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Economic Value of Green Infrastructure and Quality of Life in Metropolitan Lima, Peru. Case: Districts Of Jesús Maria And Santiago De Surco.

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Abstract

The objective of the study was to economically value (WTP) the urban green infrastructure of two districts of Metropolitan Lima, Peru, through the contingent valuation method to quantify the willingness of an individual to pay for its improvement and conservation, as well as to evidence the relationship between temperature, urban green infrastructure and human welfare by districts. A hypothetical market was created and 267 respondents, selected by random sampling, were asked to answer a pre-tested questionnaire. The results revealed that 95% of the respondents showed a positive willingness to pay and the mean predicted willingness to pay per person was $6.77 per month. A logistic regression model was used to develop the relationship between the independent variables and willingness to pay. Most of the parameters accompanied by the econometric analysis developed the expected results. The districts of Jesus Maria (HDI=0.84) and Santiago de Surco (HDI=0.80) have moderate to high NDVI and low to moderate temperatures, located in a desert area, natural desert environment, with little rainfall. The valuation should be complemented through the framework of the cultural ecosystem because they are broad, diverse and multiple.

Keywords: valuation, green infrastructure, human wellbeing, districts

Introduction

The urban population of Metropolitan Lima, capital of Peru, has grown steadily in recent decades in a disorderly manner, from 84.5% in 1940 to 99.2% in 2020 in relation to the total population of the Lima region. Peru is considered the fifth country with the largest urban population in Latin America (United Nations, 2019). According to INEI forecasts (2020), by 2030 the total population of Metropolitan Lima will be urban. At the same time, in the last 20 years there has been a rapid urban densification in older districts such as Jesús Maria and Santiago de Surco due to the construction of large multi-family buildings, with an increase of 140.3% and 157.5% inhab/km2 respectively (INEI, 2020).

This rapid urbanization leads to the substitution of natural ecosystems by urban ecosystems, radically changing the natural landscape by artificial and impermeable surfaces, permanently covering the soil with artificial materials, totally or partially impermeable such as, asphalt, concrete and brick (Morabito, et al., 2018). Impermeability contributes to the progressive and systematic destruction of the natural landscape, reinforcing the magnitude of climate change, with the loss of fertile agricultural land and natural and semi-natural areas (such as the Rimac, Chillon, Lurin valleys). Likewise, it alters the balances between soil and air modifying the climatic conditions inside the city, known as Urban Heat Island (UHI) (Kong, Yin, James, & He, 2014; CVC, 2015; Morabito, et al., 2021).

Hence, urban green infrastructure has become an important component of the complex urban ecosystem, acquiring a new value and function. Its ecosystemic functions benefit the human population, where people living in dense cities, their quality of life depends largely on the quality of the urban environment, moving from being a mere decorative element to become an important element in urban planning (Coutts & Hahn, 2015; Green, et al, 2016; Zhang & Muñoz Ramirez, 2019; Zhang S. , Meerow, Newell, & Lindquist, 2019; Zhang, Yang, Zhang, Liu, & Wang, 2020). More studies on the benefits of green infrastructure, such as absorbing and blocking air pollutants and reducing haze pollution, absorbing and converting toxic substances, being used to reduce the concentration of atmospheric particulate matter and keeping the air fresh through photosynthesis, carbon sequestration, CO2, releasing Oxygen, O2, and other ecosystem services can be found in the literature (Setälä, Rantalainen, Pennanen, & Yli-Pelkonen, 2013; Selmi, et al, 2016; Liu & Shen, 2014; Garcia, Llausas, & Ribas, 2014; Park, Kim, Lee, & Jeong, 2017; Gomez-Moreno, et al, 2019; Eguia & Baxendale, 2019; Amaya, Esenarro, Rodriguez, Vega, & Lopez, 2021).

The benefits of urban green infrastructure are strongly linked to the structure, composition and distribution, being important and necessary for the development and quality of life of cities and the levels of welfare in some of the intrinsic attributes of the person such as health, education, recreation, walking, strolling, etc., Therefore, residents are showing increasing concern for the quality of the environment in their surroundings, considering urban green infrastructure as an authentic public service, as well as sewage, roads, schools, etc., essential for people's lives, essential for people's lives, both mental and physical (Ferrini Francesco, Fini, Mori, & Gori, 2020; Chongxian, et al., 2020; Kalfas, Zagkas, Dragozi, & Zagkas, 2020; Cuya, Amaya, Esenarro, Vega, & Gomez, 2021). Hence, if the benefits of urban green infrastructure are to be preserved its direct and indirect values must be incorporated into decision making (IPBES, 2019), breaking the loop whereby economic forces continue to drive its reduction or loss.

