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The role of green roofs in post COVID-19 confinement: An analysis of willingness to pay

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ABSTRACT

Urban population is becoming less likely to contact with nature. Yet, green infrastructure, as green roofs, provide multiple ecosystem services, as promoting citizens physical and psychological well-being. With the Coronavirus 19 world pandemic public spaces, like parks and other recreational areas, were closed and most citizens were confined to their dwellings. In this context, the need for outdoor space in the housing environment became more necessary than ever. This study is based on a survey performed to citizens living in 35 different countries to identify their access and value given to existing green areas in the home environment during and after confinement, and their willingness to pay (WTP) for an accessible green roof. Results indicate that 68% of respondents missed having a garden during the confinement and the outdoor space value increased after the confinement. Most are willing to pay for a medium sized accessible green roof and their WTP increases if the green area is bigger. WTP for medium sized green roofs is higher in other countries than in Portugal but not significantly different for larger green roofs. To promote private investment in green roofs, citizens WTP should be considered when designing new urban green infrastructure incentive policies.

1. Introduction

The world urban population has been increasing significantly since the 1950s. In 2015, the European urban population became almost 75%. The numbers of the urban population are even higher in Latin America and the Caribbean with 80% and in North America with 82% [1]. In urban centres, the tendency is to live in flats with limited access to outdoor space. In 2018, almost half (46%) of the European Union (EU-27) population lived in flats [2]. However, dwelling sizes vary significantly from country to country. New homes in the USA and Australia are on average close to 200 m² while in densely populated areas of Hong Kong, China and Russia the average new home can be four times smaller [3]. In Portugal, dwellings have on average 100 m² and two bedrooms [4].

The modern lifestyle is associated with chronic stress, insufficient physical activity and exposure to anthropogenic hazards, as air pollutants, environmental noise and heat [5]. Human health and environmental quality are closely linked [6]. Urban green spaces as parks and residential green areas can help to promote mental and physical health providing psychological relaxation and stress alleviation [7]. Nature has a restorative effect on human beings, helping to recover from attention fatigue and stress [8]. Frequent contact with green spaces has also significant benefits on the well-being of its users [9].

In 2020, the Coronavirus 19 pandemic spread all over the world. Most countries closed non-essential businesses and recommended residents to stay at home. Within the confinement restrictions, public parks and other recreational areas were closed to avoid concentration of people and gatherings. Citizens were limited to the space of their dwellings most of the time and the need for outdoor and open space in the housing context became more necessary than ever.

The EU the Biodiversity strategy 2030, as part of the European Green Deal, aims to prevent the loss of biodiversity and ecosystem services in the urban environment through the integration of green infrastructure [10]. In fact nature-based solutions result with several environmental, economic and social co-benefits that may help in the transition towards urban sustainability [11]. Currently several municipalities, not only in Europe but around the world, are developing policies to encourage the implementation of nature-based solutions and green infrastructure in the urban context, including incentives to install green roofs [12].

In Portugal, for example a new monetary incentive was launched to
promote private investment in nature-based solutions, like green roofs and green walls, and minimize the impact of the economic crisis resulting from COVID-19 pandemic [13].

Green roofs enable covering roofs with vegetation, including a set of layers that protect the support and improve the system performance and can be classified as extensive, semi-intensive or intensive [14] depending on their weight, substrate thickness, vegetation types and maintenance needs. These systems have multiple associated environmental, social and economic benefits [15].

Green roofs also provide multiple ecosystem services [16]. They improve buildings energy efficiency [17,18], their acoustic performance [19–22], increase the in-service life of their envelope [23,24], add property value and are a property amenity [25,26]. And can be used as a natural greywater treatment system, helping to remove water pollutants [27]. Green roofs have also the potential to improve the urban environment when applied on a large scale. They contribute to the urban heat island mitigation [28–30], improve air quality [31–35], reduce noise pollution [22], contribute to water management [36–40], promote biodiversity [41,42] and citizens health and well-being [5], while fostering the recreational use and aesthetic enhancement [43].

However, the promotion of green roofs still faces some barriers as their installation and maintenance costs are usually higher than other traditional construction systems [44]. To overcome this economic barrier, green roofs social and environmental benefits must be promoted over individual economic interests [45]. Green roofs can have a positive net present value when their long-term benefits are considered [44, 46–51]. Therefore, it is important to determine the citizens’ preferences [52,53] and their availability to invest in green roofs [54].

