Unpacking the complexity of nature’s contributions to human well-being: lessons to transform the Barranquilla Metropolitan Area into a BiodiverCity

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ABSTRACT

Rapid urbanization trends and urban lifestyles challenge urban populations to recognize ecosystems’ contributions to their well-being, and urban planners to integrate nature at the core of urban development. This study assesses the relationships between ecosystems and people in the rapidly expanding Barranquilla Metropolitan Area (BMA) and extracts lessons for its planning as a BiodiverCity. Using 22 interviews and 400 face-to-face surveys we evaluated: 1) the perception of positive and negative contributions of specific types of ecosystems to human well-being (HWB); 2) the importance and vulnerability of multiple ecosystem services (ES) and disservices (EdS); and 3) the relationships between ES, EdS and relational values (RV), and the influence of socioeconomic factors in providing HWB, using a Structural Equation Model (SEM). Open-ended answers in the survey showed that rural and certain natural ecosystems, such as wetlands, mangroves and tropical dry forest were the least valued ecosystems and included some EdS. In contrast, urban and peri-urban ecosystems, namely the river, beaches, crops, urban green, and backyards, were the most valued. Overall, regulating ES were perceived as critical, as well as important and vulnerable. The results of the SEM model indicate that HWB is not only explained by socioeconomic factors such as income and education, but also by ES. We argue that the necessary sustainable socioeconomic development of the BMA should be coupled with an urban planning that integrates ES and their contributions to HWB.

1. Introduction

In the last few decades, and for the first time in history, humans became a predominantly urban species. It is estimated that 4.22 billion people are currently living in cities, and projections indicate that 68.4% of the worldwide population will be urban by 2050 (United Nations, Department of Economic Affairs, Population Division 2019). By then, Latin America and the Caribbean will be the second geographic region with the highest percentage of urban population (87.8%) (United Nations, Department of Economic Affairs, Population Division 2019). Urbanization significantly affects spatial patterns of land use, with direct effects on nature and its contributions to people (IPBES 2019). Its adverse impacts on species richness and composition, and on the supply of ecosystem services (ES) along the urban-rural gradient, has been widely documented (McKinney 2002; Eigenbrod et al. 2011; Peng et al. 2017).

The shift towards more urban lifestyles has caused the so-called “extinction of experience”, or the reduction of the interaction’s humans have with nature (Soga and Gaston 2016). Human beings are intimately linked to nature in several ways, from the emotional level -biophilia hypothesis (Wilson 1984)-, to cognitive and experiential (Russell et al. 2013), human health (Frumkin et al. 2017) and human well-being (HWB) (MA 2005; IPBES 2019). As a consequence, increasing urbanization patterns and the subsequent dissociation of humans from nature is having unintended consequences for HWB (Bratman et al. 2015; Frumkin et al. 2017).

The ecosystem services (ES) framework emerged to make explicit the multiple and complex linkages between HWB and ecosystems (MA 2005). A complementary vision to the ES framework is the concept of nature’s contributions to people, which considers both positive and negative contributions of nature to people’s quality of life, recognizing the role of culture in defining these links (Diaz et al. 2018). ES were defined as “the benefits people obtain from ecosystems” (MA 2005) and were classified into three main groups: provisioning, regulating and cultural (SNEA 2014; Haines-Young and Potschin-Young 2018). More recently, growing interest has also been given to the various
negatively perceived nuisances produced by ecosystem functions (Díaz et al. 2018). Thus, ecosystem disservices (EdS) emerge as a concept to define the “functions of ecosystems that are perceived as negative for human well-being” (Lyytimäki and Sipilä 2009). In urban settings, the concept of “urban ecosystem services” has been established to highlight the contributions provided by urban ecosystems and their components to HWB (Gómez-Baggethun and Barton 2013). In this work we evaluate urban ecosystem services although we use the generic term ES.

HWB is a complex construct with a pluralistic meaning. It covers basic human needs, as well as economic, environmental, and psychological needs (Summers et al. 2012; King et al. 2014). The Millenium Ecosystem Assessment (MA) presented a framework to understand HWB based on five dimensions: basic materials, health, security, social relations, and freedom of actions (MA 2005). Despite the wide literature on ES since the MA, and some reviews on the contributions of ES to HWB (Summers et al. 2012; Blythe et al. 2020) only a limited number of studies have focused on the links between ES and HWB in detail, particularly in the Latin American urban context (Cruz-Garcia et al. 2017). Previous research explored the contributions of different types of ecosystems and their ES to HWB, for example in parks (Larson et al. 2016; Scopelliti et al. 2016), forests (Oh et al. 2017), blue spaces (Gascon et al. 2017) and protected areas (Naïdoo et al. 2019). However, few of them jointly analyzed the variation in ES supply across multiple ecosystem types (e.g. García-Llorente et al. 2020). Moreover, research on integrated analysis of both ES and EdS is very limited (e.g. Liu et al. 2018; Zimmermann-Teixeira et al. 2019; Tian et al. 2020).

Another issue that deserves attention is the non-natural aspects considered as determinants of HWB, such as personal, demographic, institutional, and socio-economic factors (Diener and Seligman 2004; Yang et al. 2013; Huang et al. 2020). Regarding socio-economic factors, research in both developed and developing countries has found that income and education highly influence HWB (Guardiola and Guillen-Royo 2015; Reyes-García et al. 2016). However, few studies have evaluated, with data and statistical models, the contribution to HWB of socio-economic factors together with an evaluation of a broad range of ES and EdS provided by diverse urban ecosystems. In one study in China, Huang et al. (2020) reported that socio-economic factors had the greatest impact on HWB and that only water retention and carbon sequestration played a significant role in the well-being of rural people. However, we have not found other studies that confirm this research.

Something similar can be said in relation to the novel concept of Relational Values (RV), defined as the preferences, principles, and virtues associated with relationships, both interpersonal and as articulated by policies and social norms, involving nature (Chan et al. 2016). Empirical studies have shown that RV are relevant for several groups of people worldwide and are an important factor determining the motivation to act for nature conservation (Himes and Muraca 2018). However, to our knowledge, there are no empirical studies that incorporate RV and ES assessment as contributors to explain HWB.

In this paper, we present empirical research conducted in the Barranquilla Metropolitan Area (BMA), located in the Colombian Caribbean, that covers the gaps mentioned above. The objectives of this research were: 1) to assess the perception of positive and negative contributions of specific types of ecosystems in the BMA to HWB; 2) to identify the level of perceived importance and vulnerability of these contributions; and 3) to estimate the contributions of ecosystems that people perceive are more important for their well-being by analyzing the relationships between ES, ecosystem disservices (EdS), RV and socio-economic factors with HWB.