However, the enormous benefits of urban green infrastructure, in terms of use and non-use values, have so far in Peru, not been subjected to the empirical test of economic valuation or have hardly received the desired attention in both research and policy making, thus, little is known about the direct and indirect quantification of the indispensability of urban green infrastructure with specific regard to human well-being (Mohammad & Arfat, 2021). The moderation of high temperature conditions in the city, heat sink, reduction of heat islands or improvement of thermal comfort are also an ecosystem service provided by vegetation or green infrastructure (Valck, Beames, Liekens, Bettens, & Seuntjens, 2019); therefore, the objective of this study is to obtain opinions on the importance or economic value and contributions to the quality of life of urban green infrastructure present in nearby environments or within the places where the population lives or works as is the case of the districts of Jesús María and Santiago de Surco, using the contingent valuation method; bearing in mind that Metropolitan Lima is a city nestled in a desert, so its urban green infrastructure is not associated with rainfall like many other cities located in areas where rainfall generates the natural growth of vegetation in the city, with the exception of the agricultural valleys irrigated by the Rimac, Chillon and Lurin rivers, by the pre-Hispanic water channels of the Surco river and Huatica canal and the hills. These values are necessary to provide significant evidence to support policies aimed at the conservation of urban green infrastructure and biodiversity in general, guiding policy makers to make better informed decisions and encourage their conservation.

Materials and Method

The study was carried out in two districts of Metropolitan Lima (Jesús Maria and Santiago de Surco) located in the central zone or metropolitan core and close to the sea. The district of Jesús María has a surface area of 4.57 km2 , of which 62.283 hectares are urban green areas for public use, with an indicator of 9.27 m2/inhabitant, including squares (7.41 hectares), parks (37.77 hectares) and central berms of avenues (14.8 hectares). The surface area of Santiago de Surco is 34.75 km2, corresponding to green areas 598.78 ha, distributed in 227.94 ha to parks, 39.874 ha to berms, 38.196 to gardens and ovals and the difference to avenues, squares, etc. with an indicator of 6.43 m2/inhabitant (INEI, 2019). The universe is the occupied house-rooms in each district and the research sample was 267 (120 and 147 surveys applied in Jesús Maria and Santiago de Surco respectively). The data were collected between the months of October and November 2019, from people over 18 years of age who were present in the dwelling at the time of the survey. Both districts have 146,225 households (Jesús Maria 28,743 and Santiago de Surco 117,512 households) (INEI, 2019).

Figure 1. Distritos de Lima Metropolitana

Contingent valuation method

To achieve the proposed objectives, a contingent valuation (CV) study was designed and executed in 267 randomly selected households in the study area. The CVM is a survey-based technique in which a hypothetical market situation is created to obtain people's preference through the use of different payment vehicles (Zambrano-Monserrate, 2020). The payment vehicles used were voluntary payment, utility and self-assessed bills. The information from the CVM can play a very important role in decision making related to the efficient and appropriate use of environmental resources that will maximize the welfare of society. CVM techniques for the economic valuation of non-marketed environmental goods and services are fully consistent with standard neoclassical economics (Mitchell & Carson, 1989). A constructed market scenario is essential for a VC study. The CVM despite its limitations, is one of the effective methods for assigning value to public goods. Hence, we preferred the CVM to estimate the benefits of urban green infrastructure and to analyze the factors that determine the WTP declared by the improvement.

Econometric specification and measurement of WTP

For the analysis of data collected through VC surveys, the preferred econometric techniques such as Logit or Probit models are generally used due to their simplified functional form (Mohammad & Arfat, 2021). In this study, we used Multivariate Logistic Regression to estimate respondents' WTP for urban green infrastructure conservation since the data had a dependent variable with binary choice character. The Logit model has the form:

$$Z_i=\beta_0+\beta_1 X_{1i}+\beta_2 X_{2i}+\beta_3 X_{3i}+\cdots+\beta_n X_{ni}+\varepsilon \quad (1).$$