Willingness to pay (WTP) is a marketing strategy to determine how much citizens are willing to invest in a certain good [55]. Few studies report the preferences of consumers and their WTP for green roofs. Zhang, Ni et al. analysed WTP for the use and maintenance of small urban green infrastructures (UGIs), including green roofs, and identified that the Guangzhou residents citizens give greater importance to the environmental problems as air and noise pollution [56]. Tam et al. focused on the benefits and costs that influence the WTP for green roofs among construction professionals and others in Hong Kong [57]. Vanstockem et al. refer to the aesthetics of extensive green roofs and how the stated preferences affect the WTP of Flemish citizens [58]. Zhang et al. investigated the WTP of Beijing residents for the benefits of green roofs in mitigating the urban heat island effect [59]. Teotónio et al. refer to green roofs accessibility and recreational benefit as factors influencing the WTP of Portuguese residents [54].

In 2020 the Coronavirus 19 pandemic changed our way of living. During the confinement in most countries, the access was closed to non-essential businesses and public spaces, like parks and other recreational areas. In this period most citizens became limited to the space of their dwelling. Therefore, the need for outdoor space in the housing environment became more necessary than ever.

This study aims to identify the access and value given by citizens to existing green areas in their home environment during and after being in confinement conditions due to COVID-19 pandemic and evaluate their willingness to pay for the integration of an accessible green roof in their building.

2. Methodology

The proposed methodology aims to evaluate the importance of accessible green spaces and identify the factors that influence the WTP for green roofs for people who were in confinement conditions due to the COVID-19 pandemic.

Data were collected remotely through an online survey between May and July 2020. This was answered anonymously using a link previously disclosed to the respondents. The target population was composed of individuals from all over the world who were recently in confinement conditions. A total of 556 randomly selected respondents from 35 different countries answered this survey.

The survey was structured in five sections (Table 1) including socio-demographic characterization, housing characterization, confinement conditions, green roof knowledge and WTP for green roofs. The WTP for green roofs was measured according to a methodology proposed by [55]. A scale of percentages of monthly rent or mortgage instalments was used for a better perception among different citizens.

The data were analysed using descriptive statistic and statistical analysis. Descriptive statistics was used to determine the tendency of results. The percentual results were analysed in each section. Statistical analysis was applied to evaluate which variables influence the WTP for green roofs in the context of the COVID-19 pandemic. Statistical analysis was carried out in two ways. The first considered the analysis of each dependent variable against each independent variable without considering the influence of the remaining variables (uncontrolled analysis). This entails the assumption that when evaluating the influence of each independent variable the remaining variables are constant. The second corresponds to the evaluation of the combined effect of all variables on the dependent variables (controlled analysis). The controlled analysis tends to be more informative. However, both methods were applied, as from the comparison between the uncontrolled analysis and the controlled analysis, some conclusions could be drawn on the variable’s interaction.

The dataset comprises 29 variables, 4 of which are dependent variables related to the respondents WTP (26, 27, 27.1 and 28), and the remaining 25 are potential explanatory variables (independent variables) as shown in Table 1. Additionally, some of the dependent variables were also considered independent variables of the others (e.g., variable 28 is independent of the remaining variables 26 and 27 are independent variables for the variable 27.1). This posed a modelling challenge in terms of the number of combinations to be analysed in an uncontrolled analysis. Additionally, two other aspects were considered, the type of analysis and the type of variables. The type of analysis included the correlation/association or comparison of group means. In the type of variables, all variables were considered categorical. While some were naturally categorical (e.g., variable 25) others have implicitly an order (e.g., variable 3) or the scale used for the replies does (e.g., variable 23). Regarding the former, the coding adopted for the categories influenced the results of the correlation/association analysis. The latter can be modelled as ordinal variables, which requires using algorithms distinct from the analysis considering them as categorical variables. Finally, most variables that have an implicit order (e.g. variable 6) were transformed into a scale discrete variable by adopting the mean value of the intervals used.

For the uncontrolled analysis, several tools could be used. Considering the original nature of the variables, these were modelled as ordinal or scale, which resulted in 210 pairwise comparisons between independent and dependent variables.

Regarding the controlled analysis, a regression modelling was adopted. Considering the nature of the dependent variables, the combined effect of the independent variables was assessed by developing logistic and ordinal regression models. In this analysis, the variables were assumed to be either categorical or ordinal, and the option of approximating to scale was excluded. Both the logistic and probit link functions were used and no interaction between the independent variables was considered. Since the goal of this research was to evaluate the variables influencing the willingness to pay for green roofs in the context of the COVID-19 pandemic and not to obtain a model with higher explanation power (better fit), other options in the field of artificial intelligence (e.g. artificial neural networks, support vector machines, cluster analysis, classification trees, random forest) were excluded.
### Table 1
Survey structure and variables classification.

