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Research article

Awareness and willingness to pay for green roofs in Mediterranean areas

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ABSTRACT

Green roofs have been extensively investigated in recent years, showing that their implementation in urban areas provides multiple benefits (e.g., pluvial flood mitigation, urban heat island reduction, energy saving, increase of biodiversity, CO_2 sequestration) and supports sustainable urban development. Although green roof benefits have been widely recognized, the perception that the community has of these nature-based solutions and the willingness to pay for their installation in urban areas is still not clear nor quantified. Societal perception and willingness to pay for green roofs are fundamental for urban planners and decision makers, since they represent the community participation in the sustainable development of urban areas. In this work, we aim to analyze how citizens perceive green roofs and how willing they are to pay for the installation and maintenance of these nature-based solutions. We used an online survey to investigate the perception and the knowledge of green roofs as a potential solution to common environmental issues (i.e., urban flood, increase of temperature, energy consumption, air pollution and lack of green spaces), and the interest and willingness to pay for green roof installation on both public and private roofs. Based on the answers of 389 respondents living in Sardinia (Italy), our analysis revealed that most citizens are aware of what green roofs are, and they are aware that, although these nature-based solutions can not completely solve environmental issues, they can greatly contribute to the mitigation of these phenomena. Results also show a higher interest in the installation of green roofs on public buildings than on private ones, due to the high installation costs. Moreover, for private roofs, the possibility to install photovoltaic panels instead of GRs is generally preferred. Most of the respondents are willing to spend less than 100 € per year for the maintenance of green roofs on public buildings and to invest less than 5000 € for the installation on their own house.

1. Introduction

Nature-based solutions (NBSs), defined by the European Commission as "cost-effective solutions inspired and supported by nature, which provide environmental, social and economic benefits and help build resilience" have been widely investigated over the last decades and locally adapted to suit different areas, such as urban, landscape or seascape (EC European Commission, Directorate-General for Research, and Innovation, 2022; Nesshöver et al., 2017). NBSs can be used to support sustainable development, acting in different fields, e.g., water management and floods, climate change, biodiversity loss and temperature increase (Seddon et al., 2021; Girardin et al., 2021; Costa et al., 2021; Fletcher et al., 2015; Krauze and Wagner, 2019). In urban areas, NBSs have been used to address most of the societal challenges related to climate change and urbanization: different types of NBSs have been implemented through several tools (e.g., permeable pavements, green roofs and green walls), which aim to recreate the natural environment, increasing biodiversity, creating new ecosystems, reducing runoff generation, restoring groundwater infiltration and limiting the urban heat island effects (Dorst et al., 2019; Bush and Doyon, 2019; Ershad Sarabi et al., 2019; Pan et al., 2021; Atanasova et al. 2021).

1.1. Willingness to pay for nature-based solutions

Besides the technical aspects, however, public opinion and preferences regarding environmental issues and potential solutions are important aspects that cannot be ignored by policy makers and urban planners for the creation of sustainable and resilient cities (Simões, 2016; Ando and Freitas, 2011). Recent studies have investigated the citizens' perception and willingness to pay (WTP) for the installation of NBSs in urban environments to mitigate the runoff generation and other environmental issues, contrasting the urbanization increase, and have

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related WTP to population socio-demographic characteristics (Ando et al., 2020; Chen and Jim, 2008; Teotónio et al., 2021). Contingent valuation and choice experiment approaches are usually employed to investigate public preferences and interests for environmental issues and are commonly developed through face-to-face interviews or online surveys (Mitchell and Carson, 1989; Hanley et al., 2001; Venkatachalam, 2004; Bowman et al., 2012). Results derived from these types of analysis can be used to guide and support policy makers and urban planners in sustainable urban development (Hérivaux and Le Coent, 2021; Fruth et al., 2019; Tran et al., 2017; Kim et al., 2016), especially if combined with other approaches, such as the multicriteria analysis (Zoppi, 2007).

Most of the studies showed that, although a large fraction of the population declared a limited knowledge and understanding of sustainable drainage systems and blue-green infrastructures, there is an overall high interest in these innovative solutions since they can improve the quality of life in urban environments better than traditional structural solutions (Chui and Ngai, 2016; Teotónio et al., 2021; Ureta et al., 2021). Many factors, including demographical, geographical, cultural and climatic contexts, influence citizens' perceptions and WTP for green infrastructures and NBSs (Zalejska-Jonsson et al., 2020; Fruth et al., 2019; Hérivaux and Le Coent, 2021). O'Donnell et al. (2021) compared the NBS perception in four international cities around the world (Newcastle (UK), Ningbo (China), Portland (Oregon USA), and Rotterdam (The Netherlands)), showing how awareness regarding water challenges and NBS benefits are influenced by the geographical and climatological features of each city. Perceived risk of coastal flooding and storm surges is, for example, higher in delta cities, such as Rotterdam and Ningbo. Chui and Ngai (2016) investigated the WTP for NBSs through face-to-face interviews with 600 respondents in Hong Kong and highlighted the importance of socio-demographic characteristics: those who were relatively young, well-educated, with a high income, and with previous flood experiences manifested a higher WTP than the other survey participants.

1.2. Willingness to pay for green roofs

Among the different NBS solutions proposed in literature for sustainable urban development, green roofs (GRs) are becoming more and more popular, since they present multiple benefits for the cities (Cristiano et al., 2021a, b). Thanks to their retention capacity, GRs have shown high performance in reducing the runoff generation during rainfall events, both at building and urban scale (Cristiano et al., 2021b; Hellies et al., 2018; Charalambous et al., 2019; Liu et al., 2020; Karteris et al., 2016), under different climatic conditions (Viola et al., 2017). Moreover, the installation of GRs increases the thermal insulation of the building underneath, ensuring a corresponding energy saving from a reduced use of the heating and cooling systems (Alim et al., 2022; Jaffal et al., 2012; Coma et al., 2016; Silva et al., 2016; Susca, 2019). The presence of green and vegetated areas in the urban environment not only increases the biodiversity attracting insects and small animals (Williams et al., 2014; Gonsalves et al., 2022; Wooster et al., 2022), but also contributes to the reduction of the average temperature, limiting the urban heat island effect (Muhammad and Kim, 2017; Dwivedi and Mohan, 2018; Khare et al., 2021; Susca et al., 2022). Moreover, it is largely recognized that the installation of GRs contributes to the improvement of the air quality (Yang et al., 2008; Rowe, 2011; Abhijith et al. 2017), to the absorption of CO_2, and to the reduction of pollutants with positive effects on the water quality too (Chai et al., 2018; Chen et al., 2018; Qianqian et al., 2019; Castro et al., 2020). Finally, the increase of green areas enhances the aesthetic value of the city, improving the physical and mental health of the community (Loder, 2014).

Although the high potential of GRs has been widely shown in literature, the perception that the society has of them and the WTP for the installation and maintenance of these nature-based solutions are still not clear nor qualified. Among NBS surveys, only a few addressed this topic, and most of them focus on single specific aspects.

First studies only analyzed the perception of existing and accessible GRs, showing that although citizens know about GRs and their installation on public buildings, often they do not use them as public gardens (Yuen, Belinda, and Wong Nyuk Hien, 2005). Sarwar and Alsaggaf (2020), for example, explored through a survey the GR perception and awareness of a group of residents in Lahore (Pakistan). Findings highlight that the willingness to have GRs is strongly dependent on four factors: (i) awareness of GR technology, (ii) amendments in building rules, (iii) sustainable environmental consciousness, and (iv) cost of GRs.