Where β_0 is an intercept term; the coefficients $\beta_1 \rightarrow n$, are respectively the slope parameters and inform how much the probability of occurrence of Z varies with a change in one unit of the corresponding independent variable, all other variables remaining constant. X_1, $X_{(2,)}$ X_3... X_n, are values that the

independent variables can adopt. Ɛ represents the disturbance term or estimation error. Z_i is the logarithm of the odds ratio in favor of paying for the improvement of urban green infrastructure in the two districts. In the present study, the above econometric model (equation-1) has been used to explain the factors affecting a household's WTP using the iterative maximum likelihood estimation procedure. To test the reliability and overall adequacy of the discrete choice model, the Chi-square test of the likelihood ratio has been used (Mohammad & Arfat, 2021).
To derive the probability of an event, the Odds ratio is used which for equation 1 is expressed as follows: pr{si} = 1/(1+e-z); where Z is the linear combination of equation 1. This model estimates the probability that the individual is willing to pay for the improvement of urban green infrastructure and this will depend on a set of descriptive attributes of that individual (occupation, educational level, income level, use of green infrastructure, etc.).
To estimate the average willingness to pay we apply Hanemann's (1984) model and then analyze the socioeconomic variables that affect the probability that a respondent will or will not accept the proposed payment. Assuming that the utility function is linear, then the mean willingness to pay (WTP) coincides with the median and can be obtained through the expression (Carson & Hanemann, 2005):

WTP_MEDIA 〖= [(ln (1+ 〗 e^(-Z) 〖)]〗 ^(-1) (2)

Where, β0 is an intercept and β1 is the coefficient of the supply variable (amount to pay) in the logit model. Then, the aggregate willingness to pay (DAPT) is obtained as follows:
DAPT = (DAPM) * TH (3) In Equation (3), (DAPM) is the average willingness to pay and TH is the total number of households in the study area.

5. Results and discussion

5.1 Surface temperature in the districts of Metropolitan Lima

In the city of Lima, there is a strip of land near the coastline under the influence of coastal winds and fog; then, further inland, a wide plain as an interface with hills and the first foothills of the Andean mountain range. These physical-geographical characteristics generate microclimates in the city of Lima, so the intensity of the heat islands will be nested in a microclimatic matrix of the city. The city of Lima is located latitudinally in a tropical zone, although its climate is recognized as subtropical,
With these characteristics in mind, heat islands in the city of Lima are not necessarily correlated with human industrial or transportation activities. The heat islands in the city of Lima correspond to the sites of greatest irradiation in the city as a result of solar radiation, as shown in Figures 1 and 2, results of the analysis of thermal band 10 of Landsat 8 images.
Since heat islands are sites in the city with high temperatures that generate thermal discomfort in the population, it is consistent to assume that the districts with higher surface temperature values will present higher thermal patches. Tabulated data were obtained from spatial analysis tools, an algorithm called "zonal statistic" of ArcGIS. District NDVI data were also obtained with the same tool.
The representative surface temperature information for the warmest season was obtained from the Landsat 8 image of April 22, 2019 (autumn). In contrast, the representative information for the cooler season has been obtained from a Landsat 8 image, dated November 10, 2014. Both images were cloud-free for the study area. Figure 2 presents the aforementioned information.

Distrito	**Código**	**IDH**	**NDVI-MAX-nov**	**MIN-abr**	**MAX-abr**	**MEAN-abr**	**MIN-nov**	**MAX-nov**	**MEAN-nov**
La Molina	L12	0.85	0.2	23.7	37.2	29.8	18.3	32.7	26
Lince	L14	0.84	0.0	23.1	32.7	27.8	20.9	28.8	25
Jesús María	**L11**	**0.84**	**0.1**	**24.7**	**31.0**	**27.6**	**21.1**	**26.8**	**25**