| Section                        | Variable/Questions                                                                 | Response rating scale                          | Dependency Variable | Variable type      |
|--------------------------------|------------------------------------------------------------------------------------|------------------------------------------------|----------------------|--------------------|
| Socio-demographic characterization | 1. Age (years) 18-25; 26-40; 66-80; >80                                             | independent                                    | ordinal/scale        |
|                                | 2. Gender Male; Female                                                             | independent                                    | categorical          |
|                                | 3. Education Level Bachelor’s degree; Master’s degree; PhD                         | independent                                    | categorical          |
|                                | 4. Household inhabitants 1; 2; 3; 4; ≥5                                            | independent                                    | ordinal              |
|                                | 5. Inhabitants under 12 years old 1; 2; 3; 4; ≥5                                 | independent                                    | ordinal              |
|                                | 6. Household income No income; <500€; 500€ - 1000€; 1001€ - 2000€; 2001€ - 3000€; <3000€ | independent                                    | ordinal              |
|                                | 7. Income relative contribution 0%; 1-25%; 26%-50%; 51%-75%; 76%-100%               | independent                                    | ordinal              |
| Housing Characterization        | 8. Childhood residence City (<100.000 inhabitants); Large town (10.000-100.000     | independent                                    | ordinal/scale        |
|                                | 9. Childhood housing type Apartment; Single house                                  | independent                                    | categorical          |
|                                | 10. Current residence City (<100.000 inhabitants); Large town (10.000-100.000     | independent                                    | ordinal/scale        |
|                                | 11. Current country of residence List of all countries in the world                | independent                                    | categorical          |
|                                | 12. Current housing type Apartment; Single house                                   | independent                                    | categorical          |
|                                | 13. Current property size Studio; 1 bedroom; 2 bedrooms; 3 bedrooms; 4 bedrooms;   | independent                                    | ordinal/scale        |
|                                | 14. Property ownership Housing owner; Rented property                              | independent                                    | categorical          |
|                                | 15. Confinement weeks 0 weeks; 1-2 weeks; 3-4 weeks; 5-6 weeks; ≥6 weeks           | independent                                    | ordinal/scale        |
| Confinement conditions (COVID-19) | 16. Permanent residence Yes; No                                                    | independent                                    | categorical          |
|                                | 17. Relative/Friends with COVID-19 Yes; No                                         | independent                                    | categorical          |
|                                | 18. Useable green areas availability Balcony/terrace with plants; Garden; Green    | independent                                    | ordinal              |
|                                | 19. Useable green areas dimension 0 m$^2$; 0-2 m$^2$; 3-10 m$^2$; 11-50 m$^2$;    | independent                                    | ordinal/scale        |
|                                | 20. Garden need (in confinement) Totally agree; Agree; Indifferent; Disagree;      | independent                                    | ordinal/scale        |
|                                | 21. Value of outdoor space (after confinement) Totally agree; Agree; Indifferent;  | independent                                    | ordinal/scale        |
|                                | 22. Green roof awareness Yes; No                                                   | independent                                    | categorical          |
|                                | 23. Green roof as option to increase access to vegetation Totally agree; Agree;    | independent                                    | ordinal/scale        |
|                                | 24. Uses of green roof Observing; Exercising; Gardening; Reading/relaxing; Play    | independent                                    | categorical          |
|                                | 25. Reasons to discourage green roof installation Cost; Maintenance needs; Presence| independent                                    | categorical          |
|                                | 26. WTP for accessible green roof with 10-20m$^2$ (% monthly rent/mortgage) 0%;  | independent                                    | ordinal/scale        |
|                                | 27. Higher WTP if accessible green roof >100m$^2$ Yes; No                            | independent                                    | ordinal/scale        |
|                                | 28. Confinement influence on green spaces perception Yes; No                        | independent                                    | categorical          |

Fig. 1. Country of residence during the confinement.
3. Results and discussion

3.1. General characterization of the sample

This survey was answered by 556 respondents, where 66% were Portuguese residents and 34% were residents from other 34 countries around the world. (Fig. 1).

The respondents’ socio-demographic conditions are gathered in Table 2. Most respondents were adults in working age, from which 44% were between 26 and 40 years old and 43% were between 41 and 65 years old. The sample comprised 60% women and 40% men. Also, most respondents had a degree, where 29% obtained a bachelor’s degree, 36% a master’s degree and 28% a PhD. Only 7% of the respondents have less education. Therefore, respondents were expected to have knowledge of what green roofs are.

Households included normally 2 to 4 inhabitants, with a higher prevalence of households with 2 inhabitants (30%). Most households (69%) had no children under 12 years old. Only 15% of households had 1 child under 12 years old and 13% had 2 children.