Another important aspect concerning the perception of GRs, which has been assessed with online surveys and face-to-face interviews, is the importance of the GR visual appearance (Williams et al., 2019; Nguyen Dang et al., 2022). With an online survey, Vanstockem et al. (2018) involved 155 Flemish participants and showed how the presence of vegetation gaps and weedy species is the most important attribute evaluated by the respondents, while costs are located in second place. Aesthetic preference based on a visual choice has been investigated in Spain by Fernandez-Cañero et al. (2013), showing that green roofs with a more careful design, greater variety of vegetation structure, and more variety of colours were preferred over alternatives. Similar results, which highlight the strong connection with nature and the importance of having aesthetically attractive GRs, have been found in multiple studies, which focus on different geographical areas, such as Australia (Lee et al., 2014), Northeastern US (Jungels et al., 2013), Chicago and Toronto (Loder, 2014), and UK (White and Gatersleben, 2011).

A recent study investigated the public's WTP for large scale GR installation projects in three cities in South Korea (Ji et al., 2022). Results showed that citizens are willing to pay on average 3.77 $ per household per year, suggesting how GR installation projects are feasible only in large and densely populated cities. Results are aligned with the WTP recorded in Guangzhou (China) by Zhang et al. (2020), where citizens are willing to pay around 3.5 $ per household per year. Higher WTP has been observed by Zhang et al. (2019), in Beijing, where citizens are willing to pay on average 22 $ per year per household, ensuring the economic feasibility of the project that foresees the installation of GRs at a large scale in the city. In this case, the most highlighted GR benefit is the reduction of the urban heat island, which is a problem that Beijing citizens strongly perceived and for which they are willing to pay. A similar investigation has been proposed by Netusil et al. (2022), who analyzed the public perception of GR benefits and the WTP for GR installation on public buildings, with the aim to evaluate the feasibility of a GR large scale installation in the city of Portland (USA). Total annual estimated WTP per 1-year program varies depending on the program details, between 202 and 442 $ per household, which at city level could be potentially translated in an investment ranging from 54.4 to 116.8 million $. In Portugal, Teotónio et al. (2020) investigate the WTP for accessible GRs, estimating it as a percentage of the house expenses, such as rent or mortgage. Results from 600 participants showed that the average WTP is around 3% of their actual rent or mortgage, with a high preference for accessible GRs. Table 1 summarizes the main characteristics of the available works, in comparison with the approach followed in this work, reported in the last line.

In this context, this study aims to provide an extensive evaluation of the GR perception and interest, in Mediterranean areas, including the awareness of the most common environmental issues that characterize urban areas and the WTP for the installation of these NBSs both on public and private buildings. The study focuses on the Sardinian region, aiming to be representative of the climatic and geographical characteristics of the Mediterranean regions.

Although the benefits deriving from the implementation of GRs, and more in general of NBSs, in urban areas in Sardinia have been investigated in depth and promoted (Cristiano et al. 2020, 2021a; De Montis, Ledda, and Calia, 2022; Lai et al., 2021; Cannas et al., 2018; Isola and Leone, 2019), the citizens' perception of these solutions has not been

Table 1
Summary of the most relevant works that investigates green roofs perception and willingness to pay compared to this study.

Authors	Title	Study area	N of answers	Survey type	WTP	Specific issue addressed
Netusil et al. (2022)	Valuing the public benefits of green roof	Portland (USA)	391	Online survey	Yes, for public buildings (for a proposed green roof program)	High summer temperatures, pluvial flood mitigation, increase of biodiversity
Ji et al. (2022)	Measuring the economic value of green roofing in South Korea: A contingent valuation approach	Seoul, Sejong, and Daegu (South Korea)	1000	Face to face survey	Yes, for green roof projects	Support for green roof projects
Manso et al. (2021)	The role of green roofs in post COVID-19 confinement: An analysis of willingness to pay	35 countries around the globe during COVID-19	556	Online survey	Yes, as % of monthly rent/mortgage	Need for outdoor space
Zhang et al. (2020)	Public perception and preferences of small urban green infrastructures: A case study in Guangzhou, China	Guangzhou (China)	409	In person survey	Yes, for maintenence	High temperatures, air pollution, flood events, noise pollution, and biodiversity degradation
Sarwar and Alsaggaf (2020)	The willingness and perception of people regarding green roofs installation	Lahore (Pakistan)	400	In person survey	[-]	Environmental degradation
Teotónio et al. (2020)	Investing in Sustainable Built Environments: The Willingness to Pay for Green Roofs and Green Walls	Portugal	600	Online survey	WTP for private buildings	Preference for accessible green roofs
Zhang et al. (2019)	Households' willingness to pay for green roof for mitigating heat island effects in Beijing (China)	Beijing (China)	1040	Face to face interviews	Yes, as increase of taxes	Urban heat island
Vanstockem et al. (2018)	Do Looks Matter? A Case Study on Extensive Green Roofs Using Discrete Choice Experiments	Flanders (Belgium)	155	online survey	[-]	Aesthetic value
Chui and Ngai (2016)	Willingness to pay for sustainable drainage systems in a highly urbanized city: a contingent valuation study in Hong Kong	Hong Kong	600	Face to face interviews	Yes, for both public and private buildings	Stormwater management, lack of recreational spaces, improving environment, aesthetic value
Fernandez-Cañero et al. (2013)	Green roof systems: A study of public attitudes and preferences in southern Spain	Siviglia (Spain)	450	In person survey	[-]	Aesthetic value and lack of recreational spaces
This study	**Awareness and willingness to pay for green roofs in Mediterranean Areas**	**Sardinia (Italy)**	**387**	**Online survey**	**Yes, for both public and private buildings**	**Urban flood, heat waves, high energy consumption for heating and cooling, air quality and lack of green spaces**

evaluated. Only a few analysis have been developed in the region to evaluate the citizens' WTP for NBSs, focusing on renaturation of river flows (Strazzera et al., 2021) or on coastal wetlands (Ivčević et al., 2021) and parks (Zoppi, 2007), but citizens' WTP for urban implementation of GRs still needs to be evaluated better.

The paper is structured as follows. Section 2 defines the case study and describes the design and implementation of the survey. Results are presented and discussed in Section 3. Section 4 encloses practical indications derived from the questionnaire that could support policy makers in the development of sustainable and resilient cities, while the most important conclusions are summarized in Section 5.

2. Methodology

Several approaches have been evaluated, developed and followed in literature to elicit the citizens' preferences and WTP to mitigate the urbanization effects, with the aim to involve the society in the creation of sustainable and resilient cities (Hanley et al., 2001). Among the proposed approaches, the stated preference and the revealed preference methods are the most common approaches adopted to pursue similar purposes of our work. Specifically, the stated preference method is usually performed by surveys or interviews, where consumers are asked to state how much they are willing to pay for certain services or benefits, while the revealed preference approach uses statistical modelling to estimate the value of goods based on consumers' previous payment choices. After a careful analysis of the pros and cons, our choice fell on the first approach. Then, stated preference method is usually executed with a contingent valuation (Mitchell and Carson, 1989), which is a direct survey, where respondents are asked to express their willingness to pay for a specific nonmarket good or service. This approach has been implemented and modified through the years, and during the late 1980s there was a shift towards the dichotomous choice elicitation, which simplifies the participants' involvement and the answer analysis. The positive aspects of this approach were largely recognized by the National Oceanic and Atmospheric Administration (NOAA) Panel in 1993 (Arrow et al., 1993), which provided guidelines and recommendations for the contingent valuation. Despite the widely recognized advantages, dichotomous choice elicitation limits the respondents' expression and does not enable cases with multiple dimensions to be represented. As a partial solution for this issue, the choice experiment approach recently become more popular. The discrete choice experiment evaluates the participants' WTP for a good or service, described in term of their attributes, which respondents are asked to rate (Lancaster, 1966; Carson and Czajkowski, 2014; Hoyos, 2010; Mahieu et al., 2014).