Magdalena del Mar	L17	0.83	0.1	22.4	30.4	26.8	19.1	26.6	25
Pueblo Libre	L21	0.83	0.1	25.8	30.8	27.7	23.1	26.8	25
Miraflores	L18	0.83	0.3	19.0	29.9	26.3	15.4	26.3	23
San Borja	L41	0.82	0.2	25.1	31.4	27.6	21.0	27.1	25
San Miguel	L32	0.82	0.3	25.0	32.9	27.4	20.9	28.8	25
Barranco	L04	0.82	0.1	20.8	28.9	26.7	16.7	25.8	23
Surquillo	L34	0.82	0.1	25.5	31.8	28.0	23.0	27.5	25
Breña	L05	0.81	0.0	27.4	31.3	29.0	24.1	27.6	25
Santiago de Surco	**L33**	**0.80**	**0.3**	**24.8**	**37.9**	**28.2**	**21.1**	**32.4**	**25**
San Luis	L30	0.79	0.2	26.6	32.4	29.0	23.0	27.8	26
San Isidro	L27	0.79	0.3	23.2	31.9	26.5	20.0	27.5	24
Lima	L01	0.76	0.1	25.9	33.2	29.2	21.8	28.3	25
Los Olivos	L39	0.76	0.1	26.0	34.4	28.2	21.6	29.5	24
Chorrillos	L09	0.76	0.4	19.5	38.2	28.6	15.3	32.3	24
San Martin de Porres	L31	0.74	0.2	24.3	34.4	28.3	19.5	28.1	24
Chaclacayo	L08	0.74	0.1	23.5	34.5	29.1	17.3	28.5	23
Santa Anita	L43	0.73	0.2	26.0	38.4	29.4	22.6	32.5	25
Rímac	L25	0.73	0.2	25.7	37.3	29.4	21.8	32.2	25
San Juan de Miraflores	L29	0.73	0.1	23.9	36.7	29.4	18.9	32.4	26
Comas	L07	0.72	0.2	25.0	39.1	29.5	19.1	31.2	24
La Victoria	L13	0.71	0.2	26.3	32.1	28.9	23.2	27.4	25
San Juan de Lurigancho	L36	0.70	0.1	22.6	39.4	30.1	20.6	33.4	25
Villa El Salvador	L42	0.70	0.2	23.4	34.9	29.6	18.4	28.6	25
El Agustino	L10	0.70	0.2	21.3	37.7	29.1	16.2	31.6	25
Lurín	L16	0.69	0.3	21.6	40.1	31.2	17.9	33.2	26
Villa María del Triunfo	L35	0.69	0.1	25.7	39.4	31.4	19.8	35.0	27
Ate	L03	0.69	0.2	23.3	38.9	29.8	18.2	32.8	25

Independencia	L28	0.69	0.0	25.5	38.8	29.1	21.4	32.0	25
Lurigancho	L15	0.68	0.2	20.4	39.4	29.1	17.2	33.8	24
Ancón	L02	0.67	0.3	19.5	44.5	32.4	9.6	39.3	25
Puente Piedra	L22	0.66	0.2	25.5	39.2	30.1	13.5	32.9	24
Carabayllo	L06	0.65	0.3	19.7	40.8	30.1	16.8	33.8	26
Pachacamac	L19	0.65	0.3	24.6	40.0	31.4	20.3	34.5	27
Cieneguilla	L40	0.64	0.2	22.5	38.5	30.3	18.5	34.6	26

Figure 2. Matrix of surface temperature analysis in relation to NDVI and HDI.

Figure 2 shows the relationship between maximum, minimum and average (°C) surface temperatures by districts in relation to NDVI (vegetation cover indicator) and HDI (human well-being indicator) values. Each column of surface temperatures has been colored with shades that differentiate the highest (reddish tones), moderate (soft greenish tones) and lowest (bluish tones) values. In the case of NDVI and HDI, the highest values have been colored with an intense green tone, the moderate values (yellowish tones) and the lowest values (violet tones). The districts with the highest thermal comfort are written in blue letters and the districts in which the high surface temperature levels would be causing thermal discomfort together with the lowest values of NDVI (vegetation cover indicator) and HDI (human wellbeing indicator) are written in red letters.

Figure 1 shows that the district of San Isidro (L27) is the one with the best thermal comfort conditions, since its temperatures are moderate, it has a high intensity of vegetation cover and a high HDI. This is followed by the district of Miraflores (L18), which also has high comfort (HDI), high vegetation cover intensity (NDVI) and comfortable surface temperatures, although somewhat colder; then Barranco, although its vegetation cover (NDVI) is lower. In the case of Jesús Maria (L11) and Santiago de Surco (L33), the former has a higher indicator of human wellbeing, lower levels of surface temperature and a lower vegetation cover index compared to Santiago de Surco. The higher temperature of the latter could be explained by the existence of open land or less urban coverage.

Figure 3 shows the vegetation cover in greenish tones. The presence of urban vegetation is notorious in the district of La Molina, although it is also a district with high heat cores in the surroundings of the urban coverage area. The antithesis is the district of Villa María del Triunfo, which, like La Molina, has high irradiation but minimal urban vegetation cover. The district of Santiago de Surco has a larger urban coverage area compared to Jesús Maria.