The monthly household income was mainly above 1000 € with 38% having a monthly income above 3000 €. Only, 11% of the respondents earned less than 1000 €. The respondents were mainly workers and 54% contributed more than half to the household income. This demonstrates that most respondents can afford additional payment for accessing green areas.

Most respondents were raised in an urban environment (Fig. 2). 41% grew in a city with over 100,000 inhabitants, 29% in a large town and 16% in a small town. Therefore, it can be assumed that contact with nature wasn’t frequent during their childhood in the daily life of most respondents. Currently, more than half of the respondents (54%) live in cities and almost one third (28%) live in large towns. The trend of increasing urban population is observable in this study, given the increase in 13% of the population living in cities. A similar trend was obtained when comparing the housing typology during childhood and currently (Fig. 2). A similar percentage of respondents lived in apartments during their childhood compared to single houses, representing both 50% of the answers. When comparing these results with the current housing typology, it can be observed a 21% increase of apartment residents. This demonstrates that the tendency is to live in dwellings with less outdoor space. Also, most respondents lived in properties with 2-4 bedrooms, with a higher incidence of 3-bedroom dwellings (32%). 72% were owners of the property where they lived in and 28% were renting.

3.1.1. Confinement conditions

Most respondents (72%) were in confinement conditions for more than 6 weeks. Therefore, the period of confinement may influence future behaviour. During the confinement most respondents were living in their permanent address (90%). Also, during the time of this survey, most respondents were not yet aware of any family member or friend who had acquired the disease, as only 12% became aware of someone close to them who had COVID-19. The respondent’s confinement conditions are gathered in Table 3.

Regarding the presence of green areas in the home environment, it is observed that most respondents had a useable green area in their homes. One third had a balcony or a terrace with plants (31%) and another third had a garden (38%). But 27% had no green areas in their outdoor home environment. Also, green roofs did not prevail as green areas in the housing environment. Most respondents have indicated that their existing green areas are small. 10% had a green area under 2 m², 21% had access to an area between 3 and 10 m² and 14% have an area between 11 and 50 m². Although is important to notice that 28% of respondents had an existing green area with a significant size (>50 m²). Although most respondents mentioned the existence of a green area in their homes, many agreed with the fact that they missed having a garden in their home during confinement conditions. Also, most respondents agreed that their outdoor space at home is now more valued than before the confinement (Table 3).

Table 2 Socio-demographic characteristics of the sample (N = 556).

| Age (years) | (%) | Gender (%) | (%) | Level of education (%) | (%) | Inhabitants (%) | (%) | Inhabitants < 12 (%) | (%) | Income (%) | (%) | Contribution to income (%) |
|------------|-----|------------|-----|------------------------|-----|-----------------|-----|---------------------|-----|------------|-----|--------------------------|
| 18-25      | 26-40 | 8%         | 43% | Male                   | 40% | No studies       | 0%  | 1                   | 13% | 0%                     | 69% | 2%                      | 2%  | 1-25%                    | 6%  |
| 60%        |       | Female     | 60% | Elementary school      |     | 0%              | 2   | 30%                 | 15% | < 500€                 | 2%  | 0%                      | 1%  | -                      |
| 41-65      | 66-80 | 44%        |     | High school            | 4%  | 3                | 23% | 2                   | 13% | 500€ - 1000€           | 7%  | 26%-50%                  | 30% |
| 4%         |       | Trade school| 3%  | 4                     | 25% | 3                | 2%  | 1000€ - 2000€       | 24% | 51%-75%                 | 30% |
| 29%        | ≥ 5   | Bachelor’s Degree | 9%  | 4                     | 1%  | 1                 | 1%  | 2000€ - 3000€       | 28% | 76%-100%                | 24% |
| 36%        | ≥ 5   | Master’s Degree | 3%  | 4                     | 4    | 1                | 1%  | 3000€ - 4000€       | 28% | 76%-100%                | 24% |
| 28%        |       | PhD        |     |                        |     |                  |     |                      |     |                        |     |                         |     |

3.1.2. Green roof knowledge

As shown in Table 4, in general there is widespread knowledge of what green roofs are (90%). Also, 79% of respondents considered that it would be a good idea to have a green roof at home to increase their access to vegetation. However, most respondents gave preference to accessible green roofs, where they could read or relax (33%), do gardening (20%) or exercise outdoors (19%). However, some aspects still discouraged the respondents from installing a green roof, mainly due to its cost (30%) and maintenance needs (25%). Also, 19% referred to condominum issues, which may be influenced by difficulties in maintaining the building communal areas. In this case, the dampness and presence of insects were considered less relevant.