We expect this study to be relevant not only for other scientists, but also for urban planners, and particularly those of the BMA, in relation to the BiodiverCities National Program announced by the Colombian government. This initiative would transform Barranquilla into the first BiodiverCity of Colombia, and it would further integrate the urban area with its biodiversity. BiodiverCity, a concept that links the terms “biodiversity” and “city”, has been conceptualized as an urban area that incorporates local and regional biodiversity and its benefits in its planning, as the axis and essential instrument of its socioeconomic development (Ministerio de Medio Ambiente y Desarrollo Sostenible 2019a). Considering the benefits of biodiversity, the concept integrates the ecosystem services approach, however, the formal definition of the BiodiverCity concept is under development. It is expected that in May 2022, the Program is structured, that is, the concept is formalized, as well as the objectives, actions, and indicators. The results of this study may be useful in shedding light on this Program, as it addresses the relationship between HWB and ecosystems in urban settings.

2. Materials and methods

2.1. Study area

The BMA is located in the north of Colombia (11° 6’24”N, 74° 58’52”W, 477 Km²) and comprises five municipalities: Barranquilla, Puerto Colombia, Soledad, Malambo and Galapa (Figure 1). The natural ecosystems
of the BMA include tropical dry forest, mangroves, the Magdalena river, wetland, and scrubland. The urban area includes ecosystems such as urban green spaces and backyards, and the peri-urban area is dominated by crops, pastures, beaches, and mosaics (formed by a mix of crops, pastures and natural ecosystems). Barranquilla is the core municipality of the BMA and the main Colombian Caribbean city in terms of population and economic activity (Galvis 2009).

In 2016, the BMA population was estimated to be 2,074,592 people, 99% of which were urban inhabitants (DANE 2010). Social conditions in the BMA present a great challenge for the municipal authorities since 21.7% of the population suffers from poverty and 2.8% from extreme poverty (DANE 2017). The ecosystems of the BMA have undergone profound transformation and degradation, requiring integrative approaches that consider long-term sustainability as well as the HWB of its inhabitants (Aldana-Domínguez et al. 2018).

2.2. Sampling methods and data collection

We compiled a list of 35 potential ES and 12 EdS, based on a literature review (Maass et al. 2005; Zhang et al. 2007; Dobbs et al. 2011; Escobedo et al. 2011; Vilardy et al. 2011; Balvanera et al. 2012; Gómez-Baggethun and Barton 2013; Mukherjee et al. 2014; Von Döhren and Haase 2015; Aldana-Domínguez et al. 2017) (Appendix 1). Then, we conducted fieldwork from June to November 2016, following two steps. First, we conducted 22 semi-structured expert interviews to select the most critical ES and EdS for HWB at the BMA. The result was a selection of the 19 most relevant ES and 5 EdS provided by the BMA ecosystems (section B in Appendix 2). Second, we collected 400 direct face-to-face questionnaires covering the five municipalities of the BMA. The sample size of this survey was representative at the 95% level, yielding a sampling error of less than ±5%. We distributed the questionnaires proportionally to the municipality population size (according to the Colombian census of the year 2005) and conducted 50% of them in rural areas (defined by the Municipal Landscape Plan- POT in Spanish). The population sampled was individuals over 18 years old randomly selected and contacted in public spaces, mainly streets, parks, squares, and houses.

We adapted and expanded the questionnaire used by Aguado (2016), who investigated these subjects in the Latin-American rural-urban context. The questionnaire included 5 main sections. First, we asked respondents about their perception on the positive and negative contributions of ecosystems to HWB using open-ended questions, followed by a question in which we inquired about their perception on these contributions by each main ecosystem type in the BMA (section A in Appendix 2). Natural areas evaluated in the surveys were: tropical dry forest, scrubland, mangroves, wetlands, Magdalena River, crops, pastures, urban green, beach and backyard. We used panels with names and photos of the

![Figure 1. Map of the Barranquilla Metropolitan Area (BMA) showing its main ecosystems.](image-url)
ecosystems, the ES and EdS to facilitate their identification and improve the communication with the respondents.

Next, we asked additional closed-ended questions to inquire about perceptions on several constructs, including perception of the importance and vulnerability of relevant ES and EdS in the BMA (section B in Appendix 2), self-perception of HWB using three statements by each dimension of HWB according to the framework proposed by the Millenium Ecosystem Assessment (MA 2005) (section C), and RV using four statements (section D). We used a Likert scale ranging from 1, strongly disagree, to 5, strongly agree, to value all the statements associated with HWB and RV. Thus, higher scores were indicative of a higher HWB and higher perception of RV. Finally, we asked about socioeconomic characteristics, such as education and income (section E). We conducted a pilot survey to 50 respondents to test the suitability of the questionnaire and to improve its design.

2.3. Data analysis

2.3.1. Identification of positive and negative contribution of specific ecosystems to HWB
We classified 2990 positive and negative open-ended responses into ecosystem services typologies. We grouped positive contributions in provisioning, regulating, and cultural ES categories (Haines-Young and Potschin, 2018, SNEA 2014). Negative contributions were grouped in particular and coherent typologies. We counted the number of responses in each typology and then constructed descriptive figures, by type of contribution and ecosystem.

2.3.2. Identification of important and vulnerable ecosystem services and disservices
The importance of the ES and EdS was assigned by each interviewee in a range from 0 = not important to 4 = very important, then the average value for each ES and EdS was calculated. Vulnerability was established from the perceived trend of the availability of each ES and EdS in the last 10 years (increased, decreased, or unchanged), a decreased response was rated as -1, while the non-change as 0 and an increase like +1. Using the average values of importance and vulnerability, we classify ES and EdS into the following four categories 1) Critical, ES and EdS perceived as important and vulnerable (decreasing); 2) important but not vulnerable; 3) vulnerable but not important; 4) less relevant (neither important nor vulnerable) (Palomo et al. 2011; Iniesta-Arandia et al. 2014).

2.3.3. Exploring the contributions of ecosystems to HWB by estimating the magnitude of relationships between ES, EdS, RV and HWB, and the influence of socioeconomic factors
We used Structural Equation Modeling (SEM) approach to quantify the contribution of ES, EdS, RV to HWB. SEM is a statistical technique for multivariate data analysis that simultaneously tests causal relationships between observed (or manifested) and unobserved (or latent) variables. Literature supports covariance-based SEM as the most convenient methodology for theory and hypothesis testing, due to its confirmatory rather than exploratory nature (Hair et al. 2016; Amaya et al. 2021). SEM models have been used in ecology (Sandöm et al. 2013; Grace et al. 2016; Fischer et al. 2018; Wei et al. 2019), social sciences (MacCallum and Austin 2000; Balzano & Trinchera 2011), and social-ecological studies (Santos-Martín et al. 2013; Wakita et al. 2014; Felipe-Lucía et al. 2015; Cebrián-Piqueras et al. 2017). This analysis starts with a conceptual model representing the theoretical relations between latent variables (in our case: HWB, ES, EdS and RV). Structural equations allow evaluating the relations between the latent variables (Grace et al. 2012).

