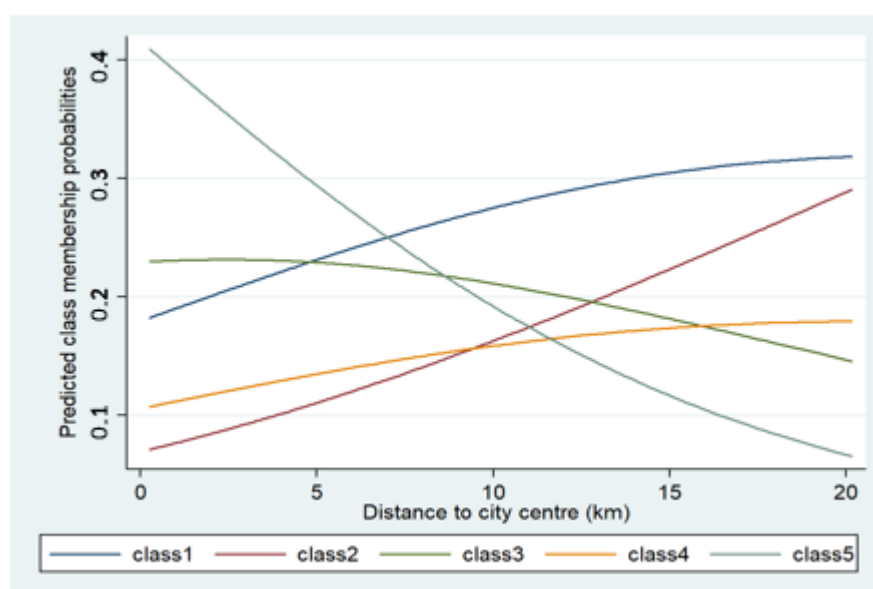


Figure 5. Post-estimation of class membership probabilities along an urban–rural gradient.

The analysis of perceptions of ES and negative effects of NBS by class (Table 8) provides additional insight into preferences. Table 8 reveals, for instance, that respondents of classes 2 and 5 have very different perceptions of the ES and negative effects associated with NBS. Class 5 respondents (“Pro-Level 2”) distinguish themselves clearly from the others by their proximity to the city centre. They associate a high number of ES with NBS, and perceive the benefits associated with air quality and temperature regulation more than the others. Class 2 respondents (12%) are located much farther from the city centre. They perceive fewer ES and more negative effects than the others, and therefore have the lowest net benefit indicators (except for GI Level 1, which they favour). They are the ones who perceive the mobility issues associated with NBS the most. They are also the only ones who express a preference for not implementing flood mitigation strategies. Additionally, the aggregate indicator of net co-benefit reflects some differences in preferences between classes quite well: respondents in class 1 (“Whatever price”) that express the highest preferences for NBS, associate the highest number of co-benefits with NBS and by far the lowest number of disadvantages: their net benefit indicator is on average the highest (Table 8). There are however some exceptions: class 4 has lower utility associated with NBS than other classes despite high net co-benefit indicators, for instance.

Table 8. NBS perception, by class.