3.1.3. Willingness to pay (WTP)

The WTP and the perception regarding the integration of an accessible green roof at home are summarized in Table 5. When considering the integration of an accessible green roof with 10–20 m² in their homes, 53% of respondents were willing to pay 0.1%–2.5% of their monthly mortgage instalment, the minimum percentage possible. 27% is willing to pay a bit more, between 2.6% and 5% and only 7% are willing to pay 5.1% to 7.5%.

However, opinions were divided when the investment was to install a green roof with more than 100 m². 54% would consider investing in a bigger green roof and 46% wouldn’t be willing to pay more. From the respondents that would be willing to pay for a bigger green roof, 16% would pay 0.1% to 2.5% of their monthly mortgage instalment, 27% would pay 2.6 to 5%, and only 12% would pay 5.1% to 7.5%.

In general, being in confinement conditions due to the COVID-19 pandemic, made citizens change their perception about green spaces and their WTP for having a green roof at home.

3.2. Statistical analysis

Table 6 summarizes the results of the uncontrolled analysis. The variables that have a statistically significant positive correlation with the WTP for medium and larger green roofs are the household income, missing a garden during the confinement, valuing more the outdoor space after the confinement, the interest in having a green roof to...
increase access to vegetation and the reasons that discourage the installation of a green roof.

The results reveal that the following variables have no statistically significant effect on the WTP or on the perception of the green spaces value namely the: gender, household inhabitants (whatever their age), childhood living conditions (residence and house type), current house type and its size, location of the confinement, acknowledgement of friends with COVID-19. Also, contrary to what was expected the availability and size of useable green areas during the confinement, and the awareness of green roofs were not statistically significant on the WTP and perception of green spaces value.

One of the most surprising is the statistically significant negative correlation between the level of education and the WTP. This is even more surprising considering that the relation between the level of education and the type of housing and the income is statistically significant. This indicates that individual with higher education levels live proportionally more in apartments than in single houses and have larger incomes. A possible explanation is that this category of individuals is more used to live without green spaces, preferring other alternatives for spending their leisure moments.

Regarding the controlled analysis, the ordinal regressions with the WTP as dependent variables (variables 26 and 27.1) yielded equivalent results using the logit and probit link functions. Herein the results using the logit link function will not be presented to avoid excessive repetition.

Concerning the WTP for a medium size accessible green roof, the statistically significant variables were country of residence (11), acceptance of a green roof as an option to increase access to vegetation (23), uses given to a green roof (24), reasons to discourage the installation of a green roof (25) and the influence of the confinement on green spaces perception (28). Due to the multiple answers possible, the categories of variables related to the country of residence (11), acceptance of a green roof as an option to increase access to vegetation (23), uses of green roofs (24) and reasons to discourage installing a green roof (25) were statistically aggregated based on strength of the relation with the dependent variable to reduce the number of categories an avoid quasi-separation of data (unique cases when combining different variables). The variables related to the childhood residence (8), confinement weeks (15) and value of outdoor space after confinement (21) also had some categories statistically significant at a 0.10 significance level, indicating some influence. The resulting model is statistically significant with pseudo R-Square were 0.298 (Cox and Snell), 0.331 (Nagelkerke) and 0.154 (McFadden), and its prediction performance is detailed in Table 7.

The model for the WTP for a larger green roof was also statistically significant, with a pseudo R-Squared of 0.705 (Cox and Snell), 0.757 (Nagelkerke) and 0.454 (McFadden). The statistically significant predictors were the following variables: confinement weeks (15), uses of green roofs (24), reasons to discourage installing a green roof (25), WTP for a medium sized accessible green roof (26) and interest in paying for a larger green roof (27). Also, the variables regarding the current property size (13) and the dimension of useable green areas (19) have some categories statistically significant at a 0.10 confidence level. Table 8 presents the prediction performance of the model.

However, the ordinal regression model for the WTP for a larger green roof fails the test of parallel lines, which means that the assumption of proportional odds is violated. This implies that the coefficients are not constant for all categories of the dependent variable. As such, a

### Table 3
Interest regarding green areas in the home environment.

| Answer                | During confinement | After confinement |
|-----------------------|--------------------|-------------------|
| Totally agree         | Missed having a garden at home | Value more the outdoor space at home |
| Agree                 | 44%                | 55%               |
| Indifferent           | 24%                | 31%               |
| Disagree              | 9%                 | 2%                |
| Totally disagree      | 11%                | 1%                |