The SEM approach also evaluates the relations between a set of manifest variables and its corresponding latent variable through measurement equations. One or more manifest variables allow identifying each latent variable. The survey design guided the construction of the latent variables (i.e. the association between manifest variables and latent variables), which allowed testing the measurement of the hypothesized latent variables through the responses collected in the perceptions section of the survey. Figure 2 presents the SEM model tested to explore the mentioned relationships.

According to Figure 2, the HWB latent variable contains four manifest variables (i.e. freedom of action, basic materials, social relations, and health), which were built from the average of the statements obtained in the survey. We tested the inclusion of security in this factor; however, we could not find significant evidence to allow us to relate these two variables (i.e. security and HWB), based on the p-value in a previous SEM model. The relationship between security perception and HWB should be explored in further research, as this perception influences HWB in global south cities (Lucchesi et al. 2021). ES is a second-order reflexive latent variable, as it is observed through three different categories of ecosystem services, namely Provisioning, Regulating, and Cultural. Fishing, livestock, agriculture, and freshwater are ES associated with Provisioning. Water regulation, erosion control, soil fertility, and biodiversity maintenance are the manifest variables that allow observing the Regulating latent variable.
Local ecological knowledge (LEK), cultural identity, and environmental education are variables linked to a Cultural dimension of ES. Finally, the RV latent variable groups the four statements in this regard (My connection with nature is part of my spirituality (RV1), I am aware of nature wherever I am (RV2), My relationship with nature is an important part of who I am (RV3), I feel very connected to all living things and the earth (RV4), while EdS is observed through the perception of importance towards vector diseases and crops pest. We tested different SEM models to ensure the robustness of the analysis. For instance, we removed the Provisioning, Regulating, and Cultural ES categories, and tested the relationships between the HWB and RV constructs and all the 11 ES and 2 EdS. However, the model’s goodness-of-fit indicators decreased (Appendix 3), indicating that the model we proposed (Figure 2) better represents the data.

We used the DWLS (diagonally weighted least squares) method to estimate the SEM model and the CFI (Comparative fit index) and TLI (Tucker Lewis Index) indexes to test the overall model fit. The SEM literature widely uses these goodness-of-fit indexes (Hair et al. 2016) and considers acceptable fitted models as those with CFI and TLI values greater or equal than 0.9. We used standardized coefficients and $R^2$ values to assess the adequacy of including manifest variables in each latent variable and test the contribution of each latent variable to explain other latent variables.

In a second step, we estimated a SEM-MIMIC model (Multiple Indicators Multiple Causes) to test the influence of socio-economic factors on HWB and represent heterogeneity within the population (Hooper et al. 2008). The socio-economic factors we measured through the surveys were age, time of residence in the study area, occupation, educational level, and income (Appendix 2, section E). Only income and education were significant. For this reason, we used it as dummies variables and introduced them in the model as regressors on the HWB latent variable. We estimated all models using the R software (R Core Team 2013) and its Lavaan package for SEM models (Rosseel 2012).

### 3. Results

#### 3.1. Positive and negative contributions of ecosystems to HWB: open-ended responses

Of the total open-ended responses recorded, 2879 (96.3%) corresponded to the contributions from the BMA ecosystems perceived as positive by the population, whereas 111 responses (3.7%) corresponded to contributions perceived as negative. Regarding the positive contributions, the BMA population perceives provision services as the most positive (46% of all positive contribution responses), followed by cultural services (29%) and regulating services (24%). At the individual level, recreational activities were the most frequently mentioned ecosystem service (23.5% of all positive contribution responses, Figure 3).

Regarding ecosystems, the Magdalena River is the most valued (13.7% of positive contribution responses), followed by the beach (12%), crops...
Primarily, the value of the Magdalena River is related to the provision of fresh water and wild food (fishing). The value of crop areas is linked to food provision, while both beaches and urban green were valued mostly for recreational activities (Figure 3).

(Figure 4) and urban green (11.6%) (Figure 4). Primarily, the value of the Magdalena River is related to the provision of fresh water and wild food (fishing).
From the interviews with experts, we identified the backyards as relevant spaces where relations between people and nature take place since these internal courtyards usually have fruit trees and maintain high biodiversity of birds and reptiles. These spaces are valued (9.3%) for recreation, social relations, and the benefits of regulation such as shade, air quality and pets (Figure 3). Pastures, which received 10% of positive contribution responses, are ecosystems valued mainly for keeping livestock.

The least valued ecosystems were wetlands (9.2%), mangroves (9.1%), tropical dry forest (8.7%) and scrublands (4.5%). The value of wetlands is linked to the provision of fishing (wild food) and water. Mangroves are valued for their contributions to air quality, biodiversity maintenance and fishing. Tropical dry forest is valued for air quality, biodiversity maintenance and to a lesser extent for providing charcoal. Finally, the scrubs are less appreciated, and their most mentioned benefits are biodiversity maintenance and air quality.

Regarding negative contributions, pollution is the most perceived (29.7% of all negative contributions responses, (Figure 5). Respondents perceived the wetlands as the most polluted ecosystem. This negative effect is perceived in almost all ecosystems, except for crops and pastures. The second most negative perception is the presence of dangerous animals, mainly in scrubs, tropical dry forests and wetlands (Figure 5). Illegal activities and places where thieves hide were also mentioned, concerning scrubs, urban green and tropical dry forest. Ecosystems identified as negative for HWB for being “mosquito houses” were wetlands, mangroves and scrubs. Other negative contributions less reported were fires in scrubs and pastures, as well as negative cultural appreciations on ecosystems considered unaesthetic and contemptuously referred to as monte in the Colombian Caribbean, such as the tropical dry forest. We found no negative perceptions about the backyards.