2.1. Case study

In this context, we developed an anonymous online survey based on the discrete choice experiment to evaluate the awareness of GR benefits and WTP for the installation of these structures. Although face-to -face surveys are less biased and more representative of the total population (Szolnoki and Hoffmann, 2013) than online surveys, we decided to follow the latter approach since it allows a greater number of participants to be reached faster. In order to investigate the perception of environmental issues and the WTP for GR installation on both public and private buildings in the Mediterranean area, the region of Sardinia has been chosen as representative case study.

To identify the minimum number of respondents n, representative

sample of the population, we applied the Slovin's formula (Eq. (1)), as done previously by (Chui and Ngai, 2016; Sarwar and Alsaggaf, 2020):

$$n = \frac{N}{(1 + N\,e^2)} \quad (1)$$

where N indicates the total population of the case study area and "e" is the standard error. Following this approach and applying Eq. (1) in Sardinia, where the total population N around 1.5 million inhabitants, and assuming a marginal error of 0.05, we obtain a sample size n around 400 participants. Although the impacts and benefits of GRs spread throughout the population, mostly young and well-educated people show interest in sustainable drainage systems and NBSs, as found by Chui and Ngai (2016). For this reason, we decided to specifically target this group of people as respondents for the online survey, keeping as n the same number resulting from Eq. (1). In particular, we focused on people holding at least a high school diploma.

The anonymous online survey was created with the support of a Google Form and shared through different channels: via email, to all the people at the University of Cagliari (academic and administrative employees and students), via social media (Instagram and Facebook), and direct contacts. Using these channels, we aimed to reach mostly university students and people with a good education. The questionnaire was shared for a couple of months, between July 11th, 2022, and September 11th, 2022, until the minimum number of respondents had been reached.

It is worth remarking that this study mostly targets highly educated people and aims to investigate their perception and WTP for GRs: consequently, the respondent sample will target specific classes in terms of age and level of education. This work has been carried out under the documented hypothesis that the target sample is the most interested and has the highest WTP for GRs, thus results must be interpreted as a reference.

2.2. Questionnaire structure

The questionnaire is composed of seven sections: 5 investigative sections, in which the 21 questions are divided, and two informative sections, where GRs and their benefits are presented and described. The goal of the questionnaire, in fact, was not only to estimate the awareness of environmental issues and the WTP for GRs, but also to increase the knowledge about this powerful nature-based solution. The two informative sections are constituted by small textual paragraphs and mostly figures and diagrams, in order to be more attractive, easy to understand and visualize.

The survey starts with some questions that aim to characterize the sample of respondents and their living conditions: the first investigative section collects the respondents' demographic and economic characteristics (age, gender, income, employment etc.), while the second gathered the information about the house (type, property, and location within the city). The third and fourth investigative sections focus on the environmental issue perception and GR awareness respectively, and the last section examines the interest in GRs and willingness to pay for their installation and maintenance. The questionnaire structure, including sections, questions and related potential answers are summarized in Table 2.

Besides the four questions about the WTP for GRs on public and private buildings, the last section includes some aspects that need to be investigated to understand fully the reasoning behind the interest (or not) in having these nature-based solutions on rooftops. A key point is the presence or potential preference for photovoltaic panels on the city roofs: thanks to the high yearly sum of global irradiation that characterizes Sardinia (Šúri et al., 2007), the installation of solar panels in the region could be highly productive (Ghiani et al., 2013; Camerada et al., 2015; Petrollese et al., 2017). Many citizens have already invested in these alternative energy sources or they are planning to invest in them

Table 2
Summary of Sections, Questions, and possible related Answers presented in the online survey.

Section	Variable/Question	Possible Answers/Classes
Socio-demographic characterization	Age	<18, 18–30, 30–45, 45–60, >60
	Gender	Male, Female, Non-binary, Other (specify)
	Town	List of all Sardinian Towns
	Education level	No degree, Elementary School, Middle School, High School Diploma, Bachelor or Master, PhD
	Employment status	Full time, Part time, Unemployed, Student, Retired
	Net monthly household income (€)	<1000€, 1000–2000€, 2000–3000€, 3000–5000€, >5000€
	Household inhabitants	1 (living alone), 2, 3, 4, >4
Housing characterization	House type	Apartment (not last floor), Apartment (last floor), Independent house, Other (specify)
	House property	Owner, Renter, Other (specify)
	House location in the city/town	Center, Suburbs, Rural area
Environmental issue perception	Have you ever experienced: • urban flood issues • heat waves issues • high energy consumption for heating/cooling • air quality issues • lack of green spaces	Never, seldom, sometimes, often, I don't know
Informative section	*Description of GR structure and functions*	
GR awareness	Do you know GRs?	Yes, I have seen many GRs; Yes, but I have never seen a GR; Vaguely; No, I don't know GRs
	Green roofs as a solution for: • urban flood • temperature increase • building insulation • air pollution • add aesthetic value to the city	Not at all, a bit, a lot, completely, No idea
Informative section	*Description of GR benefits*	
Interest in and Willingness to pay for GRs	Would you like to have GRs on ***public*** buildings?	Scale from 1 to 5
	How much are you willing to pay every ***year*** for the maintenance of GRs on ***public*** buildings?	<20€, 20–100€, 100–200€, >200€
	Would you like to install a GR on ***your*** building?	Scale from 1 to 5
	How much are you willing to pay for the installation of a GR on ***your*** building?	<1000€, 1000–5000€, 5000–10000€, 10,000–20000€, >20,000€
	Reasons not to install a green roof	High installation costs, High maintenance costs, Presence of insects, Humidity, Allergies, Other (specify)
	Preference between a green roof and solar panels	green roof, solar panels
	Potential increase in house value with a green roof?	0% (no increase), <2%, 2%–5%, 5%–10%, >10%
	In the case of a new pandemic situation (e.g., Covid), would your interest in installing GRs increase?	Yes, No

now, considering the energy crisis and the increase of energy costs that all of Europe is facing due to the war in Ukraine (Liadze et al., 2022; Khudaykulova et al., 2022). However, their presence is an obstacle to GR installation: due to the high installation costs of both structures, it is, in fact, difficult to have both systems installed on one single roof. For this reason, a specific question regarding the preference between GRs and solar panels has been included.

An additional benefit that is not often highlighted is the increase in value of the building that derives from the GR installation. Several studies have shown how the value of the building can increase, with a variation of between 6% and 15%, depending on the type of installed GR (Peck et al., 1999). Results were confirmed by Ichihara and Cohen (2011), who investigated the potential variations of the values of buildings in New York, showing how the rental prices could increase up to 16% when a GR is present. In this context, we decided to include a question in the survey, which specifically aims to evaluate the perception that the community has regarding the potential increase in the value of the building achievable with the GR installation.

Finally, a specific question to evaluate if the Covid-19 pandemic situation increased the need for accessible green areas in the urban environment has been added to the survey. Manso et al. (2021) investigated this aspect in detail, analyzing through a choice experiment the WTP for GRs of people who were in confinement conditions due to Covid-19. Results, which involved citizens living in 35 different countries, showed how Covid-19 changed the perception of green urban spaces, and highlighted the fact that a citizen's interest in having vegetated accessible areas has increased after confinement. Based on these conclusions, we decided to include the potential influence of the recent pandemic situation in the analysis.

3. Results

3.1. Socio-demographic, socio-economic and housing characterization

The online survey was answered by 387 people, who live in different cities in Sardinia. Collected information regarding the socio-demographic and house characterization of the survey respondents has been compared with the most recent data (2021) collected by the Italian National Institute of Statistics (ISTAT) and summarized in Fig. 1.

As shown in Fig. 1(a), the respondent's gender is almost equally split between male (51.3%) and female (47.9%); 0.5% of the participants identify as non-binary and only 0.3% prefer not to answer. The distribution represented well the real Sardinian situation, where, according to ISTAT data, 48.9% of the population is male and 51.1% is female.