### Table 4
Respondent’s interest and knowledge about green roofs (GR).

| GR awareness (%) | GR at home (%) | GR uses (%) | GR installation discouragement (%) |
|------------------|----------------|-------------|-----------------------------------|
| Yes 90%          | Totally agree 46% | Reading/relaxing 33% | Cost 30% |
| No 10%           | Agree 33%        | Gardening 20% | Maintenance needs 25% |
|                  | Indifferent 12%  | Exercise outdoors 19% | Presence of insects 9% |
|                  | Disagree 5%      | Observing 13% | Dampness 12% |
|                  | Totally disagree 4% | Play with kids 13% | Condominium issues 19% |
|                  | Others 3%        | None 5%       | |

### Table 5
Willingness to pay (WTP) and perception regarding the integration of a green roof (GR) at home.

| WTP GR (10-20 m²) (%) | Invest in GR (>100 m²) (%) | WTP GR (>100 m²) (%) | Change in green spaces perception/WTP (%) |
|-----------------------|----------------------------|---------------------|------------------------------------------|
| 0% 13%                | Yes 54%                    | 0% 20%              | Yes 55%                                  |
| 0.1% - 2.5%           | 53%                        | 0.1% - 2.5%         | 16% No                                    |
| 2.6% - 5%             | 27%                        | 2.6% - 5%           | 27% No                                    |
| 5.1% - 7.5%           | 7%                         | 5.1% - 7.5%         | 13% No                                    |
| No answer             | 25%                        |                     |                                          |
multinomial logistic regression model was developed, which relaxes the existence of order in the dependent variable by adjusting an equation for predicting the probability for each category of the independent variable separately. The pseudo R-Squared obtained in this case is slightly higher than with the ordinal regression model, 0.765 (Cox and Snell), 0.822 (Nagelkerke) and 0.540 (McFadden). The prediction performance of the model is presented in Table 9.

With 366 replies, Portugal makes up 66% of the sample. As such, a complementary analysis was done splitting the data into replies from Portugal and all other countries, while excluding the country as a potential explanatory variable. To avoid excessive repetition, the results presented herein pertain to the controlled analysis. Furthermore, since some ordinal regressions fail the test of parallel lines, the results presented herein are only for the multinomial logistic regression models. Regarding the WTP for a medium size accessible green roof, the models’ accuracy is similar to the models for Portugal and other countries (Table 10). However, the models are significantly distinct. The variables statistically significant in the model for Portugal are: age (1),

### Table 6
Results of the uncontrolled statistical analysis.

| Variables                                                                 | Dependent variables                                      |
|---------------------------------------------------------------------------|----------------------------------------------------------|
| 26. WTP for GR with 10-20m² (% monthly rent/mortgage)                     |                                                          |
| 27. Higher WTP if GR >100m² (%)                                           |                                                          |
| 27.1 WTP for GR >100m² (% monthly rent/mortgage)                         |                                                          |
| 28. Confinement influence on green spaces perception                      |                                                          |
| 1. Age                                                                   |                                                          |
| 2. Gender                                                                |                                                          |
| 3. Level of education                                                     |                                                          |
| 4. Household inhabitants                                                  |                                                          |
| 5. Inhabitants under 12 years old                                        |                                                          |
| 6. Household income                                                      |                                                          |
| 7. Income relative contribution                                           |                                                          |
| 8. Childhood residence                                                    |                                                          |
| 9. Childhood housing type                                                 |                                                          |
| 10. Current residence                                                     |                                                          |
| 11. Current country of residence                                          |                                                          |
| 12. Current housing type                                                  |                                                          |
| 13. Current property size                                                |                                                          |
| 14. Property ownership                                                   |                                                          |
| 15. Confinement weeks                                                    |                                                          |
| 16. Permanent residence                                                  |                                                          |
| 17. Relative/Friends with COVID-19                                       |                                                          |
| 18. Usable green areas availability                                       |                                                          |
| 19. Usable green areas dimension                                          |                                                          |
| 20. Garden need (in confinement)                                         |                                                          |
| 21. Value of outdoor space (after confinement)                           |                                                          |
| 22. Green roof awareness                                                 |                                                          |
| 23. Green roof as option to increase access to vegetation                |                                                          |
| 24. Uses of green roof                                                   |                                                          |
| 25. Discourage GR installation                                           |                                                          |
| 26. WTP for accessible GR with 10-20m² (% monthly rent/mortgage)         |                                                          |
| 27. Higher WTP if GR >100m² (%)                                           |                                                          |
| 27.1 WTP for GR >100m² (% monthly rent/mortgage)                         |                                                          |
| 28. Confinement influence on green spaces perception                      |                                                          |
| NA not applicable; GR green roof; WTP willingness to pay.                 |                                                          |
| +/− statistically significant positive/negative relation between ordinal variables. |                                                          |
| * Statistically significant relation between categorical variables or between ordinal and categorical variables. |