	Class 1	Class 2	Class 3	Class 4	Class 5
	“Whatever the Price”	“GI Only”	“Pro-Level 1”	“Conserv Only”	“Pro-Level 2”
<b>Conservation Level 1</b>					
Average number of significant co-benefits <sup>2</sup>	3.6 (2.0)	2.1 (2.2) ***	2.8 (2.2) **	3.4 (2.1)	3.5 (2.1) REF
ES perceived as significant <sup>1</sup>					
Flood risk reduction	74.7	45.7 ***	50.6 ***	64.2	70.8 REF
Air quality	56.0	37.0 **	50.6	56.6	58.3 REF
Temperature	56.0	28.3 **	43.8	39.6	50.0 REF
Climate change	65.9	43.5 **	43.8 **	58.5	60.0 REF
Landscape	58.2	37.0 ***	48.3 **	58.5	61.7 REF
Agriculture	38.5	8.7 ***	19.1 **	28.3	32.5 REF
Average number of negative effects	0.6 (1.4) *	1.6 (1.9) **	1.1 (1.6)	0.8 (1.5)	0.9 (1.5) REF
Negative effects perceived as significant <sup>1</sup>					
Aesthetic	5.5 *	26.1 **	12.4	13.2	12.5 REF
Safety	1.1	15.2 **	11.2 *	7.5	5.0 REF
Mobility	5.5 **	30.4 **	15.7	9.4	15.8 REF
Effectiveness	3.3	13.0 **	10.1 *	3.8	3.3 REF
Average net co-benefits indicator <sup>3</sup>	3.0 (2.5)	0.5 (3.4) ***	1.7 (3.1) **	2.6 (3.0)	2.6 (2.8) REF
<b>Conservation Level 2</b>					
Average number of significant co-benefits <sup>2</sup>	3.1 (2.2)	1.5 (1.9) ***	2.3 (2.2)	2.9 (2.1)	2.7 (2.3) REF
ES perceived as significant <sup>1</sup>					
Air quality	47.3	23.9 ***	41.6	49.1	49.2 REF
Climate change	52.7	28.3 **	38.2	50.9	47.5 REF
Agriculture	35.2	8.7 **	21.3	24.5	25.8 REF
Biodiversity	41.8	21.7 **	34.8	45.3	38.3 REF
Average number of negative effects	1.2 (1.9) ***	2.5 (2.4)	1.6 (2.0) *	1.4 (1.9) **	2.1 (2.5) REF
Negative effects perceived as significant <sup>1</sup>					
Aesthetic	14.3 **	34.8	19.1	22.6	26.7 REF
Health	5.5 **	17.4	7.9	13.2	14.2 REF
Economic	36.3	47.8	25.8 **	26.4 *	47.5 REF
Mobility	9.9 ***	37.0	18.0 **	17.0 *	30.0 REF
Psychology	16.5 ***	47.8	34.8	30.2	35.8 REF
Average net co-benefits indicator <sup>3</sup>	1.9 (3.1) ***	−1.0 (3.5) ***	0.8 (3.1)	1.5 (3.0) *	0.6 (3.7) REF
<b>Green infrastructure Level 1</b>					
Average number of significant co-benefits <sup>2</sup>	3.5 (1.9)	3.4 (2.2)	3.2 (1.9)	3.3 (2.0)	3.5 (2.1) REF
Average number of negative effects	0.4 (1.0)	0.2 (0.7)	0.5 (1.0)	0.5 (1.1)	0.4 (0.9) REF
Average net co-benefits indicator <sup>3</sup>	3.0 (1.9)	3.2 (2.4)	2.8 (2.3)	2.8 (2.2)	3.1 (2.3) REF
<b>Green infrastructure Level 2</b>					
Average number of significant co-benefits <sup>2</sup>	3.5 (1.9)	2.9 (2.0) *	3.1 (1.9)	3.0 (2.2)	3.5 (2.1) REF
ES perceived as significant <sup>1</sup>					
Flood risk reduction	75.8	58.7 **	61.8 **	62.3 *	75.0 REF
Temperature	51.6 *	47.8 *	49.4 **	47.2 **	63.3 REF
Agriculture	26.4	6.5 **	15.7	13.2	23.3 REF
Average number of negative effects	0.4 (0.9) ***	0.9 (1.1)	0.7 (1.1)	0.7 (1.2)	0.8 (1.1) REF
Negative effects perceived as significant <sup>1</sup>					
Aesthetic	7.7 ***	13.0	14.6	17.0	20.0 REF
Mobility	9.9 **	37.0 **	18.0	11.3	20.0 REF
Average net co-benefits indicator <sup>3</sup>	3.1 (2.0)	2.0 (2.3) *	2.4 (2.1)	2.2 (2.6)	2.7 (2.4) REF

SD are in parentheses. \*:  $p < 0.1$ ; \*\*:  $p < 0.05$ ; \*\*\*  $p < 0.001$ : mlogit with class5 as reference (each variable being tested individually); only the significant ES and negative effects with  $p < 0.05$  are kept in this table. <sup>1</sup> Percentage of respondents, by class. <sup>2</sup> ES excluding flood risk reduction. <sup>3</sup> Number of ES excluding flood risk reduction—number of negative effects.

#### 4.6. Heterogeneity in WTP for NBS Strategies

The coefficients obtained for each of the classes are used to estimate the Willingness to Pay (WTP) of households for the two levels of implementation (compared to Level 0), for each type of NBS (Table 9). This WTP is an estimation of the value residents place on the net co-benefits associated with NBS, integrating both ES and negatives effects. We estimate the average marginal WTP in preference space for level  $\theta$  of the two attributes (as compared to level 0) with  $-\frac{\beta_{k\theta}-\beta_{k0}}{\beta_p}$  where  $\beta_{k\theta}$  is the coefficient of level  $\theta$  of attribute  $k$ ,  $\beta_{k0}$  the coefficient for level 0 of attribute  $k$ , and  $\beta_p$  is the coefficient for the Payment attribute. In the latent class model, we use the same approach with the coefficients of the five classes.

**Table 9.** Heterogeneity in willingness to pay (WTP) (EUR/household/year) for NBS strategies in the sample.

		MXL <sup>3</sup>	Class 1 <sup>2</sup>	Class 2	LCL <sup>4</sup> Class 3	Class 4	Class 5
Share		1.00	0.23	0.12	0.22	0.13	0.30
EUR/household/year							
Conservation of peri-urban ecosystems	L1 <sup>1</sup>	140.9	na	-	161.3	54.8	170.6
	L2 <sup>1</sup>	178.8	na	-	151.6	52.0	224.5
	L2–L1	+37.9	na	-	−9.7	−2.8	+53.9
Development of GI	L1 <sup>1</sup>	142.7	na	136.8	304.0	-	169.3
	L2 <sup>1</sup>	180.4	na	128.2	322.4	-	240.9
	L2–L1	+37.7	na	−8.6	+18.4	-	+71.6
EUR/ha/household/year							
Conservation of peri-urban ecosystems	L1 <sup>1</sup>	0.088	na	-	0.101	0.034	0.107
	L2 <sup>1</sup>	0.075	na	-	0.063	0.022	0.094
	L2–L1	0.047	na	-	−0.012	−0.004	0.067

<sup>1</sup> In comparison with level 0. <sup>2</sup> WTPs cannot be assessed for class 1, since the coefficient associated with payment is insignificant. <sup>3</sup> the average WTP can be estimated from the coefficients in Table 4. For example for conservation level 1, compared to level 0:  $-(0.5424 + 1.1410)/(-0.0158) = 140.9$ . <sup>4</sup> the average WTP for each class can be estimated from the coefficients in Table 6. For example for conservation level 1, compared to level 0 (class 5):  $-(0.4942 + 1.1781)/(-0.0127) = 170.6$ .