The age distribution of the participants is plotted in Fig. 1(b), divided in classes with different ranges. A large participation (almost 40%) of young people, between 18 and 30 years old, is evident as expected due to the fact that the questionnaire was distributed through the University mailing list and via social media. A direct comparison with the ISTAT data was not possible, since we did not involve minors, who constitute a large percentage of the Sardinian population. At the same time and for the same reasons listed above, it is clear that the proposed questionnaire did not reach a representative percentage of people older than 60: 8.5% of the survey's respondents are older than 60, while they constitute more than 32% of the Sardinian population.

The geographical distribution of the participants is illustrated in Fig. 1(c). The participants' distribution follows the inhabitants' one, with the majority of the respondents living in the metropolitan area of Cagliari, where most of the Sardinian residents are. Moreover, we observed many participants from Sassari, Olbia and Oristano, which are, after Cagliari, the most populated cities.

Fig. 1(d) represents the education level of the respondents. For this socio-demographic aspect, we decided to target highly educated people, since results presented by Chui and Ngai (2016) suggested that the WTP for NBSs of this group of people is generally high. Sharing the survey through the mailing list of the University, enabled us to reach many professors and administrative staff. More than 99% of the respondents are representative of the target group of highly educated people, who hold at least a high school diploma. Considering the above premises, the level of education of the participants is higher than the average level in the region. If we consider the highest degree, in Sardinia only 0.4% of the population holds a PhD, while 9.3% of the respondents do. At the same time, more than half of the population does not hold a high school diploma, while from the survey only 0.8% of the participants are in this situation.

For the employment status, reported in Fig. 1(e), a direct comparison with the ISTAT data was not possible due to the lack of some classes. However, only 1.8% of the survey respondents are retired compared to 16% of the Sardinian population who are pensioners. This aspect could be related to the fact that the survey was shared only in an online format, a factor that could limit the accessibility for older people.

The analysis of the monthly net income of the household, illustrated in Fig. 1(f), did not allow a direct comparison with the data collected by ISTAT, which provide only an average of the net income for retired people (2135 € per month), full time employees (2550 € per month) and freelancers (3708 € per month). Most of the survey's participants (33%) declare a cumulative monthly net income of the family members of between 1000 and 2000 €, followed by a large fraction (29%), which has a family net income of between 2000 and 3000 € per month. Only a small portion, less than 5% of the respondents, lives with less than 1000 € per month.

The number of the family members, plotted in Fig. 1(g), is overall well representative of the Sardinian households, except for the people who live alone: in Sardinia, in fact, almost 38% of the population lives alone, while less than 19% of the survey respondents do. The imbalance could be related to the high percentage of university students that answered the survey.

The second investigative section of the questionnaire mostly focuses on the identification of the house characterization. Fig. 1(h) shows that almost 40% of the respondents live in a detached house, 20% live in an apartment on the last floor and the remaining 40% live in a flat on the ground or intermediate level. This classification is particularly relevant, since it is expected that people who do not live directly under the roof might be less interested in investing in GRs, not having direct benefits. As illustrated in Fig. 1(i), most of the respondents own the house where they live (85%) and only 15% are renting it. Finally, most of the participants live either in the center of the town (51%), or in the suburban area (53%), while only 6% of them are in the rural areas.

3.2. Environmental perception and GR awareness

The third and fourth investigative sections aim to investigate the respondent's perception about the most common environmental issues for the urban areas and about how GRs could be a solution. With the aim to provide all the participants with the instrument to answer the questions, it was asked first how often they experienced specific environmental issues (i.e., pluvial floods, high temperatures, high energy consumption for heating and cooling systems, air pollution and lack of green spaces) and if they knew what a GR is. Subsequently, an informative section has been placed in the questionnaire with a short description of GRs, to provide all participants with basic information on GRs and how they work. Only after the informative section, were they asked to rate the potential of GRs in solving the beforementioned environmental issues.

Regarding the knowledge of GRs, most of the respondents know something about GRs: 26.1% are familiar with the concept of GRs and have seen these structures in real life, 41.6% know about these nature-based solutions but have never seen them, and 20.2% have only a vague knowledge about them. Only 12.1% (47) of the participants declare they do not know GRs at all.

The Sankey diagram, plotted in Fig. 2, illustrates the relationship between the frequency perception of each environmental issue (plotted

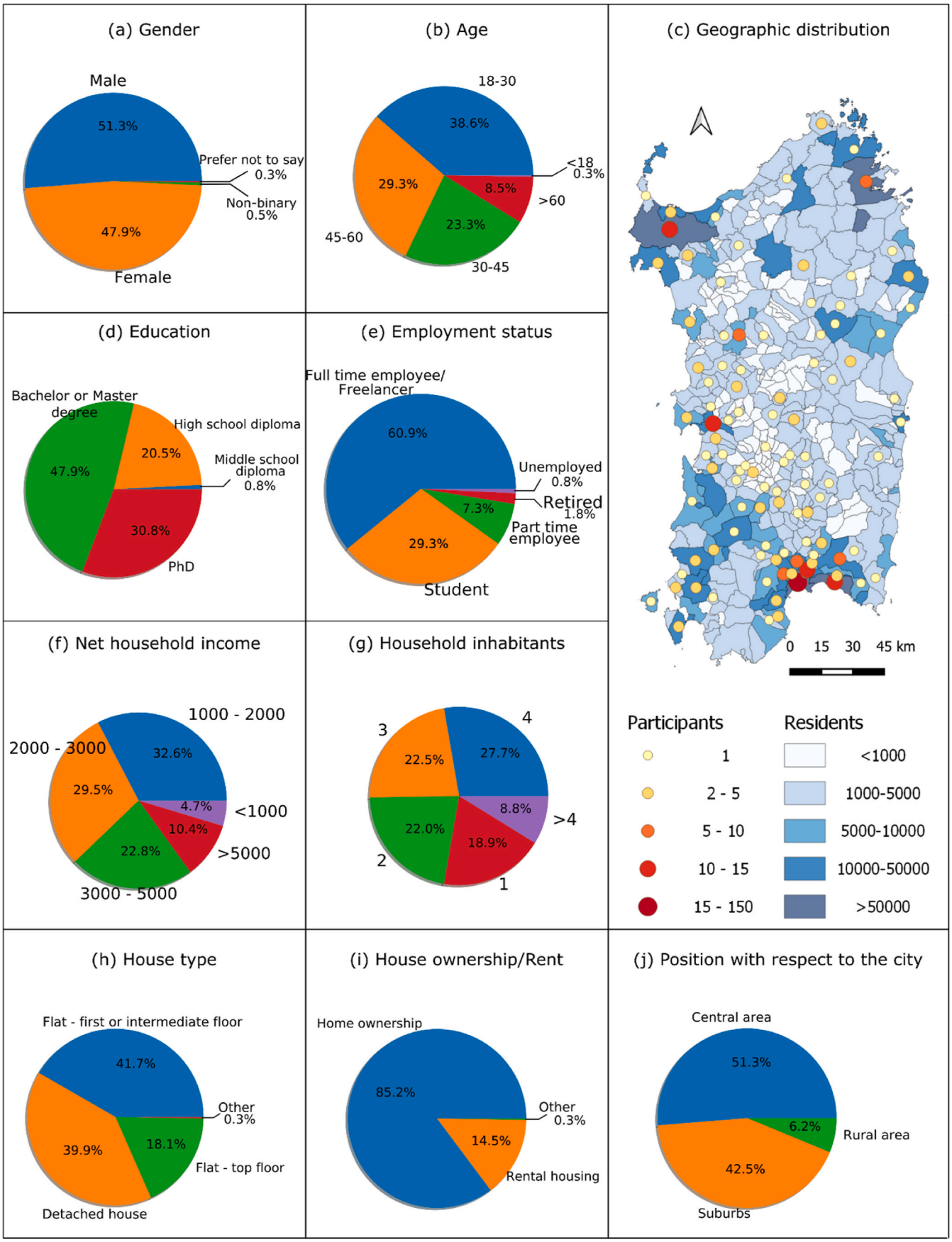

Fig. 1. Socio-demographic and house characterization of the survey participants. (a) Gender, (b) Age, (c) Geographical distribution, (d) Education level, (e) Employment status, (f) Net monthly household income, (g) Household inhabitants, (h) House type, (i) House ownership and (j) Position with respect to the city.