#### Table 7
Observed versus predicted WTP for a medium size accessible green roof.

| Observed | Predicted | Percent Correct |
|----------|-----------|-----------------|
| 26       | 22        | 27              |
| 27       | 5         | 26              |
| 27.1     | 0         | 110             |
| 28       | 1         | 21              |
| Overall Percentage | 7% | 106% |

#### Table 8
Observed versus predicted WTP for a larger green roof (ordinal regression model).

| Observed | Predicted | Percent Correct |
|----------|-----------|-----------------|
| 26       | 104       | 5               |
| 27       | 9         | 27              |
| 27.1     | 3         | 12              |
| 28       | 0         | 1               |
| Overall Percentage | 28% | 11% |

#### Table 9
Observed versus predicted willingness to pay for a larger green roof (multinomial logistic regression model).

| Observed | Predicted | Percent Correct |
|----------|-----------|-----------------|
| 26       | 108       | 5               |
| 27       | 8         | 40              |
| 27.1     | 5         | 19              |
| 28       | 1         | 0               |
| Overall Percentage | 29% | 14% |

than with the ordinal regression model, 0.765 (Cox and Snell), 0.822 (Nagelkerke) and 0.540 (McFadden). The prediction performance of the model is presented in Table 9. With 366 replies, Portugal makes up 66% of the sample. As such, a complementary analysis was done splitting the data into replies from Portugal and all other countries, while excluding the country as a potential explanatory variable. To avoid excessive repetition, the results presented herein pertain to the controlled analysis. Furthermore, since some ordinal regressions fail the test of parallel lines, the results presented herein are only for the multinomial logistic regression models. Regarding the WTP for a medium size accessible green roof, the models’ accuracy is similar to the models for Portugal and other countries (Table 10). However, the models are significantly distinct. The variables statistically significant in the model for Portugal are: age (1),
education level (3), number of inhabitants under 12 (5), household income (6), income relative contribution (7), current property size (13), confinement weeks (15), knowledge of friends/relatives with COVID-19 (17), value of outdoor space after confinement (21), green roof awareness (23), uses of green roof (24), reasons to discourage investing in green roofs (25) and confinement influence on green spaces perception (28). Conversely, the variables statistically significant in the model for the other countries are: gender (2), number of inhabitants under 12 (5), income relative contribution (7), childhood housing type (9), current residence (10), useable green areas availability (18) and garden need during confinement (20). Comparing both models, the only two variables in common are the number of inhabitants under 12 and the relative contribution to the household income. Apart from these two, the Portuguese respondents are more connected with practical issues (e.g., uses and constraints of a green roof) whereas the respondents from the other countries seem to be more sensible to personal motivations (e.g., missing having a garden during confinement).

Regarding the WTP for a large size green roof (Table 11) the variables statistically significant in the model for Portugal are the variables 26 and 27 related to the WTP for a smaller green roof. It is interesting to notice how the WTP for a large green roof in Portugal builds up on the WTP for a smaller one and the availability to pay for more for a larger one. This basically means that the drivers for WTP are the same regardless of the size of the green roof. Considering the WTP for a larger green roof the variables statistically significant in the model for the other countries are: educational level (3), household inhabitants (4), childhood housing type (9), current residence (10), current property size (13), confinement weeks (15), value of an outdoor space after confinement (21), green roof as option to increase access to vegetation (23) and reasons to discourage the installation of a green roof (25). The drivers for the WTP for a large green roof in the other countries are mostly distinct from the WTP for a medium sized green roof. The only two common variables are the childhood housing type and the current residence. This inconsistency may be due to large economic, social, and cultural differences of the countries from which the replies were obtained.

4. Conclusions

This study provides an overview regarding the access and value given by citizens from different countries to existing green areas in their home environment, especially after passing through the confinement period due to the pandemic of COVID-19.

The sample is comprised by a high percentage of citizens with higher education and stable financial standing. As 93% had a degree either in the undergraduate and graduate level, it implies that they are aware of the value of green roofs. Also, the vast majority earned an adequate income. Indicating that they can afford additional payment for accessing to green areas. Also, most respondents have an urban background, and they tend to live in apartments in cities.

The confinement due to COVID-19 pandemic had a significant impact on these citizens opinion regarding green spaces. In fact, most respondents passed more than one month confined to their homes. Although most of them had access to a useable green area, 68% agree that they missed having a garden in their homes during the confinement. Also, 86% of respondents agree that they value more the outdoor space of their homes after the confinement. The perception of outdoor green spaces in the home environment has changed to most respondents after being in confinement, demonstrating their importance to the well-being of urban citizens.