Based on the coefficients obtained with the MXL model (Table 4), we estimate that respondents are willing to pay on average EUR 140.9 and EUR 142.7/household/year if the Level 1 is implemented instead of Level 0, and EUR 178.8 and EUR 180.4 if the Level 2 is implemented instead of Level 0 respectively for conservation of peri-urban ecosystems and the development green infrastructure. These figures represent the mean overall value residents give to the net co-benefits (the level of flood risk control is constant across the different strategies—the estimated value therefore does not include the benefit associated with the reduction in the flood risk, but only ES and negative effects) generated by these different NBS.

The WTPs obtained with the coefficients of the LCL model (Table 6) is another illustration of the heterogeneity of preferences between classes (RQ2), in terms of the order of magnitude of the amounts: from EUR 52/household/year for class 4 to EUR 240/household/year for class 5, but also in terms of marginal utility for the transition from Level 1 to Level 2. The marginal WTPs for a change of level are low or negative for the first three classes. Marginal WTPs are positive for class 5, although the marginal utility per hectare preserved decreases for the most ambitious level (Table 9). Therefore, LCL model results reveal several findings uncovered by the MXL model: the differences in the magnitude of overall WTP across households and the differences in the preferences for different NBS types and levels. The LCL model also allowed for different marginal utilities of income for separate classes.

## 5. Discussion

### 5.1. Perceptions, Preferences and Value Pluralism

This paper provides an innovative contribution to the NBS valuation studies by combining a socio-cultural valuation approach (perception of co-benefits and negative effects) with a stated preference approach (preferences for NBS). Our analysis suggests that residents associate a large diversity of co-benefits with NBS: namely, in order of importance, landscape conservation, air quality improvement, climate change mitigation, local temperature regulation and biodiversity conservation. In order to ensure sustained political support in NBS development, it is essential that NBS aiming at reducing water risks implemented in the city indeed produce these co-benefits. For example, bioswales should be planted with trees and not only covered with grass in order to maximize the effective production of these co-benefits. Our study also identifies negative effects that NBS programs should intend to minimize, such as the potential impact on mobility (especially car transportation) of green infrastructure and the landscape deterioration and the psychologic difficulties associated with ambitious densification of urban habitat. The analysis of differences in perception between individuals is an interesting perspective for socio-cultural evaluations, complementing the economic evaluation of preferences, as it provides additional insight into preferences. The analysis of the differences in perceived ES and negative effects makes it possible to identify some levers for implementing NBS (e.g., air quality and temperature regulation for class 5) or, on the contrary, possible sources of opposition (e.g., mobility issues for class 2). In line with a value pluralism perspective [60], we therefore recommend analysing NBS aiming at reducing flood risk by taking into account co-benefits and negative effects, and by combining monetary valuation approaches with socio-cultural valuation approaches [61], for instance through a specific socio-cultural section in stated preference surveys (contingent valuation, choice experiment).

Although the perception of co-benefits and negative effects is an important driver of preferences, other aspects—not addressed in our research—also influence preferences, such as knowledge and behavioural anomalies. As Venkataramanan et al. (2020) point out, knowledge—that includes “both awareness (familiarity), as well as knowledge, defined as information leading to understanding, or for taking informed action”—has also the potential to shape preferences. Our results highlight potential differences in knowledge levels among respondents (Section 4.1) and reflects some potential knowledge gaps. Although the impact of this assessment of the level of information seems limited on average preferences (Appendix A, robustness check), future approaches would gain from being completed by a specific analysis of the “knowledge” box, as it may also help to understand perception and preferences. This may be achieved by using experimental approaches, with random sub-samples being exposed to different levels of information on the impact of flood protection strategies, and assessing the impact on residents’ preferences as in Hoehn et al. [62]. Another key factor influencing choices is behavioural anomalies. Some respondents’ choices may not be consistent, with economic rationality leading them to not reveal their true preferences in choice experiments [59]. These issues often arise when individuals apply simplified decision rules to reduce the cognitive burden presented by a survey. Kahneman [63] highlights the existence of two modes of thinking and deciding, the intuitive system (system 1) and the reasoning system (system 2). While respondents following the reasoning system may have stable preferences that could be used in economic valuation, intuitive thinking may be strongly susceptible to framing effects and to variations of contexts and elicitation procedure [64]. Our research is prone to behavioural anomalies as other choice experiments. Respondents may have been influenced by intuitive thinking to respond to our questionnaire rather than their perception of the welfare impact of the attribute levels of the choice alternatives. We nevertheless argue that our method may have limited the impact of these anomalies. First, the sequence of questions in the survey, which makes first respondents weigh co-benefits and negative effects associated with each attribute and then choose alternatives composed of these attribute levels in the CE question, may lead respondents to follow a system 1 thinking and limit the behavioural

biases that may be linked to system 2 thinking. Second, the cognitive burden of the choice tasks remains limited as respondents had only to choose between two alternatives and an opt-out option.