3.2. Identification of important and vulnerable ES and Eds

The critical ES (here defined as being important and vulnerable) were mostly regulating services, being air quality the most critical (Figure 6). Microclimatic regulation (which is understood as shade), soil fertility and water regulation were also identified in this group. Fishing and, to a much lesser extent, livestock were identified as critical too. Among cultural ES only cultural identity and local ecological knowledge
(LEK) are perceived as critical (Figure 6). Within the group of less important but vulnerable, biodiversity maintenance and erosion control were the only regulating ES identified, and Charcoal was the only provisioning ES. Pollen allergies are the least important of all the contributions evaluated, including EdS and ES, and are considered to have decreased (Figure 6). Agriculture, fresh water and environmental education were valued as important but not vulnerable. The only EdS in this group was vector diseases, considered among all the EdS and ES, like the one that has increased the most in the BMA (Figure 6). Finally, in the group of less relevant (less important and not vulnerable), we found mostly cultural ES (social relations, recreation, aesthetic value, scientific knowledge), as well as the EdS crop pests, fear of dark areas and damage to the infrastructure (Figure 6).

3.3. Exploring the relationships among ES, EdS, RV and HWB, and the influence of socio-economic factors to HWB

The SEM model presents an adequate fit since the CFI and TLI fit indexes are greater than 0.9, as recommended by Hu and Bentler (1999). All coefficients included in the measurement model are statistically significant at the 95% confidence level. Also, they are highly reliable because the standardized coefficients are between 0.359 and 0.841 (Table 1).

From the four HWB dimensions, freedom of action is the one with the highest factor loading (St. coeff = 0.813), followed by basic materials (St.coeff = 0.783), health (St.coeff = 0.73), and social relationships (St.coeff 0.69). The data supported the hypothesis that the three considered components adequately represent the ES latent variable. Provisioning services have the highest factor loading (St.coeff = 0.765), followed by cultural services (St.coeff = 0.657), and regulating services (St.coeff = 0.499). The predominant loading from the EdS factor is the vector disease variable (St.coeff = 0.841), followed by crop pest (St. coeff = 0.620). The RV factor appears to be unidimensional, highlighting that all the statements significantly contribute to measuring this latent variable. A high value in the RV variable reflects an individual who recognizes nature as part of his spirituality, considers nature important for his/her life, and feels connected to earth and living things.

As mentioned in the methodology section, we used the SEM-MIMIC approach to assess the effect of education and income on HWB. We found that by
including these two socioeconomic factors the variance explained by the model improved to 36% (Table 2). The above supports the idea that, in the BMA, HWB is highly influenced by socioeconomic conditions because these relationships were highly significant. The model suggests that as the income increases the HWB also increases. To a lesser extent, the model shows that HWB is also higher as the level of education increases. However, interestingly, when controlled by these individual socioeconomic conditions, the influence of ecosystems on HWB decreases. Thus, the only significant latent variable that contributes to the HWB in our model is ES (St.coef = 0.441, p = 0.037). EdS and RV maintained their signs, although both turned out to be non-significant (Figure 7b).

4. Discussion

4.1. Most important ecosystems in the provision of positive and negative contributions for well-being

Our results show that the Magdalena River is the most valued ecosystem in terms of its positive contributions, and that it is valued mostly for provisioning ES, being fresh water and fishing largely recognized. A closer look at the order in which ecosystems are valued, after the Magdalena River, suggests that differences in perception exist across the BMA rural-urban gradient. In order of importance, a higher number of positive contributions were recognized in urban and peri-urban ecosystems such as crops, beach, urban green, backyard, and pastures (Figure 4). Respondents also identified a smaller number of negative contributions provided by these ecosystems. On the other hand, fewer positive, mostly regulating services, and more negative contributions were associated with natural ecosystems such as wetlands, mangroves, tropical dry forest, and scrubs (Figure 4). These results suggest that the BMA population does not fully appreciate these more natural ecosystems as important providers of positive contributions to their well-being, but instead providers of EdS.

4.2. The positive and negative contributions of the BMA’s ecosystems to well-being

Our results show that the population of the BMA perceives provisioning ES as the group that contributes the most to their well-being. This is in line with other studies that evaluate social preferences for ES (Pereira et al. 2005; Vilardy et al. 2011; Paudyal et al. 2018). However, other studies, in different contexts, found a preference towards regulating ecosystem services, such as air quality (Martin-López et al. 2012). One possible reason is that regulating ES might be harder to identify and more difficult to verbalize without prior guidance (García-Llorente et al. 2020). However, it stands out that even though regulating ES were the less valued group, when we analyzed the services separately, some of them, namely air quality and microclimatic regulation, were identified as critical (Figure 6). This highlights that context, among other aspects such as several socioeconomic factors, plays an important role in ES preferences. Despite previous studies have shown the influence of gender
in the perception of ecosystem services (Yang et al. 2018) we did not analyze if the HWB dependence of socio-economic factors, ES and RV is influenced by gender aspects. Likewise, we recognize that this research was based on social perceptions and that the use of other sources of information, such as indicators of the use of some ES, may be useful in future studies to deepen the understanding of the links between ES and HWB.

Open-ended responses showed that the most valued single ES are recreational activities, and that urban green and beaches are the ecosystems most related to this ES (as seen in Figure 3). Barranquilla has a deficit of green areas. The latest report available states that the city only has 0.89 m² of green space per inhabitant (Alcaldía Of Barranquilla 2012), in comparison with the international recommendation of 9 m² per inhabitant (World Health Organization-WHO 2017). Considering the above, we call attention to the importance of expanding and improving green areas, as the citizens strongly recognize these for their recreational needs, but also for social relations and...
microclimatic regulation (Figure 3). Furthermore, green areas also contribute to the health of the urban population (WHO 2017).

Regarding the negative contributions to HWB of ecosystems in the BMA, open-ended responses showed that pollution is the most important one. Pen-ended questions unveiled that the most important negative contribution of the BMA ecosystems to HWB is pollution. However, this EdS was not evaluated in the closed-ended questions of the survey because it was not included in our initial list made from the literature review. Most of the literature on EdS is more recent (Campagne et al. 2018) and it is a field under construction. Some of the deficits in the EdS concept are the lack of enough systematic information and inventories on EdS that allow their categorization, as well as the difficulty in distinguishing between negative effects of ecosystems due to anthropogenic sources (e.g. pollution) and negative contributions from ecosystems due to natural or ecological processes (e.g. vector-borne diseases), especially in highly human-transformed ecosystems (Von Döhren and Haase 2015). As well as ES are co-produced from the interaction of natural capital with other human related capitals (Palomo et al. 2016), EdS are also often co-produced and can emerge as side effects of ecosystem management (Liu et al. 2018).