This study tries to understand if and how much the respondents are willing to pay for the installation of a new accessible green roof in their homes. And if the confinement conditions had an impact on their perception and WTP for green areas in their homes. Most of the inquired citizens are aware of green roof systems (90%) and consider that they are a good option to increase access to vegetation in their homes. Also, most respondents are interested in accessible solutions where they can relax (33%), do gardening (20%) or exercise outdoors (19%). However, the cost (30%) and maintenance needs (25%) are still the reasons that would mainly discourage the installation of these greening solutions.

When investing in the application of an accessible green roof in their homes, more than half of the respondents are willing to pay at least 0.1–2.5% of their monthly mortgage instalment for a medium-sized green roof and 54% are willing to pay more for a bigger green area. Also, the WTP is higher when investing in a bigger green area. The results lead to the first conclusion that the WTP for green roofs in Portugal and the other countries are not substantially different. The proportions of replies in each WTP interval are similar in both cases, particularly regarding the WTP for a larger green roof. Concerning the WTP for a medium sized green roof, there is a higher proportion of individuals willing to pay more in other countries than in Portugal. However, looking at the statistically significant variables for each model of each group of countries, it becomes clear that the drivers for the WTP in Portugal and the other countries are distinct. When considering the WTP for medium sized accessible green roofs the Portuguese respondents are more concerned with the uses and constraints of a green roof, whereas other respondents from other countries demonstrate other personal motivations as missing having a garden during confinement. When considering the WTP for larger green roofs, in Portugal the drivers for WTP are the same regardless of the green roof size, while in other countries the drivers for WTP are distinct for medium and larger green roofs, being the childhood housing type and current residence the only two common variables. A possible explanation for these results is that while the perceived value of a green roof is constant to a certain extent, the economic, social, cultural, and other differences between the countries result in a distinct set of motivations supporting that same valuation.

The sample comprises mainly citizens with a degree and an adequate income. However, it would be interesting to understand the value given to green roofs by population living in urban areas with less education and income.

This study was performed while the pandemic was going on and the confinement was still a recent event, which implies that the sample was still craving for using green spaces. Further studies could be developed after the situation alleviate to determine if the WTP may change over time by carrying out further surveys within the next few years, when the situation alleviate and people can access green areas as before. Including face-to-face surveys and country-specific analyses, may also help to understand the socioeconomic factors influencing citizens WTP for

### Table 10

Comparison of the observed versus predicted WTP for a medium size accessible green roof multinomial logistic regression models for Portugal and other countries.

|         | Portugal | Other countries |
|---------|----------|----------------|
|         | Observed | Predicted      |            | Observed | Predicted      |            |
|         |         | 26 | 27 | 27.1 | 28 | Percent Correct | 26 | 27 | 27.1 | 28 | Percent Correct |
| 26      | 44 | 10 | 1 | 0 | 80.0% | 5 | 6 | 5 | 0 | 31.3% |
| 27      | 8 | 187 | 12 | 5 | 88.2% | 1 | 64 | 15 | 2 | 78.0% |
| 27.1    | 2 | 38 | 36 | 2 | 46.2% | 0 | 19 | 47 | 3 | 68.1% |
| 28      | 0 | 3 | 0 | 17 | 85.0% | 0 | 5 | 5 | 11 | 52.4% |
| Overall Percentage | 14.8% | 65.2% | 13.4% | 6.6% | 77.8% | 3.2% | 50.0% | 38.3% | 8.5% | 67.6% |
green roofs

WTP is a determining factor in the economic analysis of green roofs. Therefore, their potential economic value must be considered when designing local urban green infrastructure incentive policies to promote private investment in green roofs.

CRediT authorship contribution statement

Maria Manso: Conceptualization, Writing – original draft, Writing – review & editing. Vitor Sousa: Writing – original draft, Methodology, Investigation. Cristina Matos Silva: Conceptualization, Methodology, Supervision. Carlos Oliveira Cruz: Supervision, Validation.

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.

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Table 11
Comparison of the observed versus predicted willingness to pay for a large size green roof multinomial logistic regression models for Portugal and the other countries.

| Observed | Predicted |
|----------|-----------|
| Portugal | Other     |
| 26       | 26        |
| 27       | 27        |
| 27.1     | 27.1      |
| 28       | 28        |
| Percent Correct |              |
| 0.97%  | 1.1%      |
| 3.3%   | 4.0%      |
| 73.2%  | 90.9%     |
| 66.7%  | 99.9%     |
| Overall Percentage | 29.6% |

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