### *5.2. Net Co-Benefits and Efficiency Criteria*

Our estimations also reveal that resident households are ready to contribute large amounts, through a tax increase, for the development of NBS (from EUR 140 to 180/year, on average). These amounts are largely higher than the tax collected since 2018 to fund flood prevention investment in the Montpellier Urban community at EUR 6.6/person/year. By comparison, benefits associated to flood damage reduction by developing green infrastructure in the Lez catchment at the most ambitious level have been evaluated at EUR 29 million [52]. Total discounted costs for their implementation are estimated at EUR 148 million (excluding the opportunity cost associated with land value) [65]. As a first approximation, considering that 225,250 households live in the catchment area, the total discounted value of the average net co-benefits (MXL model) associated with these NBS is estimated at EUR 355 million. Our results reveal that the net co-benefits generated by these solutions could be a sufficient justification to trigger investment programs by local authorities in ambitious green infrastructure and peri-urban ecosystems preservation. If the decision on NBS strategies is to be based on efficiency criteria, we therefore recommend considering not only the costs of implementation and the benefits related to flood risk control, but also the net co-benefits reflecting a diversity of co-benefits and negative effects.

### *5.3. Preferences Heterogeneity and Environmental Inequalities*

Results highlight the heterogeneity of preferences for NBS at the catchment scale and validate our initial hypotheses that preferences for NBS vary along an urban–rural gradient (H1), according to socio-demographic (H2) and attitudinal (H3) characteristics. In particular, we bring an innovative insight to NBS valuation through the analysis of the preferences heterogeneity along an urban–rural gradient. In the context of the development of NBS in rapidly urbanizing catchments, we therefore recommend analysing the preferences of the population at the catchment scale (and not only at the city scale) and studying possible differences along an urban–rural gradient, as they may reflect potential urban environmental inequalities [21,66]. For example, the distance to the city can be a source of inequality because people who live further away from the city centre spend more time and money commuting by car and have no transportation alternatives. Ambitious NBS policies reducing the place of the car in the city, if they are not compensated by an alternative mobility offer (e.g., cycle paths, public transport) are likely to generate more negative effects on the mobility of the inhabitants of peri-urban areas. Respondents of class 2 who live further away from the city centre expressed this negative effect well. A second type of inequality lies in inhabitants of dense urban centres, which are more concerned by air pollution and high temperatures during heat waves. These inhabitants can express a stronger demand for solutions addressing these issues. Again, the analysis of heterogeneity highlights this finding with respondents from class 5 who distinguish themselves from the others by their proximity to the city centre and perceive more than the other the benefits associated with air quality and temperature regulation. These different preferences for NBS among individuals are important to consider when designing NBS strategies and accompanying policies that may include mechanisms to compensate potential distributive inequalities at a catchment scale. In line with Aragão et al. [67], we therefore anticipate exciting research perspectives, combining environmental justice and integrated NBS assessment.

## **6. Conclusions**

We present the results of a choice experiment implemented with 400 people in a rapidly urbanizing French Mediterranean catchment. This choice experiment investigates the population's preferences for two types of NBS aiming at reducing flood risk that

illustrate two different approaches of sustainable cities: (1) the conservation of peri-urban ecosystems from urban sprawl and (2) the development of green infrastructure in the city. Our analysis highlights that people associate numerous co-benefits to NBS, but also negative effects. On average, respondents associate a positive additional value on NBS (compared to grey solutions) for the same level of flood risk management. Our results also show a strong heterogeneity of preferences at the catchment scale. Several factors influence this heterogeneity, including income, location of the respondent along an urban–rural gradient, and perception of the importance of ecosystem services.

From an operational perspective, these results can inform sustainable urban development and flood risk management strategies at the city and the catchment scale, and enhance the implementation of the regional biodiversity conservation strategy whose first challenge is to achieve no net land take by 2040. Indeed, the large value placed by citizens in NBS net co-benefits suggests that programs aiming toward the development of NBS for water-related risks would receive large residents' support. The 2020 results of municipal elections in Montpellier and more generally in large cities of France, that favoured candidates with ambitious city greening programs, are an illustration of this political buy-in. These results also highlight the heterogeneity of preferences and the factors that explain them, such as the location of the respondent along an urban–rural gradient. It is fundamental to identify those groups of individuals that can either benefit from or be harmed by an NBS [9], to anticipate possible oppositions and conflicts. Understanding the reasons for these oppositions (e.g., negative effects borne by a category of the population, lack of information on potential benefits) may help to design mechanisms to tackle the issues raised.

Perspectives for the implementation of this methodological framework are numerous, as solutions studied in this case may be relevant to most urbanized catchments of the Mediterranean region, which are largely exposed to rapid urbanization and dry climate, with violent storms generating flash floods [50]. More globally, the proposed approach can be transposed for the analysis of all types of NBS, including ones that are not primarily aimed at managing floods, such as NBS for erosion control or protection of water resources.

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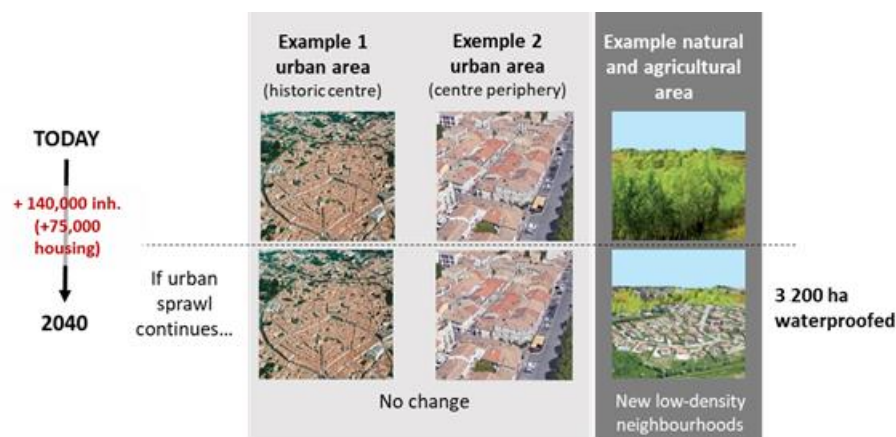
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## Appendix A. Extract from the Questionnaire (Translation of Parts II and III)