4.3. What really matters for BMA’s population well-being?

The relationships between HWB and ecosystems are complex and context-dependent (MA 2005; Duraiappah 2011; Delgado and Marin 2016). HWB is a multidimensional phenomenon composed of several factors that allow having a good quality of life, which includes material, social, emotional, and psychological well-being, autonomy, and accomplishment, as well as ecosystem services as the basis to meet basic needs and capabilities that correlate with these dimensions (Summers et al. 2012; King et al. 2014). In this paper, we showed that when only nature related aspects are considered, in this case ES, EdS and RV, ES is the most significant contribution of ecosystems to HWB (Figure 7a). Furthermore, the results show that although the EdS negatively influence the HWB, the positive contributions of the ecosystems are much more recognized than the negative ones. ES also seem to be significantly more important for the HWB of respondents than RV according to the results of our model. In this sense, we argue that there is a difference in practice between ES and RV in contrast to what other studies have found (See et al. 2020) and concur with the need to further include quantitative approaches into RV research in order to increase the empirical evidence on RV and to improve the political legitimacy of environmental decision-making (Schulz and Martin-Ortega 2018). The lower contribution of RV to HWB, in contrast with ES, education and income, in this urban context, may be a consequence of the predominantly urban lifestyle of the inhabitants of BMA, which in many other places has caused a reduction in the experience with nature (Soga and Gaston 2016). This idea is also supported by the fact that regulating ES, which are the least tangible, are also the least perceived.

According to our model, when socioeconomic factors are taken into account, ES explain HWB to a lesser extent than socioeconomic variables such as income and education (Figure 7b). This result is in line with previous studies in China that have found that socio-economic factors had the greatest impact on HWB compared to ES (Huang et al. 2020). This result isn’t surprising as income and education have been recognized for decades to shape human well-being (Diener et al., 1993; MA 2005). The high influence of income and education on the HWB suggests that further studies should evaluate the mediating and moderating effects of other indicators of socio-economic status, such as gender, age and economic activity. The value that people give to urban nature is also mediated by social and cultural norms, institutional and financial capacity, past experiences, health issues, and other variables such as time spent in contact with nature (Keeler et al. 2019), among other aspects, which were not taken into account in this study. Future studies may address these issues. Moreover, this result should not be taken as broadly applicable, as it may well be the case that after a certain level of ecosystem degradation, with few ES remaining, these may become more important for HWB than income or education (Raudsepp-Hearne et al. 2010). Further research in the BMA could also benefit from using inductive approaches to measure HWB, given its context-specific character (Fagerholm et al. 2020).

4.4. ES and EdS perception as important inputs for the planning of the BMA

Regulating services have been barely included in decision-making frameworks by the difficulties in measuring them and in identifying the pathways by which they generate short-term benefits for people; nevertheless, they are fundamental to maintaining the integrity of the biosphere, human safety, and the provision of most other ES (Sutherland et al. 2018; González-García et al. 2022). In the hinterland of Barranquilla, forest ecosystems and wetlands have been degraded by several infrastructure and urbanization projects (Schubert et al. 2018; Rojas et al. 2020). It is urgent to conserve, to better manage,
and to restore the natural ecosystems in the BMA that supply important ES for well-being, especially regulating services, since they have undergone drastic transformations throughout history, particularly ecosystems such as tropical dry forest and mangroves (Aldana-Domínguez et al. 2018). Air quality, the most vulnerable ES in our study, should be a priority for the planning of the BMA, through the conservation and management of tropical dry forest and urban green, as well as through the reduction of sources of pollution and the monitoring of air quality. Additionally, since the population barely recognizes the contribution of regulating services to their well-being (Figure 4), we suggest strengthening environmental education on ecological processes.

Among EdS, vector-borne diseases were perceived as one of the most important ones. In the BMA, the main vector-borne diseases are dengue, and, more recently, zika and chikungunya (Padilla et al. 2017). In this study wetlands, mangroves and shrubs (Figure 5) were the ecosystems mostly associated with this EdS due to the presence of mosquitoes. However, previous EdS assessment conducted in BMA found that the highest incidence of vector-borne diseases occurred in urban areas. The above suggests that landscape planning should consider other socioeconomic aspects (e.g. inadequate management of water storage) that might be promoting the co-production of such EdS (Aldana-Domínguez et al. 2019).

In order to adequately integrate ES into urban planning, it will be necessary to differentiate among diverse social groups, given the importance of heterogeneity within social contexts in determining people’s positioning within social groups, the ways in which they engage with nature and the meanings they assign to greenspaces (Dinnie et al. 2013; Mandle et al., 2021). Official citizen surveys applied in Barranquilla have shown that, even though among respondents the level of satisfaction with urban green areas has had a positive tendency throughout the years, levels of satisfaction are significantly higher for respondents with high socioeconomic backgrounds (84%), whereas respondents from low socioeconomic backgrounds show lower levels of satisfaction (44%) (BqCV 2017). Inequitable access to urban green areas influences the enjoyment of ES and therefore well-being, with wealthier groups usually having more access to green spaces, trees, and higher plant diversity as compared to historically unprivileged social groups (Schell et al. 2020; Venter et al. 2020). This highlights the importance of advancing in the inclusion of equity and social and environmental justice considerations into urban greening and ES assessment (Anguelovski et al. 2020; Calderón-Argelich et al. 2021). Decision-makers must also tackle the challenge of implementing participatory approaches that bring together a broader range of stakeholders and institutions to co-produce knowledge that serves as input for the collaborative planning and design of urban interventions (Bryan et al. 2010; Reyers et al. 2015). Further research should explore the differences in perception of ES and EdS held by different groups in the BMA, which could ultimately be an important input for the planning and management of BiodiverCities and their sustainable and socially just development.

4.5. Towards a BiodiverCity

BiodiverCity, a concept that links the terms “biodiversity” and “city”, is a new concept in the scientific literature. The term has been used worldwide in the context of urban planning to name different strategies and projects concerned with green urbanization (Sykes et al. 2020). The policy community has also given increasing recognition to the relevance of biodiversity as the base for human development and well-being, as seen in the importance of biodiversity in the UN Sustainable Development Goals (Isbell et al. 2017).

To date, many cities have included biodiversity in their planning. For example, Leipzig created a “New Lake Landscape” in place of former open-cast mines, creating new urban green spaces and recreational facilities and generating economic opportunities based on tourism. Likewise, they improved the connectivity between the city and peri-urban and rural areas, focusing on water bodies, inter-community management of brownfields and biodiversity through green facades and urban gardens. Barcelona has invested in the regeneration and clean-up of the two main rivers that surround the city, and in combining social revitalization with the protection of biodiversity and food management in vulnerable areas of the city (naturvation project, https://naturvation.eu). Nevertheless, in the urban context, acknowledging the importance of biodiversity and its contributions to people is still a task in process.