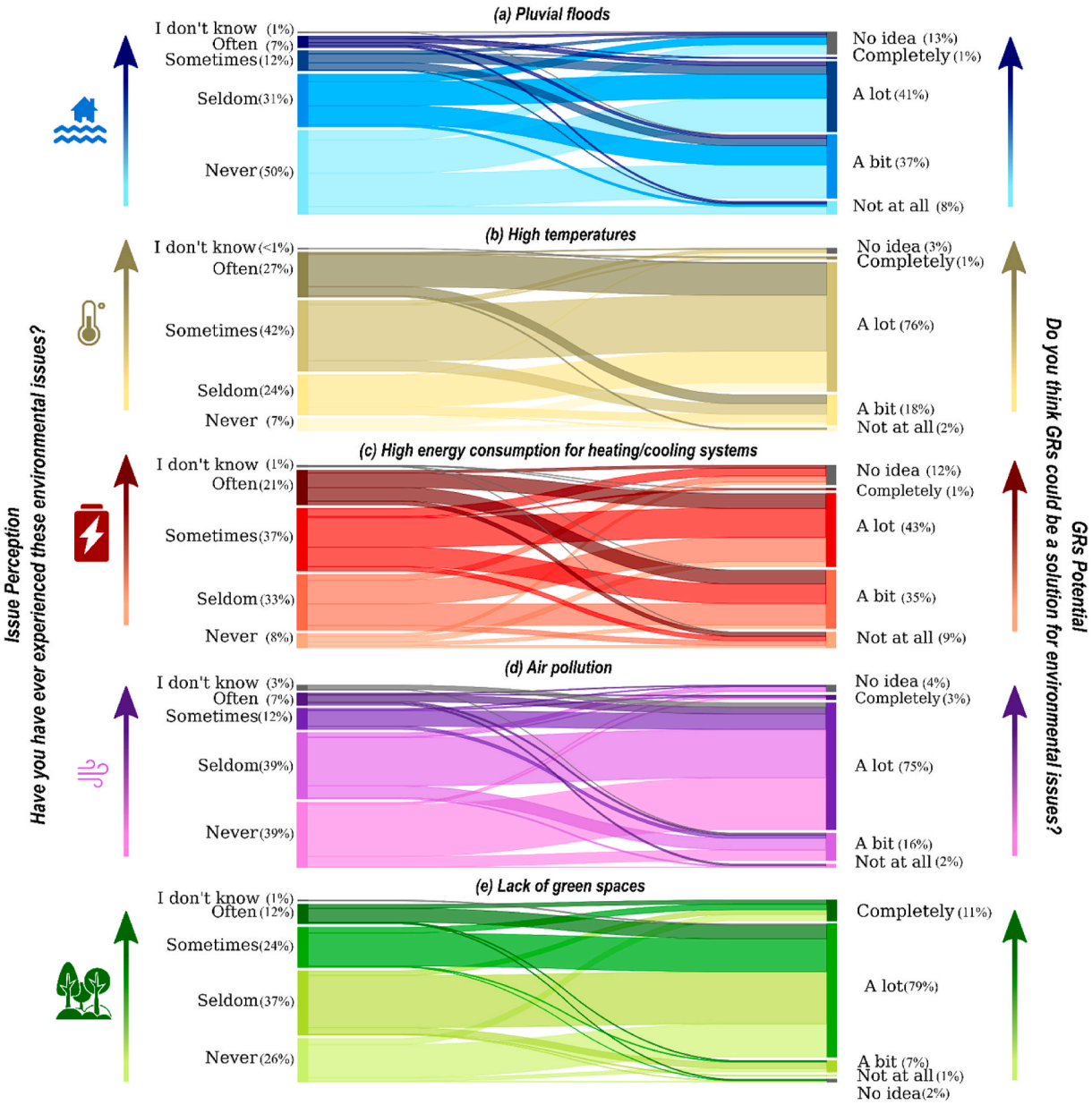

Fig. 2. Experienced environmental issues in relation with the perception that GRs could be a solution to solve them. Each plot investigates a different environmental issue: (a) pluvial floods, (b) high temperatures, (c) high energy consumption for the heating and cooling systems to regulate the temperature in the buildings, (d) air pollution and (e) lack of green spaces in the urban areas. Each environmental issue could have been experienced with a frequency from "Never" to "Often", with the additional "I don't know" option. GR installation could solve each potential environmental issue at a different level, from "Not at all" to "Completely", with the additional "No idea" option.

on the left side) and the belief that GRs could act as possible solutions (plotted on the right side). These two aspects are connected using the flow bands which represent the fraction of respondents that have experienced a specific environmental issue with a certain frequency, linked with the trust they have that GRs could be a solution. These diagrams enable the visualization of the influence that having experienced a specific environmental issue could have on the belief that GRs could be a potential solution for it.

Pluvial floods (Fig. 2(a)) have been directly experienced with a medium to high frequency only by a few participants, while most of them declared to have never experienced this issue. This situation represents well the actual conditions in Sardinia, where the pluvial flood issue is a critical issue only in specific areas, hence involving only a small portion of the Sardinian population.

Among the proposed environmental issues, high temperatures (Fig. 2(b)) and high energy consumption for heating and cooling systems (Fig. 2(c)) are the most perceived. These answers might have been influenced by the fact that the questionnaire was shared in summer, when the temperatures are higher than in the rest of the year, and the media attention on the increase of energy costs was quite high. On the other hand, the frequency of the abovementioned environmental issue is higher than pluvial flood, polluted air, or lack of green spaces in Sardinia, highlighting how the perception of the environmental issues represent fairly the real conditions of the island.

At the same time, there is the general perception that GR installation could not completely solve any environmental issue but could help "a lot" in solving high temperatures, air pollution and lack of green spaces in the urban environment. This answer shows that most of the population is aware of the importance of GRs in providing benefits for urban development, but also the awareness about their limitations.

3.3. Interest and WTP for GRs

The last investigative section examines the WTP for GRs, both on public and on private buildings, and the reasons and motivations that could lead the citizens to desire or not GRs in urban areas. Fig. 3 shows, through two Sankey diagrams, the interest in having GRs on public and private buildings, on a scale from 1 to 5, and the WTP for their maintenance and installation. On the left side (Fig. 3(a)) the interest in having GRs on public buildings is linked to the WTP for their maintenance (in terms of annual taxes), while the diagram on the right illustrates the connection between interest and WTP for private buildings. The two diagrams are mirrored to enable a direct comparison (in the middle of Fig. 3) between the willingness to have GRs on public and private buildings. Traffic light colours support the visualization of the interest in having GRs, where dark green corresponds to the maximum interest and red to the minimum.

If we focus on public buildings (Fig. 3(a)), most of the participants (63%) showed a very high interest in having GRs, but the WTP is relatively low, with almost 80% of the respondents willing to pay less than 100 € per year. Only a few people (3.5%) are so interested in having GRs on public building, that they are willing to invest more than 200 € per year for maintaining these nature-based solutions.

For private buildings, on the other hand, the interest in having GRs is overall lower: most of the participants (38%) declared their high interest, but a high percentage of them (more than 22%) are not very interested in these tools (giving a grade lower than 2). Moreover, the WTP for GR installation is relatively low, with 86% of the respondents willing to pay less than 5000 €, and half of them less than 1000 €. Considering that the average surface of apartments in Sardina is about 100 m^2 (from the Revenue Agency annual statistics) and according to the outcome of our questionnaire, about half of the respondents are willing to contribute with a fee between about 10 to about 50 €/m^2 for installations that cover the whole average surface. On the other hand, assuming a unitary cost between 100 €/m^2 for extensive GRs and 250 €/m^2 for intensive ones, the same numbers give evidence that the majority of the families are willing to invest in a GR of 20–50 m^2 at most, depending on the selected type. Obviously, the economic feasibility of GR installation increases for buildings with many floors, where the costs are split among many families, while for covering the roof of a detached house, a higher investment per family is generally required.