### Part II—Nature-Based Solutions to Reduce the Risk of Flooding

By 2040, it is estimated that the basin will be welcoming almost **140,000 new inhabitants**, which will generate an additional need for about 75,000 housing units. Until now, new housing has mainly been built in low-density neighbourhoods to the detriment of natural and agricultural areas. If this process of urban sprawl were to continue, it is estimated that by 2040 almost **10% of agricultural and natural areas would be waterproofed by urbanisation (3200 ha, equivalent to 200 football fields per year)**. Soil waterproofing impedes the infiltration of water, thereby **increasing runoff and the risk of flooding**.



In order to **reduce this risk of flooding** in the future, **local authorities** are defining strategies combining several types of solutions: **traditional “grey” solutions** (dikes, piping network for rainwater...), and **“nature-based solutions”** favouring natural infiltration and retention of rainwater in the soil, as well as a **variety of benefits**, as illustrated in this video.



(Q) Was the video displayed correctly?

☐ Yes ☐ No

In this questionnaire, we would like to collect your preferences for two types of nature-based solutions:

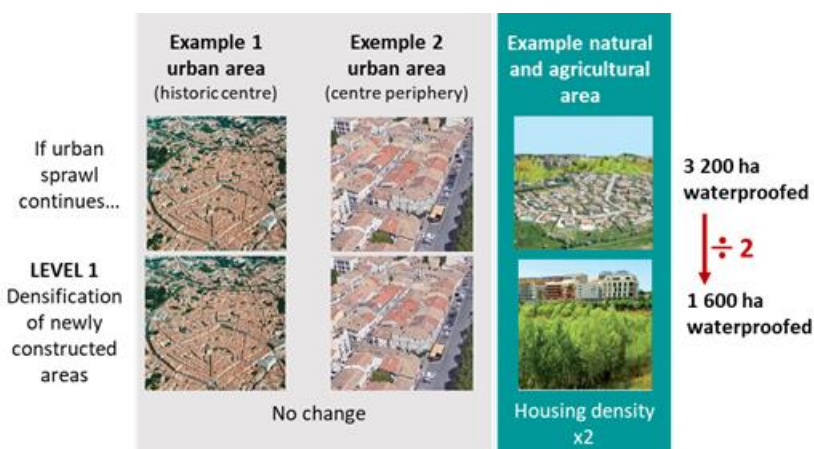
- the conservation of peri-urban ecosystems from urban sprawl
- the development of green infrastructure in the city

#### SOLUTION 1: the conservation of peri-urban ecosystems from urban sprawl

Two levels of ambition are proposed for the preservation of natural and agricultural areas.

**Level 1** consists of **doubling the housing density of all new neighbourhoods** under construction, for example by favouring mixed housing (small apartment blocks and individual houses on small plots) rather than individual villas on large plots. This solution

makes it possible to **divide by two the surface area that will be waterproofed by 2040** and **thus preserve 1600 ha of natural and agricultural areas**.



**(Q) Do you think that achieving the benefits presented in the video with this solution by 2040 is realistic?**

- ☐ Totally realistic
- ☐ Rather realistic
- ☐ Not very realistic
- ☐ Not at all realistic

*If not "Totally realistic": (Q) Can you explain why?*

**(Q) In your opinion, does this solution bring significant benefits for society?**

- ☐ Yes
- ☐ No

*If "Yes": (Q) What are the most important benefits for you? (Unlimited number of responses)*

- ☐ Flood risk reduction
- ☐ Climate change mitigation by storing carbon in vegetation
- ☐ Reducing the temperature in the city during heat waves
- ☐ Air quality improvement
- ☐ Conservation of landscape and living environment
- ☐ Biodiversity conservation
- ☐ Local agriculture and food conservation
- ☐ Preservation of nature activity areas (biking, walking...)
- ☐ Other (please specify):

**(Q) In your opinion, does this solution bring significant negative effects?**

- ☐ Yes
- ☐ No

*If "Yes": (Q) What are the most important negative effects for you? (Unlimited number of responses)*