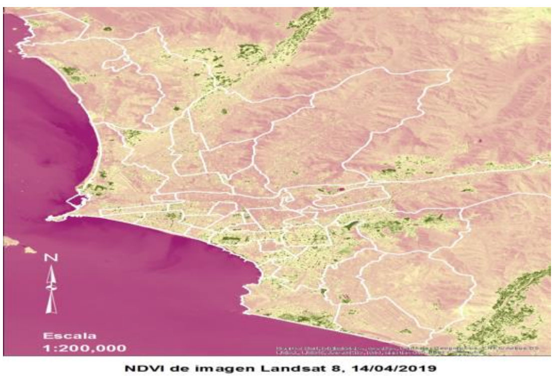

Figure 3. NDVI in Metropolitan Lima

5.2 Calculation of Economic Value:

5.2.1 Dependent variable.

The WTP offered to respondents is the dependent variable considered for the Logit analysis. It is dichotomous, since the possibility of accepting an offer can be "yes" or "no". It was considered "1" if the i-th household was willing to pay the WTP offered as a monthly contribution for the improvement of urban green infrastructure, and "0" otherwise. Ninety-five percent of the respondents in Santiago de Surco and Jesús Maria were willing to pay for the improvement of urban green infrastructure attributes and only 4.9% of the respondents were not willing to pay.

5.2.2 Explanatory variables

The assumption is that the decision a household makes in favor or rejection of a proposed WTP is the desire to maximize its expected utility. But this desire may be influenced by the socioeconomic and demographic characteristics of the residents, preferences over environmental concerns, length of residence, use and function of urban infrastructure, etc., which are considered as independent variables in the logit model.

a. Age of respondent (AGE)

AGE is a continuous variable indicating the respondent's age in years, it can have both positive and negative effect on the WTP decision of residents. That is, it does not have a well-defined relationship with respondents' WTP decision. The mean age of the respondent turned out to be 36.9 years for Jesus Maria and Santiago de Surco.

In this study, education has been considered as a discrete variable considering three educational levels: elementary, middle and high school. The majority of the people surveyed have higher education 77.2% in Jesús Maria and Santiago de Surco and the difference indicates having middle level education.

c. Number of family members (TF)

The number of family members (NFM) is a continuous explanatory variable, and refers to the total number of family members of a surveyed household. Family size is expected to influence a household's decision to accept or reject the WTP; that is, the larger the family size, the greater the pressure on household income and expenditures. Due to the high dependency ratio and limited sources of income, large households are often indifferent to paying for an improvement in urban green infrastructure. Therefore, the TF is assumed to have a negative influence on the household's acceptance of a WTP. 86.9% of the households in Jesús Maria and Santiago de Surco are made up of 4 members at most.

d. Monthly family income:

This variable has been considered as discrete and is assumed to have a positive relationship with the acceptance of a DAP; that is, the higher the monthly income, the greater the probability of a positive response to accept the DAP. Therefore, the relationship between income and WTP was proposed to be positive. About 20.2% of the families in Jesús Maria and Santiago de Surco have an income of less than 3 000 soles (US$ 890 as of October 2019) and 39.3% report having an income between 3 000 and 4000 soles.

b. Education (EDU)

Table 1

Descriptive statistics of socioeconomic variables

Variable	Jesús Maria and Santiago de Surco	
	Mean	Desv. Stand
Years of life	36.93	11.588
Educational level	2.77	0.640
Family Size	3.06	1.257
Occupation	5.66	2.10

e. Home ownership (PV)
In the case of the variable "home ownership" where the respondent lives, it is dichotomous. In Jesús Maria and Santiago de Surco, 64.4% say they are homeowners. It is expected that the decision of homeowners is to accept the WTP.

f. Time of residence (TR)
This variable has been considered as discrete and is assumed to have a positive relationship with the acceptance of a WTP; that is, the longer the time of residence in the district, the greater the probability of a positive response to accept the WTP. 37.4% live less than 3 years in both districts and 62.6% reside more than three years in the study area.

g. Distance to public green areas (D):
The distance variable has been included in the Logit model to find out its influence on residents' responses against WTP values. The distance to public green areas is an important variable and is measured in terms of the time it takes to walk from their home to the nearest public green area. On average, 46.4% of the residents of Jesús Maria and Santiago de Surco take up to five minutes to reach the nearest green area in their district and 29.2% take between five and ten minutes walking.

h. Frequency of use (FU)
Frequency of use is an important variable, it is expected to determine the respondent's knowledge of the benefit provided by the attributes of a public green area. In Jesús Maria and Santiago de Surco about 60% go at least once a week to a green area in their district and 20.6% make use of their public green areas at least once a month.