The most frequent answer (almost 30%) among the respondents that do not want a GR on private buildings is the potential increase of humidity inside the building, followed by the high installation (22%) and maintenance (21%) costs. More than 5% of the partecipants provide "Other" reasons not to install GRs, and among them, there is a high percentage of partecipants that do not want a GR, because they already have, or they are planning to install, a photovoltaic system. It is interesting to note this high percentage of answers, since the specific question regarding the preference between GRs and solar panels was only asked later. When the specific question was asked, the majority of the partecipants (more than 70%) declared their preference for solar panels.

With the aim to investigate the potentianl reasons that could drive to the installation of GRs, we asked the participants how they thought the value of the house could increase when installing a GR. Only 14% of the respondents do not believe there could be any increase in value, while 13% believe that the value of the building could rise by more than 10%.

The final question addresses the variation of interest in having a GR after the lockdown situation we experienced worldwide during the pandemic in 2020. Most of the partecipants share that their interest in installing a GR would increase in the case of a new pandemic situation, while for 40% of the respondents the interest would remain the same.

3.4. WTP in relation to socio-demographic characteristics

This section aims to investigate the interest in having GRs and the WTP for them, both on public and private buildings, in relation to socio-demographic characteristics and house classification. Fig. 4 illustrates through heat maps the relation between the interest or WTP for GRs (main columns of Fig. 4) and the different classes (i.e., possible answers) of each socio-demographic question (rows of the heat maps). For each question related to the WTP, each class has been normalized, meaning that the number of respondents in each cell is divided by the total number of respondents for each class, and values are expressed as percentages (range from 0 to 100). Classes with less than 1% of the total respondents (i.e., less than 4 participants for each class) have been removed. If we consider, for example, the interest in having GRs on public buildings (1st main column) in relation with the gender (1st rows), we can say that 72% of the female population is very interested in having GRs on public buildings, while only 55% of the male population expressed the same interest. Females showed higher interest than males in having GRs both on public and private buildings, but the WTP seems not to be influenced by the gender, and both female and male participants are willing to spend less than 100 € per year for public GRs and to invest less than 5000 € for GR installation on their own building. Young participants (both 18-30-year-old and 30-45-year-old classes) declared a higher interest in having GRs in the urban environment, and the youngest (18-30-year-old class) manifested a higher WTP for the installation of GRs on private buildings, confirming results found by Chui and Ngai (2016). On the other hand, WTP for GRs on public buildings is not influenced by a citizen's age.

Contrary to what was expected, education level does not have a significant impact on interest and WTP for GRs, and people with the highest degree (i.e., PhD) are slightly less interested in having GRs and less willing to pay for the installation on their own buildings. On the other hand, participants holding a PhD are more willing to pay for GRs on public buildings, with more than 25% of them willing to pay between

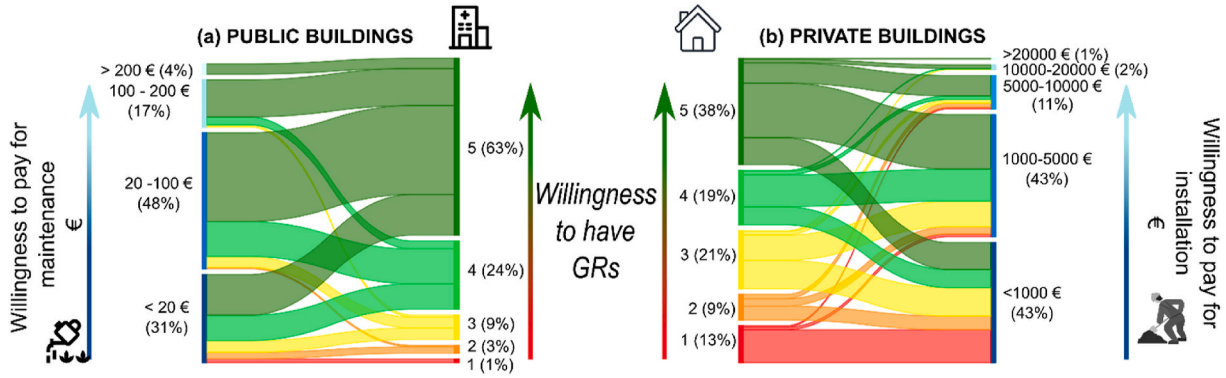

Fig. 3. Willingness to have GRs (on a scale from 1 to 5, where 1 is the minimum and 5 the maximum) on (a) public and (b) private buildings, in relation with the WTP for their (a) maintenance (in the case of public buildings) or (b) installation (in the case of private buildings).