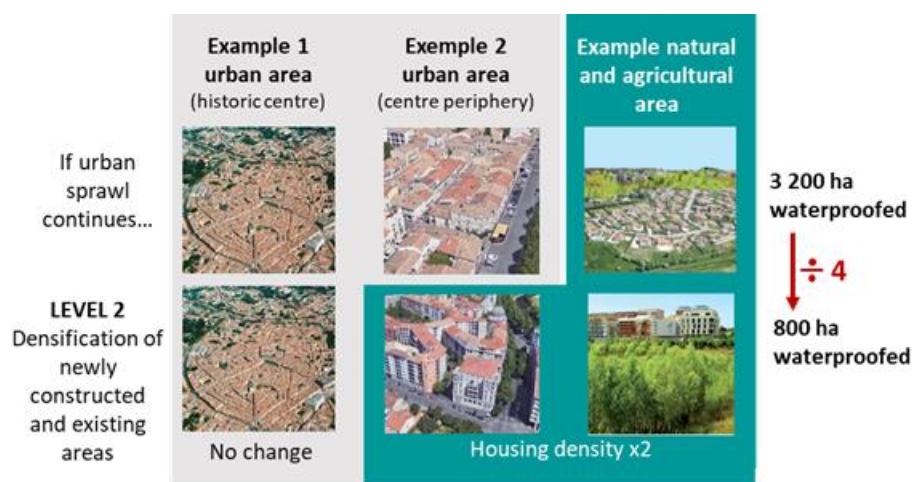
- ☐ Nuisance of natural and agricultural areas (mosquitoes, pesticides, allergies...)
- ☐ Lower quality of life (limited space, individualism and neighbourhood nuisance)
- ☐ Unsafety
- ☐ Increase in house prices
- ☐ Traffic and car park problems
- ☐ Landscape deterioration
- ☐ Barrier to village development
- ☐ Little effect on flooding
- ☐ High cost and implementation difficulties
- ☐ Loss of cultural and historical heritage

☐ Other (please specify):

**(Q) Would you be in favour of implementing this solution?**

- ☐ Totally in favour  
☐ Rather favourable  
☐ Not very favourable  
☐ Not at all favourable

**Level 2 of peri-urban ecosystems conservation consists in doubling the density of newly constructed areas AND of certain existing urban areas**, through urban regeneration (demolition and reconstruction), for example by transforming individual houses into collective housing, or three-storey collective housing into six-storey collective housing. This option makes it possible to **reduce the area of waterproofed land by a factor of four** by 2040 and thus **preserve 2400 ha of natural and agricultural areas**.



**(Q) Do you think that achieving the benefits presented in the video with this solution by 2040 is realistic?**

- ☐ Totally realistic  
☐ Rather realistic  
☐ Not very realistic  
☐ Not at all realistic

If not "Totally realistic": **(Q) Can you explain why?**

**(Q) In your opinion, does this solution bring significant benefits for society?**

- ☐ Yes  
☐ No

If "Yes": **(Q) Are the benefits the same as for level 1?**

- ☐ Yes  
☐ No

If "No": **(Q) What are the most important benefits for you? (Unlimited number of responses)**

- ☐ Flood risk reduction  
☐ Climate change mitigation by storing carbon in vegetation  
☐ Reducing the temperature in the city during heat waves  
☐ Air quality improvement  
☐ Conservation of landscape and living environment  
☐ Biodiversity conservation  
☐ Local agriculture and food conservation  
☐ Preservation of nature activity areas (biking, walking...)  
☐ Other (please specify):

**(Q) In your opinion, does this solution bring significant negative effects?**

- ☐ Yes  
☐ No

**If “Yes”: (Q) Are the negative effects the same as for level 1?**

- ☐ Yes  
☐ No

**If “No”: (Q) What are the most important negative effects for you? (Unlimited number of responses)**

- ☐ Nuisance of natural and agricultural areas (mosquitoes, pesticides, allergies...)  
☐ Lower quality of life (limited space, individualism and neighbourhood nuisance)  
☐ Unsafety  
☐ Increase in house prices  
☐ Traffic and car park problems  
☐ Landscape deterioration  
☐ Barrier to village development  
☐ Little effect on flooding  
☐ High cost and implementation difficulties  
☐ Loss of cultural and historical heritage  
☐ Other (please specify):

**(Q) Would you be in favour of implementing this solution?**

- ☐ Totally in favour  
☐ Rather favourable  
☐ Not very favourable  
☐ Not at all favourable

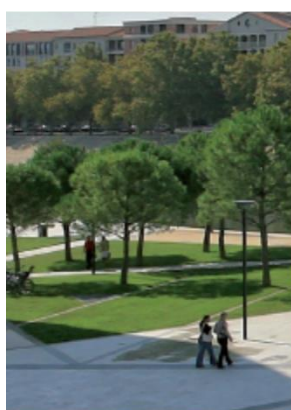
## **SOLUTION 2: the development of green infrastructure in the city**

The development of green infrastructure in the city by creating green spaces in existing and new urban areas also limits the risk of flooding by improving the infiltration and retention of rainwater. Green infrastructure can also bring a **variety of benefits** as illustrated in the video. The importance of these benefits depend on the intensity of their deployment in the territory. As the city is a constrained space, **the introduction of these green spaces can compete with other uses such as streets**. We will describe below two levels of development of green infrastructure in the city.

**Level 1 of development of green infrastructure in the city consists of:**

- ① deproofing and vegetalization of available public space,
- ② replacing waterproof parking areas with permeable pavements,
- ③ creating 50 cm wide bioswales along the streets that do not change the direction of street traffic.