The Colombian government announced in 2019 its plan to advance towards the creation of a National Program in BiodiverCities as an opportunity to highlight the relevance of natural ecosystems in the development of future sustainable cities. Barranquilla’s current Development Plan 2020–2023 contemplates a series of policies to support the goal of turning the city into one of the first BiodiverCities of Colombia. These policies aim to restore strategic ecosystems and hydric resources, to begin the city’s transition into a low carbon pattern and to increase climate change resilience (de Barranquilla 2020). However, it is not clear how this plan will be articulated with the other municipalities that comprise the BMA to guarantee a holistic management of the
different ecosystems surrounding the city, and how it will consider the social perceptions of these ecosystems.

Our results are relevant in this context given the lower social valuation of natural ecosystems in comparison with semi-natural ecosystems in cities or close to them. This represents a challenge for landscape managers and environmental authorities, who must also manage natural ecosystems to conserve biodiversity and guarantee the continuity in the provision of ES, especially of the regulating type. Conserving critical ecosystems such as wetlands and tropical dry forest in an urban setting like the BMA will only be possible if people perceive their contribution to biodiversity conservation and HWB. A city will become a BiodiverCity only if its managers and inhabitants recognize the importance of natural ecosystems and include them in the landscape planning and socioeconomic development processes by enhancing the valuation of ES. Consequently, it will be of paramount importance for the BMA BiodiverCity to create opportunities for environmental education and experiences in nature in order to increase people’s connection to nature, promote relational values and foster pro-environmental behaviors (Schultz and Tabanico 2007; Prévot et al. 2018). Furthermore, social activities in nature also hold the potential to enhance environmental stewardship, which might ultimately lessen negative effects of human lifestyles on ecosystems and increase positive ones (Chan et al. 2016). For instance, if the BMA population had more experiences in nature, it could contaminate less, thus reducing its contribution to the co-production of this EdS.

At the national level in Colombia, a BiodiverCity has been conceptualized as one that incorporates local and regional biodiversity and its benefits in its planning, as the axis and essential instrument of its socioeconomic development, but it lacks a formal definition (Ministerio de Medio Ambiente y Desarrollo Sostenible 2019b). We suggest this conceptualization can be nurtured from the results of this research, and accordingly, we propose the following definition: “a BiodiverCity incorporates local and regional biodiversity in its planning as a basis for maintaining human well-being, restoring and conserving its ecosystems and strengthening the links between people and nature”. As a city transitions to being a BiodiverCity, the contributions of ecosystems to the HWB, through the enjoyment of urban and natural ecosystem services should be reinforced.

5. Conclusion

This study shows how the population of the BMA perceives the contributions of different types of ecosystems to their well-being and extracts lessons for planning the forthcoming BMA BiodiverCity. The population recognizes ecosystems as providers of positive and negative contributions to their well-being, and place greater value on positive contributions such as recreational activities in urban green and beach areas. Increasing urban green in the BMA, specifically in the urban setting, should therefore be a priority for the future BMA BiodiverCity. The fact that in rural and mainly natural ecosystems (e.g. wetlands, mangroves, and tropical dry forest) less ES and more EdS are identified in comparison to urban ecosystems, suggests the need to facilitate access to these areas, as well as to implement environmental education strategies, as a means to increase people’s experiences in nature and foster awareness of nature’s values. These natural ecosystems are also important providers of ES identified as critical by the BMA population (e.g. air quality, microclimatic regulation and water regulation) and therefore should be sustainably integrated to the BMA BiodiverCity’s planning and prioritized for conservation. To our knowledge, this is the first study including empirical data on relationships between ES, EdS, RV and socioeconomic factors as contributors of HWB. We found that HWB is not only explained by socioeconomic factors such as income, and education, but also by ecosystem services, according to the social perceptions evaluated. These results stress the importance of aligning conservation and restoration endeavors for enhancing ecosystems contributions to people with human development and education goals. Further research to understand the relationships between people and ecosystems can provide important inputs for urban planning and guide the transition of cities into BiodiverCities.

Acknowledgments

We wish to thank all the people who were interviewed. We would like to express our gratitude to David Borge and Paola Garces for supporting the field work and Carlos Montes from the Social-ecological System Laboratory at the Autonomous University of Madrid for his support and guidance. All procedures were in accordance with the ethical standards of the Research Ethics Committee of the Autonomous University of Madrid under the approval number CEI 73-1325. All respondents gave their informed consent verbally.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Colombian Administrative Department of Science, Technology and Innovation-Colciencias under Grant [646-2014].
References

Aguado M 2016. Vivir bien en un planeta finito: una mirada socio-ecológica al concepto de bienestar humano [Doctoral Dissertation]. Universidad Autónoma de Madrid.

Aldana-Domínguez J, Montes C, Martínez M, Medina N, Hahn J, Duque M. 2017. Biodiversity and ecosystem services knowledge in the Colombian Caribbean: progress and challenges. Trop Conserv Sci. 10. doi:10.1177/1940082917714229.

Aldana-Domínguez J, Montes C, González JA. 2018. Understanding the past to envision a sustainable future: a socio–ecological history of the Barranquilla Metropolitan Area (Colombia). Sustainability. 10 (7):2247. doi:10.3903/su-1007227.

Aldana-Domínguez J, Palomo I, Gutiérrez-Angonese J, Arnaiz-Schmitz C, Montes C, Narvaez F. 2019. Assessing the effects of past and future land cover changes in ecosystem services, disservices and biodiversity: a case study in Barranquilla Metropolitan Area (BMA). Colombia Ecosyst Serv. 37:100915. doi:10.1016/j.ecoser.2019.100915.

Amaya J, Delgado-Lindeman M, Arellana J, Allen J. 2021. Urban freight logistics: what do citizens perceive? Transp Res Part E Logist Transp Rev. 152:103290. doi:10.1016/j.tre.2021.103290.

Anguelovski I, Brand AL, Connolly JJ, Corbera E, Kotsila P, Steil J, García-Lamarca M, Triguero-Más M, Cole H, Baro F, et al. 2020. Expanding the boundaries of justice in urban greening scholarship: toward an emancipatory, anti-subordination, intersectional, and relational approach. Ann Am Assoc Geogr. 110(6):1743–1769. doi:10.1080/24694452.2020.1740579.

Balvanera P, Uriarte M, Almeida-Leñero L, Altesor A, DeClerck F, Gardner T, Hall J, Lara A, Laterra P, Peña-Claraos M, et al. 2012. Ecosystem services research in Latin America: the state of the art. Ecosyst Serv. 2:56–70. doi:10.1016/j.ecoser.2012.09.006.