i. Benefits of public green areas
The environmental benefits or welfare obtained by the population of the districts of Jesus Maria and Santiago de Surco is given through their direct and indirect use and functions of great interest to citizens, by improving microclimatic conditions, acting as regulators of air and temperature exchange, control or reduction of noise pollution and in altering the composition of the urban atmosphere (Mittman & Kloss, 2014). With greater use, it is to be expected that citizens will become more aware of their value and the importance of urban green infrastructure, especially in times of health crises such as the current one. We measured physical, mental and social well-being through their most frequent uses and most relevant functions. Respondents were asked to indicate the three most frequent uses of urban green infrastructure. Residents in Jesús Maria and Santiago de Surco use it most frequently for recreation (80.1%), sports (42.3%) and reading (16.1%); that is, for their physical well-being, as well as for circulation and reading (mental and social well-being). Through these outdoor activities indirectly the population is becoming aware or developing their environmental awareness. In these same districts, respondents indicate as the most relevant functions of urban green infrastructure recreation, sports and the improvement of environmental quality through pollution reduction and noise attenuation (41.2%); that is, they benefit from aesthetic surroundings, increase their satisfaction with daily life and a meaningful relationship between human beings and green infrastructure. Additionally, through the shade of trees they are covered from ultraviolet radiation contributing to reduce health problems.

j. Value of WTP
The value of the WTP offered to a respondent is considered the most important independent variable that determines the respondent's willingness to accept or reject the WTP offered. Its response potentially reflects a household's maximum willingness to pay for the service/good proposed in the offer. We assume that budget constraint is a determining factor for a household's decision on their consumption preferences, as people tend to behave cautiously in case of having to pay for the improvement of urban green infrastructure and this is more relevant for any developing country like Peru. The average value of supply (WTP) for the sample households was estimated at 25 nuevos soles (US$ 7). Of the 267 sample respondents in both districts, about 95% were willing to pay the proposed offer prices (WTP) to enjoy the "offered" urban green infrastructure improvement and conservation. The remaining 5% rejected the offer. In other words, an overwhelming percentage of respondents in both districts were willing to support the improvement and conservation of urban green infrastructure.

5.3 Reasons for Not Supporting the WTP
Probing the reasons why respondents are not willing to pay for an improvement and

conservation of urban green infrastructure in their district they pointed out that it was the sole responsibility of the local government as it is a public area. The reasons that may explain this decision not to pay, is the lack of environmental awareness and education about the consequences of poor management of urban green infrastructure attributes, as well as the low income of some respondents (5%). Therefore, it can be suggested to expand awareness activities through educational institutions to educate people about ecosystem benefits to humans. This may also help in raising additional financial resources through increased property tax compliance.

5.4 Empirical estimates of the econometric models

Table 3 presents the results of the data collected through the Contingent Valuation (CV) survey and analyzed using logistic regression given that the dependent variable is binary choice (Bhat & Sofi, 2021). It shows that half of the explanatory factors showed statistically significant influence on the WTP behavior of the respondents. These results are significant considering the socioeconomic characteristics of the respondents and their preferences for urban green infrastructure improvement and conservation. It is interesting to note that four independent variables such as, Family size, Frequency of use, Reason for payment, Occupation and Recreation function, were statistically significant ($p < 0.05$). Through the bivariate analysis we observed that these five variables and additionally Home ownership and Time of residence, their Chi-square values are significant and with the Omnibus test of model coefficients we determined that these variables are significant ($p < 0.05$) for the logistic regression model (Table 2).

Table 2
Omnibus test of model coefficients

	Chi-cuadrado	gl	Sig.
Paso	35.773	10	0.000
Bloque	35.773	10	0.000
Modelo	35.773	10	0.000

The coefficients of the explanatory variables calculated are presented in Table 4.

Table 3

Summary of logistic regression results

Variables	B	Sig.
Family Size (TF)	-0.878	0.028
Monthly Family Income	-1.476	0.915
Frequency of use (FU)	1.254	0.004
Reason for Payment (MP)	0.485	0.027
Occupancy (EM)	0.462	0.020
Home Ownership (PV)	0.957	0.289
Sport Function (FD)	-0.948	0.211
Recreation Function (FR)	-2.569	0.049
Time of ResidenceTR)	-0.735	0.064
Use of sport (UD)	0.539	0.499
Pollution Reduction Function (RC)	0.482	0.521
Constant	-6.937	0.004