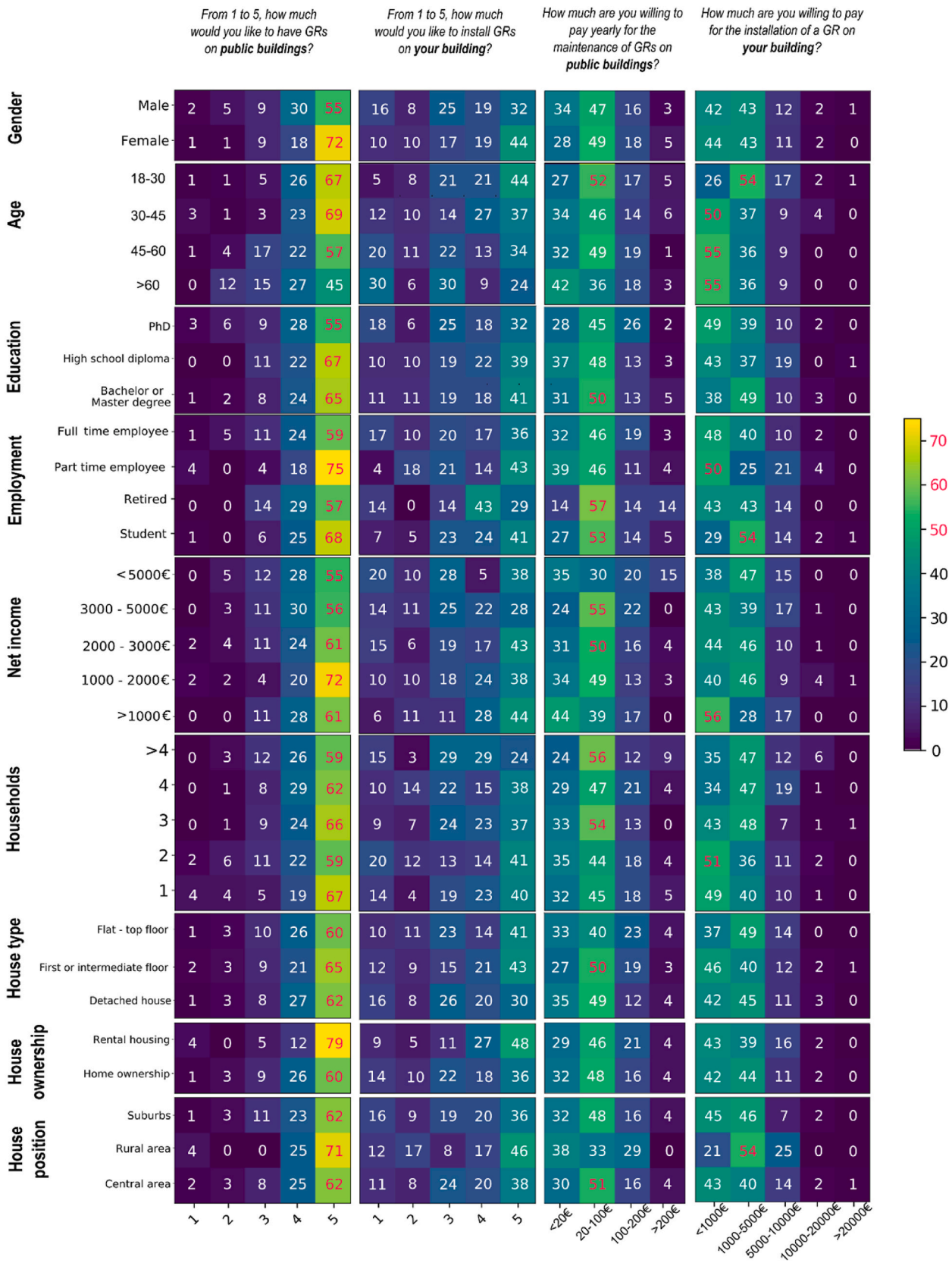

Fig. 4. Heat maps relating socio-demographic respondents' classes to the interest in having and WTP for GRs on public and private buildings. Values have been normalized for each class and are expressed as percentages. Classes with less than 1% of the participants have been removed since not representative. Values higher than 50% are highlighted in red.

100 and 200 € per year to maintain these NBS, recognizing the value of a large-scale GR installation. Part-time employees and students exhibit a higher interest in having GRs on both public and private buildings, probably recognizing all the potential benefits deriving from GR installation: 75% of part-time employees and 68% of students rated as 5 (scale from 1 to 5) their interest in having GRs on public buildings. Retired participants, on the other hand, showed a lower interest in having GRs than the other classes, but a surprisingly high WTP for GRs on public buildings, with 14% of them willing to pay more than 200 € per year for the maintenance of these NBSs. People that declared lower monthly net incomes showed a higher interest in having GRs both on public and private buildings. WTP, on the contrary, is strongly and directly related to the net household income, especially for public buildings: people with a net income of more than 5000 € are willing to spend more (15% of them declare a WTP more than 200 € per year for public GRs), while people that earn less than 1000 € per month exhibited a lower WTP than the other classes, for both public and private investment. Household dimension seems to influence both interest and WTP for GRs, but in an opposite direction: on one hand, in fact, participants with smaller households (3 or less family members) are more interested in public GRs, but, on the other hand respondents with larger households are more willing to invest in the installation of private GRs.

Beside socio-demographic characteristics, house type, ownership and location can also influence the interest and WTP of citizens. House type does not influence the interest and WTP for public GRs, while owners of detached houses are less interested in having GRs on their own buildings. This is probably due to the fact that they already have private and accessible green areas, such as gardens. Citizens renting a house or apartment showed a higher interest in GRs on both public and private buildings than respondents who own their home: 79% of the people renting a house declared the maximum interest for public GRs. On the other hand, no influence of the house ownership on the GR WTP is observed. Finally, it is interesting to notice that citizens living in rural areas are not only more interested in having GRs on both public and private buildings, but they also declared an overall higher WTP for the installation and maintenance of these NBSs. This is a counterintuitive result, since we expect that people living in rural areas are less affected by environmental issues that characterize urban areas, such as lack of green spaces or air pollution, and it is assumed that they are less interested in investing in solutions to mitigate these problems.

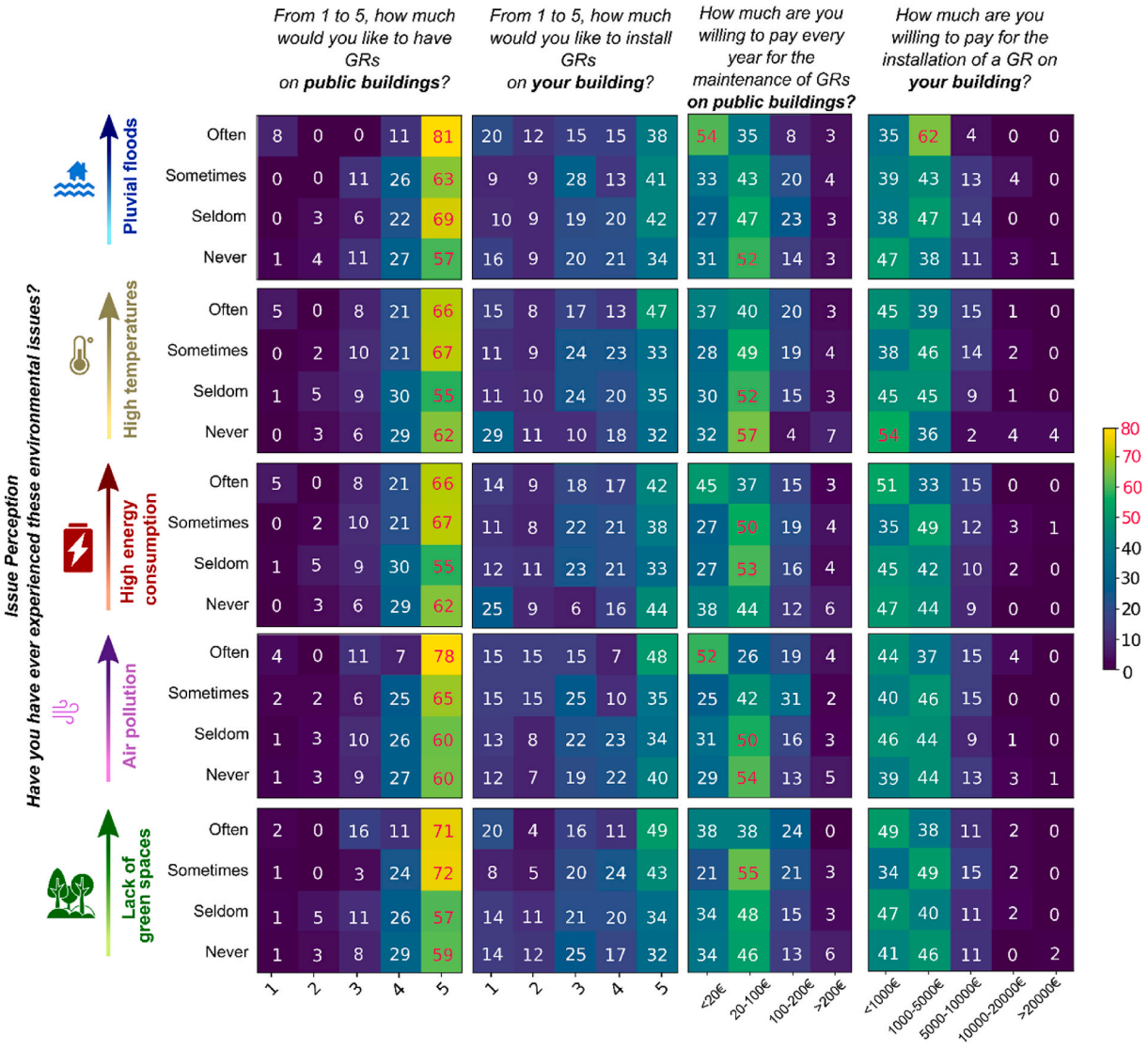

Fig. 5. Heat maps relating interest and WTP for GRs on both public and private buildings to the frequency perception of the most common environmental issues that characterize the urban areas (i.e., pluvial floods, high temperatures, high energy consumption for heating/cooling systems, air pollution and lack of green spaces). Values have been normalized for each class and expressed as percentages. The class "I don't know" has been removed since for each environmental issue only a few participants provided this answer, which cannot be considered as representative of the class. Values higher than 0.5 are highlighted in red.