Balzano S, Trinchera L. 2011. Structural equation models and student evaluation of teaching: a PLS Path Modeling Study. In: Attansio M, Capursi V, editors. Statistical methods for the evaluation of university systems. Berlin, Germany: Springer Physica-Verlag Heidelberg. doi:10.1007/978-3-7908-2375-2.

Blythe J, Armitage D, Alonso G, Campbell D, Estevess D, Dias AC, Epstein G, Marschke M, Nayak P. 2020. Frontiers in coastal well-being and ecosystem services research: a systematic review. Ocean Coast Manag. 185:1–10. doi:10.1016/j.ocecoaman.2019.105028.

BqCV. 2017. Informe de Calidad de Vida 2008-2016. Programa Barranquilla Cómo Vamos -10 años.

Bratman GN, Daily GC, Levy BJ, Gross JJ. 2015. The benefits of nature experience: improved affect and cognition. Landsc Urban Plan. 138:41–50. doi:10.1016/j.landurbplan.2015.02.005.

Bryan BA, Raymond CM, Crossman ND, Macdonald DH. 2010. Targeting the management of ecosystem services based on social values: where, what, and how? Landsc Urban Plan. 97(2):111–122. doi:10.1016/j.landurbplan.2010.05.002.

Calderón-Argelich A, Benetti S, Anguelovski I, Connolly JJT, Langemeyer J, Baró F. 2021. Tracing and building up environmental justice considerations in the urban ecosystem service literature: a systematic review. Landsc Urban Plan. 214:104130. doi:10.1016/j.landurbplan.2021.104130.

Campagne CS, Roche PK, Salles JM. 2018. Looking into Pandora’s Box: ecosystem disservices assessment and correlations with ecosystem services. Ecosyst Serv. 30:126–136. doi:10.1016/j.ecoser.2018.02.005.

Cebrián-Piqueras MA, Karrasch L, Kleyer M. 2017. Coupling stakeholder assessments of ecosystem services with biophysical ecosystem properties reveals importance of social contexts. Ecosyst Serv. 23:108–115. doi:10.1016/j.ecoser.2016.11.009.

Chan KMA, Balvanera P, Benessiaa K, Chapman M, Diaz S, Gómez-Baggethun E, Gould R, Hannahs N, Jax K, Klain S, et al. 2016. Opinion: why protect nature? Rethinking values and the environment. Proc Natl Acad Sci. doi:10.1073/pnas.1525002113.

Cruz-García GS, Sachet E, Blundo-Canto G, Vanegas M, Quintero M. 2017. To what extent have the links between ecosystem services and human well-being been researched in Africa, Asia, and Latin America? Ecosyst Serv. 25:201–212. doi:10.1016/j.ecoser.2017.04.005.

DANE. 2010. Population estimates 1985-2005 and municipal total population projections 2005-2020 by area. Bogotá, Colombia: Departamento Administrativo Nacional de Estadística.

DANE. 2017. Monetary and multidimensional poverty in Colombia 2016. Bogotá, Colombia: Departamento Administrativo Nacional de Estadística.

de Barranquilla A. 2020. Plan de desarrollo distrital de Barranquilla 2020-2023. Gac Districial. 665:569.

Delgado LE, Martin VH. 2016. Well-Being and the use of ecosystem services by rural households of the Rio Cruses watershed, southern Chile. Ecosyst Serv. 21:81–91. doi:10.1016/j.ecoser.2016.07.017.

Díaz S, Pascual U, Stenseke M, Martín-López B, Watson RT, Molnár Z, Hill R, Chan KMA, Baste IA, Braunman KA, et al. 2018. Assessing nature’s contributions to people. Science. 359(6373):270–272. doi:10.1126/science.aap8826.

Diener E, Sandvik E, Seidlitz L, and Diener M 1993. The relationship between income and subjective well-being: Relative or absolute? Soc Indic Res. 28(3):195–223. doi:10.1007/BF01079018.

Diener E, Seligman MEP. 2004. Beyond money: toward an economy of well-being. Psychol Sci Public Interest. 5(1):1–31. doi:10.1111/j.0963-7214.2004.0005010.01.x.

Dinnie E, Brown KM, Morris S. 2013. Community, cooperation and conflict: negotiating the social well-being benefits of urban greenspace experiences. Landsc Urban Plan. 112:1–9. doi:10.1016/j.landurbplan.2012.12.012.

Dobbs C, Escobedo FJ, Zipperer WC. 2011. A framework for developing urban forest ecosystem services and goods indicators. Landsc Urban Plan. 99(3–4):196–206. doi:10.1016/j.landurbplan.2010.11.004.

Duraiappah AKA. 2011. Ecosystem services and human well-being: do global findings make any sense? Bioscience. 61(1):7–8. doi:10.1525/bio.2011.61.1.2.

Eigenbrod F, Bell VA, Davies HN, Heinemeyer A, Armsworth PR, Gaston KJ. 2011. The impact of
projected increases in urbanization on ecosystem services. Proc R Soc B Biol Sci. 278(1722):3201–3208. doi:10.1098/rspb.2012.2754.

Escobedo FJ, Kroeger T, Wagner JE. 2011. Urban forests and pollution mitigation: analyzing ecosystem services and disservices. Environ Pollut. 159(8–9):2078–2087. doi:10.1016/j.envpol.2011.01.010.

Fagerholm N, Martín-López B, Torralba M, Oteros-Rozas E, Lechner AM, Bieling C, Stahl Olafsson A, Albert C, Raymond CM, Garcia-Martín M, et al. 2020. Perceived contributions of multifunctional landscapes to human well-being: evidence from 13 European sites. People Nat. 2(1):217–234. doi:10.1002/pn.10067.

Felipe-Lucía MR, Martín-López B, Lavello S, Berazaquero-Díaz I, Escalera-Reyes J, Comín FA, Margalida A. 2015. Ecosystem services flows: why stakeholders’ power relationships matter. PLoS One. 10(7):1–21. doi:10.1371/journal.pone.0132232.

Fischer C, Gayer C, Kurucz K, Riesch F, Tscharntke T, Batáry P, Rhodes J. 2018. Ecosystem services and disservices provided by small rodents in arable fields: effects of local and landscape management. J Appl Ecol. 55(2):548–558. doi:10.1111/1365-2664.13016.

Frumkin H, Bratman GN, Breslow SJ, Cochran B, Kahn PH, Lawler JJ, Levin PS, Tandon PS, Varanasi U, Wolf KL, et al. 2017. Nature contact and human health: a research agenda. Environ Health Perspect. 125(7):1–18. doi:10.1289/EHP1663.