Table 3 shows that the recreation and sport functions (benefit to mental and physical health) are not significant variables for the logistic model ($p > 0.05$), they have an inverse relationship with the probability of accepting the WTP values offered, which would indicate that these urban green infrastructure functions are not important for the respondents, giving greater importance to the pollution reduction function, highlighting the important role of vegetation in the reduction of small particles that are suspended in the atmosphere and indicating that they are more likely to accept the WTP offered.
indicating that they are more likely to accept the WTP offered. Family size records the expected relationship, meaning that respondents with larger families are likely to pay less. It is also observed that the frequency of use of urban green infrastructure, employment (occupation), providing spiritual well-being through recreation and the reason for paying to continue practicing sports in urban green areas are in line with expectations. That is, the greater the use of urban green infrastructure, the more willing they are to pay for its improvement, and thus, continue to experience greater satisfaction in areas where the heat island of the city is lower due to the shade of the trees. Likewise, having a well-paid job, obtaining spiritual well-being and continuing to practice sports are associated with a higher probability of positive responses. In terms of the respondent's home ownership, there are no differences between being a homeowner and not being a homeowner. There are also no differences in terms of the most frequent use of urban green infrastructure. Monthly household income does not present differences in its levels and has no influence in model, in addition to a negative association, so its results are not conclusive as pointed out by Cazabon-Mannette, Schuhmann, Hailey, & Horrocks (2017). The negative sign implies that the older person is less willing to pay for improving and preserving urban green infrastructure. The Logit model is:

$$Z_i=\beta_0+ \beta_1 X_{1i}+ \beta_2 X_{2i}+ \beta_3 X_{3i}+\cdots+ \beta_n X_{ni}+ \varepsilon$$

where "e" is Euler's constant (2.497) a is the coefficient of the equation, and b are the socio-economic and socio-psychological variables that were found to be statistically significant for the model.

$$Z_i=-6.937 -0.878TF+1.254FU+ 0.485MP +0.462EM-2.569FR$$

And the predictive model is as follows:

$$Prob(si)= 1/(1+e^{-(Z_i)})$$

Replacing the values of Zi we have:

$$Prob(si)= 1/(1+e^{-(-6.937 -0.878TF+1.254FU+ 0.485MP +0.462EM-2.569FR)})$$

This logistic regression model expresses a likelihood ratio, understood as the quotient between the probability of success and the probability of failure, or in other words the quotient of the number of cases that present the characteristic (Yes to WTP) by the number of cases that do not present it.

5.5 Average Willingness to Pay (WTP)

To further explore the determinants of willingness to pay for the improvement and maintenance of urban green infrastructure, we estimate the average willingness to pay (WTP) taking into account the specification presented in equations 2 and 3. The CVM method is consistent with the estimate of the average willingness to pay of the surveyed households. Hanemann's (1989, cited by Loomis, Brown, Lucero, & Peterson, 1997) formula for non-negative random variables is used to calculate the DAPM.

$$DAP\_MEDIA = [(\ln (1+ e^{(-Z)})]^{(-1)}$$

In the DAPM we use the "n" variables that are incorporated in the final model due to their statistical significance, excluding the payment offer. The βn values correspond to the statistical coefficients returned by the program and the Xn values are the averages of each in the total sample. This way of calculating DAPM is an appropriate welfare measure when environmental quality is assessed through a simple dichotomous format (Cerda, Rojas, & Garcia, 2007).

Considering the mean values for Family Size (3.06), Frequency of Use (2.53), Reason for Payment (2.93), Occupation or Employment (5.66) and Recreation (1.64) we obtain a DAPM of 23.71 nuevos soles (US$ 6.77), the amount that each respondent is willing to pay to improve and maintain the urban green infrastructure of the districts of Jesus Maria and Santiago de Surco. This DAPM multiplied by all the families living in both districts (146,255) yields a total annual value of 3,467,880 nuevos soles (US$ 990,823).

Discussion

Much of the literature has investigated the case of urban heat islands in relation to vegetation cover in and around the city in cities with rainy climates, where there is natural vegetation (Morabito, et al., 2021). In contrast, Metropolitan Lima is located in a desert area with a natural desert environment, where there is no precipitation and no natural vegetation. All its vegetation is irrigated and therefore the city has a lower surface temperature compared to the desert environment, due to the higher albedo of the objects and the radiation and irradiation of the place. In some places in Lima, solar irradiation is high, therefore, depending on the albedo of the objects that cover the surface, the surface temperature will be higher or lower. The asphalt absorbs more radiation than the earth and sand in the daytime and at night its emissivity is higher. In Metropolitan Lima there are many small islands or nuclei of heat that vary during the day, months and years because they are subject to the microclimatic conditions of the city. Lima districts with HDI ≥ 0.79 have lower (bluish) or moderate (soft green) temperatures and 50% of these districts have a moderate to high vegetation cover indicator (NDVI). The district of Santiago de Surco has a high NDVI and Jesus Maria the lowest, whose urban area is fully consolidated.
Mitigation measures such as green walls and green roofs are feasible to implement in Jesús María (HDI=0.84) and Santiago de Surco (HDI=0.80), where there is greater purchasing power and there are large areas covered with vegetation. On the other hand, in other districts such as Villa Maria del Triunfo (HDI=0.69) and Independencia (HDI=0.69) it will not be possible to have green walls and roofs due to the high cost of design, installation, construction and maintenance. Therefore, urban green spaces should be provided by the State (Municipalities) and private with the aim of reducing socioeconomic inequity and inclusion, rights and responsibilities (Adegun, 2017).