①



②



③



**(Q) Do you think that achieving the benefits presented in the video with this solution by 2040 is realistic?**

- ☐ Totally realistic
- ☐ Rather realistic
- ☐ Not very realistic
- ☐ Not at all realistic

*If not "Totally realistic": (Q) Can you explain why?*

**(Q) In your opinion, does this solution bring significant benefits for society?**

- ☐ Yes
- ☐ No

*If "Yes": (Q) What are the most important benefits for you? (Unlimited number of responses)*

- ☐ Flood risk reduction
- ☐ Climate change mitigation by storing carbon in vegetation
- ☐ Reducing the temperature in the city during heat waves
- ☐ Air quality improvement
- ☐ Conservation of landscape and living environment
- ☐ Biodiversity conservation
- ☐ Local agriculture and food conservation
- ☐ Preservation of nature activity areas (biking, walking...)
- ☐ Other (please specify):

**(Q) In your opinion, does this solution bring significant negative effects?**

- ☐ Yes
- ☐ No

*If "Yes": (Q) What are the most important negative effects for you? (Unlimited number of responses)*

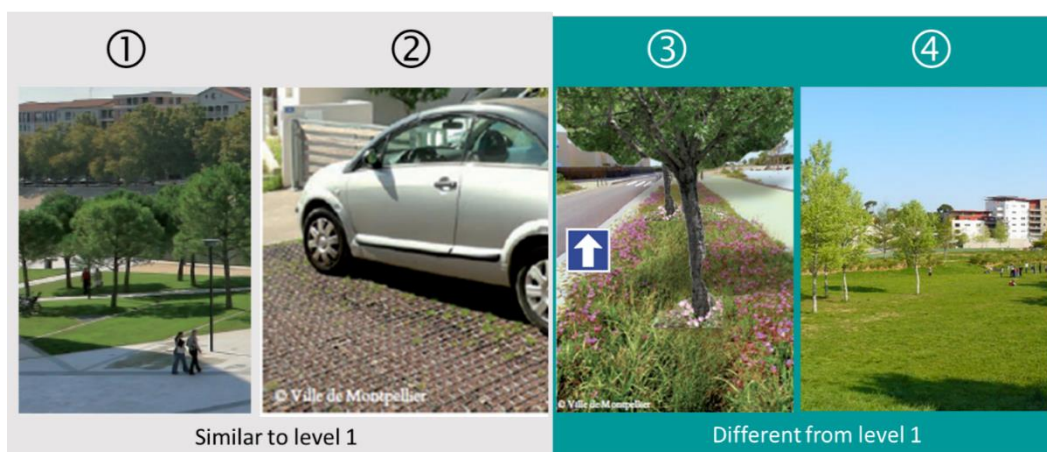
- ☐ Nuisance of natural and agricultural areas (mosquitoes, pesticides, allergies...)
- ☐ High cost and implementation difficulties
- ☐ Traffic and car park problems
- ☐ Unsafety
- ☐ Poorly maintained green spaces
- ☐ Low resistance to drought and urban pollution
- ☐ Little effect on flooding
- ☐ Other (please specify):

**(Q) Would you be in favour of implementing this solution?**

- ☐ Totally in favour
- ☐ Rather favourable
- ☐ Not very favourable
- ☐ Not at all favourable

**Level 2 of development of green infrastructure in the city consists of:**

- ① deproofing and vegetalization of available public space,
- ② replacing waterproof parking areas with permeable pavements,
- ③ creating 2 m wide bioswales along the streets involving a shift to one-way traffic on some streets.
- ④ transforming 25% of the parking areas in vegetated multifunctional retention basins (walking areas, children's play areas, etc.).



**(Q) Do you think that achieving the benefits presented in the video with this solution by 2040 is realistic?**

- ☐ Totally realistic
- ☐ Rather realistic
- ☐ Not very realistic
- ☐ Not at all realistic

*If not "Totally realistic": (Q) Can you explain why?*

**(Q) In your opinion, does this solution bring significant benefits for society?**

- ☐ Yes
- ☐ No

*If "Yes": (Q) Are the benefits the same as for level 1?*

- ☐ Yes
- ☐ No

*If "No": (Q) What are the most important benefits for you? (Unlimited number of responses)*

- ☐ Flood risk reduction
- ☐ Climate change mitigation by storing carbon in vegetation
- ☐ Reducing the temperature in the city during heat waves
- ☐ Air quality improvement
- ☐ Conservation of landscape and living environment
- ☐ Biodiversity conservation
- ☐ Local agriculture and food conservation
- ☐ Preservation of nature activity areas (biking, walking...)
- ☐ Other (please specify):

**(Q) In your opinion, does this solution bring significant negative effects?**

- ☐ Yes
- ☐ No

*If "Yes": (Q) Are the negative effects the same as for level 1?*

- ☐ Yes
- ☐ No

*If "No": (Q) What are the most important negative effects for you? (Unlimited number of responses)*

- ☐ Nuisance of natural and agricultural areas (mosquitoes, pesticides, allergies...)
- ☐ High cost and implementation difficulties
- ☐ Traffic and car park problems
- ☐ Unsafety
- ☐ Poorly maintained green spaces
- ☐ Low resistance to drought and urban pollution
- ☐ Little effect on flooding

☐ Other (please specify):

**(Q) Would you be in favour of implementing this solution?**















- ☐ Totally in favour  
☐ Rather favourable  
☐ Not very favourable  
☐ Not at all favourable

### Part III—Flood management strategies in the future

Several strategies for developing nature-based solutions are possible in the future. In this section, you will have to choose between several strategies.

Each strategy is divided into three components.

- Components 1 and 2 reflect the levels of implementation of the solutions (0, 1 or 2) presented above.
- The implementation of these solutions requires significant investment by local authorities. We would therefore also like to determine the contribution that you would agree to make in the form of an increase in your local taxes for 10 years to finance flood risk management (component 3).