3.5. WTP for GR installation and maintenance and environmental issues perception

In this section the interest in GR installation on public and private buildings and the WTP for installation and maintenance of these structures is related to the frequency perception of the most common urban environmental issues (i.e., pluvial floods, high temperatures, high energy consumption for heating/cooling systems, air pollution and lack of green spaces). Fig. 5 highlights potential connections and dependency with the support of heat maps. Prior exposure to pluvial floods seems to influence the interest in having GRs, especially on public buildings: more than 80% of the participants that have often undergone urban floods rated as 5 (scale from 1 to 5) their interest in public GRs. Moreover, this previous experience also directly impacts the WTP for GRs on private buildings: participants that have often undergone urban floods are willing to pay more than who has never had this issue. The increase of average temperature, which is a problem perceived by many respondents (See Section 3.2), seems not to affect the interest in GRs on public buildings, while it impacts the interest in private GRs: if on one hand, almost 50% or the citizens that had issues related to the temperature rise are very interested in private GRs (rating their interest as 5 out of 5), on the other hand, almost 30% of the people that have never experienced this problem are not interested at all in private GRs. These dynamics are, however not reflected on the WTP for GRs for both public and private building, which seems not to be influenced by this environmental issue. Although the high energy consumption for heating and/or cooling systems is often perceived as an issue, this aspect does not influence the interest in GRs. This could be explained by the fact that the thermal insulation property of GRs is not clear to respondents. On the other hand, it is interesting to note that more than 50% of the participants that have often experienced high energy consumption to regulate the temperature inside buildings are not willing to invest more than 1000 € for GR implementation on private buildings. Following the same way of thinking, also the WTP for public GRs is lower for this class than for the others, highlighting how the thermal insulation that can be achieved with GRs is not perceived as a benefit and it is not clear how this tool can insulate the buildings, limiting temperature variations.

GRs seem to be a potential solution for people who have often experienced issues connected to air pollution, especially if installed on public building: the interest in this case, however, does not translate in WTP, where those who experience air pollution more often are willing to spend less for the maintenance of public GRs. Finally, the lack of green spaces in the urban texture drives the interest in GRs, especially on public buildings, on which more than 70% of the citizens that have often or sometimes experienced this environmental issue, are very interested in GR installation. This aspect, however, seems not to influence the WTP, for both installation on private buildings and maintenance on public structures.

4. Advice for policy makers

Results derived from the survey presented in this work represent a valid support for stakeholders and policy makers in Sardinia and other Mediterranean insular contexts, contributing to the sustainable development of urban areas. The questionnaire clearly reveals that citizens have a correct perception of the frequency of the most common environmental issues, such as urban flood, increase of temperature, energy consumption, air pollution and lack of green spaces, and most of them are aware of the GR concept and potential benefits. Citizens know that GRs cannot completely solve all the environmental issues, but they are also aware of the high potential of this tool in limiting and contributing to solving many problems, while improving the quality of life.

The survey also shows a general interest in having GRs, especially on public buildings. On private structures, results are contrasting: the interest is lower, due to the high installation and maintenance costs and to the strong competition with the solar panels. Citizens that are willing and can afford a big investment are generally more interested in solar panels, valuing the economic benefits of this solution. Photovoltaic systems, however, are beneficial only in terms of energy savings, and do not provide any additional benefit for the community and the environment, unlike GRs. Combined GR and photovoltaic systems should be promoted by policy makers with financial support for the installation and included in the city development by urban planners. Moreover, it is important to highlight that not all roofs are suitable for GR installation: GRs are, in fact, generally installed only on flat roofs, where the performance is higher than on sloped ones (Chow et al., 2018; VanWoert et al., 2005; Getter et al., 2007). Solar panels, on the other hand, perform better on sloped roofs and consequently the most adequate solution should be chosen also depending on the roof slope and characteristics.

Moreover, considering the high interest in having GRs on public buildings and the declared WTP yearly for the maintenance of these structures, we can hypothesize a large-scale GR installation project at an urban or regional scale. Based on the questionnaire, it is, in fact, possible to derive from a weighted average among the participants, a minimum WTP for public GRs of 34 € per person per year. This value confirms what found by Zhang et al. (2019) in Beijing and it is lower than the estimated WTP in Portland, reported by Netusil et al. (2022). It is important to note that, although this value is based on the minimum WTP of each class range, it is obtained by distributing the survey mostly to highly educated people, who in a previous study have shown a higher WTP for NBSs (Chui and Ngai, 2016). If we consider a city like Cagliari, with almost 150,000 inhabitants and with nearly 42% of the population highly educated (high school diploma or higher qualification), 2.14 million € can be collected every year from this class of citizen only and invested in an urban scale GR implementation and maintenance on public buildings. If a 25-year project is foreseen, assuming a unitary GR installation cost of 150 €/m^2 and a maintenance cost of 10 €/m^2/year, it would be possible to cover a surface of 126000 m^2. At a regional scale, this approach would enable GRs to be installed and maintained for 25 years on a 1.5 km^2 surface, with the contribution of the highly educated class. Benefits in terms of flood mitigation, urban heat island reduction, increase of biodiversity and CO_2 sequestration, achievable with this large-scale installation of GRs would be undeniable and would support a resilient urban development aligned with the Sustainable Development Goals defined in the United Nation 2030 Agenda.

5. Conclusions and future developments

This work investigates through a choice experiment the perception of green roofs (GRs) in Sardinia and the willingness to pay (WTP) for the installation of these nature-based solutions on public and private buildings in the region. An online survey was developed using Google Forms and distributed via social media and via email thanks to the University of Cagliari mailing lists. The questionnaire is structured with five sections, collecting information regarding socio-demographic aspects, house type, perception of the most common environmental issues that characterize the urban areas, GR awareness and interest and WTP for GRs on private and public spaces. The Sardinia region has been chosen as a case study representative of the Mediterranean areas. The survey was completed by almost 400 participants in a few months. Respondents are well representative of the Sardinian population in terms of gender, geographical distribution, and number of household members, while educational level is intentionally bias, following the conclusions presented by Chui and Ngai (2016), which suggest that this group of people are the most willing to pay for NBSs. The use of social media and university mailing lists to distribute the survey, in fact, has led to a larger participation of people with a higher educational level than the average, while older and retired citizens are partially underestimated.

Results show a correct perception of the citizens of the most common environmental issues, and the awareness that although GRs do not completely solve the problems, they are a valid support in the mitigation of the abovementioned issues, and they provide additional benefits to

the urban environment. The high interest in the WTP for GRs on public buildings enable a project for the installation of these nature-based solutions at a large urban or regional scale to be foreseen. On the other hand, the interest and WTP for private GRs are limited, due to the high installation and maintenance costs and the rivalry with the photovoltaic systems. Solar panels, which in some cases are already installed on citizens' roofs and enable the energy costs to be reduced, are generally preferred to GRs. Although photovoltaic systems are financially more attractive than GRs, they do not contribute to the flood mitigation, to the urban heat island reduction, to the biodiversity increase nor to the CO_2 sequestration, which are important benefits for sustainable urban development. Combined systems, which integrate GR benefits with the energy production, should be strongly promoted in the community by decision makers, also depending on the slope of the roofs available for the implementation. The obtained results should, in fact, be taken into account by Sardinian policy makers and urban planners for the sustainable development of the urban environment, proposing solutions that could be not only appreciated, but also financially supported by the citizens.

Due to the limited number of studies investigating the GR's perception and WTP, and since they focus on different aspects, it is difficult to derive a direct comparison. Future investigations should involve multiple regions, characterized by different climatological aspects, and populations, with different socio-economic and cultural background, in order to better evaluate how these factors influence GR's perception and WTP.

Credit author statement

Elena Cristiano: Conceptualization, Methodology, Data collection, Visualization, Writing - Original Draft. Roberto Deidda: Conceptualization, Methodology, Supervision, Writing - Review & Editing. Francesco Viola: Conceptualization, Methodology, Supervision, Writing - Review & Editing

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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