Regarding the economic valuation of urban green infrastructure, the CVM allows us to estimate that there is a large majority of respondents who are willing to pay for improving and maintaining urban green infrastructure in the districts of Jesus Maria and Santiago de Surco at 95% and the percentage who responded No to the WTP of 5%, which is below those found by Bhat & Sofi (2021) of 27%; Flores (2018) of 16% and Gelo & Koch (2015) of 14. 7%, which is not surprising since the sample is random, including employed individuals, of all ages and higher educational levels and the object of valuation is a good that people are becoming accustomed to valuing because it is a public good.

As extremely useful information obtained with this method is the fact that public green areas are considered as assets that provide environmental services (non-use value) and contribute to the wellbeing of families for 80. 1% of those who answered Yes to the WTP, so they should be used more efficiently and not replaced by gray infrastructure, generating conflict with the population since 40% consider that urban green infrastructure reduces pollution and attenuates noise and use it daily or at least once a week 60.1% contributing to their physical and mental health (Chongxian, et al., 2020).

The mean DAPM in the present study of 6.77 US$ (0.08% of average monthly income) is higher than that found by Bhat & Sofi (2021) of 3.32 US$, by Martinez (2004) of 1.2 US$ and by Nielsen-Pincus, Sussman, Bennett, Gosnell, & Parker (2017) of 1.6 US$. But in turn, the DAPM of our study is lower than that obtained by Vasquez (1998) of 9.5 US$ and (Flores, 2018) of 9.05 US$. Likewise, the DAPM of the present study of 6.77 US$ is low in relation to the DAPM per household, for urban green infrastructure based on green façade, green roof and living wall (from 39 US$ to 53 US$) of Collins, Schaafsma, & Hudson (2017), demonstrating a favorable opinion to green policies, associated to green infrastructure that increases biodiversity. That is, the public attaches significant utility to increasing biodiversity compared to maintaining biodiversity or slowing the ongoing decline of biodiversity.

These results highlight two important aspects in the field of research on attitudes towards urban green infrastructure: i) it is relevant that residents express their support for its contribution to environmental quality (reduction of pollutants and noise attenuation);

ii) this attachment and identification of ecosystem services can facilitate environmental managers to implement communication strategies to improve or develop favorable attitudes that could lead to greater support for the ecosystem services provided by urban green infrastructure. To this we must add that residents reported that recreation, sports are the most common and most frequent uses, suggesting that they may also develop greater support for the services provided by urban green infrastructure.

Unlike the other variables considered in our analysis, such as household income, age, gender, and family size, which are generally not amenable to change by environmental managers, favorable attitudes are not static, but rather the product of social construction, which can be leveraged to increase the likelihood or number of people supporting local green infrastructure programs (Nielsen-Pincus, Sussman, Bennett, Gosnell, & Parker, 2017). The use of newsletters, websites, property tax bills, and utility bills can be an important strategy for environmental managers developing urban green infrastructure improvement and expansion programs.

Conclusions:

Each respondent is willing to pay 6.77 US$ to improve and maintain the green infrastructure of the districts of Jesús Maria and Santiago de Surco, which multiplied by all the families living in both districts gives a total annual value of 990,823 US$.

There is a positive willingness to pay to conserve public goods, such as public green areas, because society values this resource positively, mainly for its contribution to the environment, as a recreation/sports area, for its contribution to the physical, mental and cultural well-being of families, rejecting decisions to change green for gray.

The districts with the highest HDI have the highest NDVI and the lowest temperature levels.

Recommendations

This result opens the possibility to economically value the urban green infrastructure of the other districts, considering the HDI and through the framework of the cultural ecosystem for being broad, diverse and multiple, so that municipal authorities or environmental managers can implement more urban green infrastructure with an equitable sense in the long term, and improve the environmental quality of Metropolitan Lima.

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