<b>COMPONENT 1</b> Conservation of peri-urban ecosystems	<b>LEVEL 0</b> Urban sprawl continues	OR	<b>LEVEL 1</b> 1 600 ha of preserved peri-urban ecosystems	OR	<b>LEVEL 2</b> 2 400 ha of preserved peri-urban ecosystems
			   Pas de changement    Densité de logements x 2		   Pas de changement    Densité de logements x 2
<b>COMPONENT 2</b> Green infrastructure	<b>LEVEL 0</b> No new green infrastructure	OR	<b>LEVEL 1</b>	OR	<b>LEVEL 2</b>
			   ① ② ③		   ① ② ③ ④
<b>COMPONENT 3</b> Contribution to local taxes	20, 40, 60, 80, 100 or 120 €/household/year				

We will now introduce you 6 different choices.

- For each choice, you must choose between two strategies (Strategy A or Strategy B) with different combinations of components 1, 2 and 3 presented above. These two strategies lead to the same level of flood risk management. They differ in the levels of implementation of the nature-based solutions; the grey solutions (rainwater network, dikes) are always the adjustment variable in order to achieve the same level of risk.
- If neither of the two strategies suits you, you can choose “Neither of the two strategies”. In this case, which does not include any intervention, flood risk control is not guaranteed.

You must therefore make a total of 6 choices. Please consider each choice in isolation, without taking into account the other choices proposed to you.

### Choice 1

Conservation of peri-urban ecosystems	<b>Strategy A</b> <b>LEVEL 2</b> 2 400 ha of preserved peri-urban ecosystems  No change      Housing density x2		<b>Strategy B</b> <b>LEVEL 1</b> 1 600 ha of preserved peri-urban ecosystems  No change      Housing density x2		None of the 2 strategies
	<b>LEVEL 1</b>  60€/household/year		<b>LEVEL 2</b>  60 €/household/year		
	Green infrastructure		Green infrastructure		
Contribution to local taxes	60€/household/year		60 €/household/year		
Tick your preferred option <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>					

### Choice 2

(choice set n°2)

### Choice 3

(choice set n°3)

### Choice 4

(choice set n°4)

### Choice 5

(choice set n°5)

### Choice 6

(choice set n°6)

If “None of the 2 strategies” selected each time: **(Q) You have chosen “neither of the 2 strategies” each time. Can you tell us why? (1 possible answer)**

- ☐ These solutions are interesting but I can't afford to pay.
- ☐ These solutions are interesting but the proposed amounts are too high.
- ☐ I don't agree with the proposed solutions.
- ☐ I do not believe that the proposed solutions are effective in reducing the risk of flooding.
- ☐ In my opinion, the proposed solutions do not bring any significant benefit.
- ☐ It's not fair that I'm the one paying for these solutions, I already pay enough local taxes.
- ☐ These solutions should be paid for by existing taxes.
- ☐ Other (please specify):

### Appendix B. Choice Experiment Design

The choice experiment design is a D-efficient design elaborated with Ngene, with two-blocks with six choice sets each. The choice situations are described in Table A1.

**Table A1.** Choice experiment design used in the survey (D-error: 0.111447, A-error: 0.463876).

Choice Sets	Block	Alternative 1			Alternative 2		
		Conservation	Green Infrastructure	Payment	Conservation	Green Infrastructure	Payment
1	1	Level 2	Level 1	60	Level 1	Level 2	60
2	1	Level 2	Level 2	40	Level 1	Level 1	80
3	1	Level 0	Level 1	80	Level 1	Level 0	60
4	1	Level 2	Level 2	120	Level 0	Level 1	20
5	1	Level 1	Level 0	40	Level 0	Level 2	100
6	1	Level 2	Level 0	60	Level 0	Level 0	80
1	2	Level 1	Level 2	100	Level 2	Level 1	40
2	2	Level 0	Level 2	20	Level 2	Level 1	100
3	2	Level 0	Level 0	100	Level 1	Level 0	40
4	2	Level 1	Level 1	120	Level 2	Level 0	20
5	2	Level 0	Level 0	80	Level 0	Level 2	120
6	2	Level 1	Level 1	20	Level 2	Level 2	120

### Appendix C. Robustness Check

**Table A2.** MXL model estimation of choice experiment data without respondents who consider their level of information to be insufficient (N = 341).

	MXL
Mean	
Conserv_L1	0.521 ***
Conserv_L2	1.172 ***
GI_L1	0.564 ***
GI_L2	1.173 ***
BAU	−2.411 ***
Payment	−0.015 ***
SD	
Conserv_L1	−0.065
Conserv_L2	−0.765 ***
GI_L1	−0.520 ***
GI_L2	0.807 ***
BAU	2.580 ***
Log likelihood	−1717.0281
LR chi <sup>2</sup>	
Pseudo R <sup>2</sup>	
AIC	3456.056
BIC	3530.001

The sign of SD is irrelevant, must be interpreted as positive. \*\*\*: significance at 1%.

**Table A3.** Comparison of estimation of WTP with and without respondents who consider their level of information to be insufficient.

		MXL N = 7200	MXL N = 6138
Share		1.00	1.00
<b>EUR/household/year</b>			
Conservation of peri-urban ecosystems	L1	140.9	143.4
	L2	178.8	185.5
	L2–L1	+37.9	+42.1
Development of GI	L1	142.7	149.0
	L2	180.4	188.5
	L2–L1	+37.7	+39.5
<b>EUR/ha/household/year</b>			
Conservation of peri-urban ecosystems	L1	0.088	0.090
	L2	0.075	0.077
	L2–L1	0.047	0.053

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