Galvis L. 2009. Geografía económica del Caribe Continental. Doc Trab Sobre Econ Reg. 119:1–77.

Garcia-Llorente M, Castro JA, Quintas-Soriano C, Oteros-Rozas E, Iniesta-Arandia I, González J, García Del Amo D, Hernández-Arroyo M, Casado-Arzuaga I, Palomino J, et al. 2020. Local perceptions of ecosystem services across multiple ecosystem types in Spain. Land. 9(9):330. doi:10.3390/land9090330.

Gascon M, Zijlema W, Vert C, White MP, Nieuwenhuijsen MJ. 2017. Outdoor blue spaces, human health and well-being: a systematic review of quantitative studies. Int J Hyg Environ Health. 220(8):1207–1221. doi:10.1016/j.ijheh.2017.08.004.

Gómez-Baggethun E, Barton DN. 2013. Classifying and valuing ecosystem services for urban planning. Ecol Econ. 86:235–245. doi:10.1016/j.ecolecon.2012.08.019.

González-García A, Palomo I, González JA, García-Diez V, García-Llorente M, Montes C. 2022. Biodiversity and ecosystem services mapping: can it reconcile urban and protected area planning? Sci Total Environ. 803:150048. doi:10.1016/j.scitotenv.2021.150048.

Grace JB, Schoolmaster DR, Guntenspergen GR, Little AM, Mitchell BR, Miller KM, Schweiger EW. 2012. Guidelines for a graph-theoretic implementation of structural equation modeling. Ecosphere. 3(8):1–44. doi:10.1890/E12-00048.1.

Grace JB, Anderson TM, Seabloom EW, Borer ET, Adler PB, Harpole WS, Hauerst Y, Hillebrand H, Lind EM, Pärtel M, et al. 2016. Integrative modelling reveals mechanisms linking productivity and plant species richness. Nature. 529(7586):390–393. doi:10.1038/nature16524.

Guardiola J, Guillen-Royo M. 2015. Income, unemployment, higher education and wellbeing in times of economic crisis evidence from Granada (Spain). Soc Indic Res. 120(2):385–409. doi:10.1007/s11205-014-0598-6.

Haines-Young R, Potschin-Young M. 2018. Revision of the Common International Classification for Ecosystem Services (CICES V5.1); a policy brief. One Ecosyst. 3: e27108. doi:10.3397/oneco.3.e27108.

Hair J, Hult T, Ringle C, Sarstedt M. 2016. A primer on partial least squares structural equation modeling (PLS-SEM). Sage publications. doi:10.1177/1743727X151005806.

Himes A, Muraca B. 2018. Relational values: the key to pluralistic valuation of ecosystem services. Curr Opin Environ Sustainability. 35:1–7. doi:10.1016/j.cosust.2018.09.005.

Hooper D, Coughlan J, Mullen MR. 2008. Structural equation modelling: guidelines for determining model fit. Electron J Bus Res Methods. 6:53–60. doi:10.21427/D79B73.

Hu LT, Bentler PM. 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equation Model A Multidiscip J. 6(1):1–55. doi:10.1080/10705519909540118.

Huang Q, Yin D, He C, Yan J, Liu Z, Meng S, Ren Q, Zhao R, Inostroza L. 2020. Linking ecosystem services and subjective well-being in rapidly urbanizing watersheds: insights from a multilevel linear model. Ecosystem Serv. 43:101106. doi:10.1016/j.ecoser.2020.101106.

Iniesta-Arandia I, García-Llorente M, Aguilera PA, Montes C, Martín-López B. 2014. Socio-Cultural valuation of ecosystem services: uncovering the links between values, drivers of change, and human well-being. Ecol Econ. 108:36–48. doi:10.1016/j.ecolecon.2014.09.028.

IPBES. 2019. Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Bonn, Germany.

Isbell F, Gonzalez A, Loreau M, Cowles J, Díaz S, Hector A, MacE GM, Wardle DA, O’Connor MI, Duffy JE, et al. 2017. Linking the influence and dependence of people on biodiversity across scales. Nature. 546(7656):65–72. doi:10.1038/nature22899.

Keeler BL, Hamel P, McPherson T, Hamann MH, Donahue ML, Meza Prado KA, Arkems KK, Bratman GN, Brauman KA, Finlay JC, et al. 2019. Social-ecological and technological factors moderate the value of urban nature. Nat Sustain. 2(1):29–38. doi:10.1038/s41893-018-0202-1.

King MF, Renó VF, Novo EMLM. 2014. The concept, dimensions and methods of assessment of human well-being within a socioecological context: a literature review. Soc Indic Res. 116(3):681–698. doi:10.1007/s11051-013-0320-0.

Larson LR, Jennings V, Cloutier SA, Lepczyk CA. 2016. Public parks and wellbeing in urban areas of the United States. PLoS One. 11(4):1–19. doi:10.1371/journal.pone.0153211.

Liu H, Hu Y, Li F, Yuan L. 2018. Associations of multiple ecosystem services and disservices of urban park ecological infrastructure and the linkages with socioeconomic factors. J Clean Prod. 174:868–879. doi:10.1016/j.jclepro.2017.10.139.

Lucchesi ST, Larranaga AM, Ochoa JAA, Samios AAB, Cybis HBB. 2021. The role of security and walkability in subjective wellbeing: a multigroup analysis among different age cohorts. Res Transp Bus Manag. 40:100559. doi:10.1016/j.rtbm.2020.100559.

Lyytinenä J, Sipilä M. 2009. Hopping on one leg – the challenge of ecosystem disservices for urban green management. Urban for Urban Green. 8(4):309–315. doi:10.1016/j.ufug.2009.09.003.
MA. 2005. Ecosystems and human well-being: current state and trends. Washington, DC, USA: Island Press.

Maass JM, Balvanera P, Castillo A, Daily GC, Mooney HA, Ehrlich P, Quesada M, Miranda A, Jaramillo VJ, García-Oliva F, et al. 2005. Ecosystem services of tropical dry forests: insights from long-term ecological and social research on the Pacific Coast of Mexico. Ecol Soc. 10(1):17. http://www.ecologyandsociety.org/vol10/iss1/art17/.

MacCallum RC, Austin JT. 2000. Applications of Structural Equation Modeling in psychological research. Ann Rev Psychol. 51(1):201–226. doi:10.1146/annurev.psych.51.1.201.

Mandle L, Shields-Estrada A, Chaplin-Kramer R. et al. 2021. Increasing decision relevance of ecosystem service science. Nat Sustain. 4:161–169. https://doi.org/10.1038/s41893-020-00625-y

Martín-López B, Iniesta-Aranda I, García-Llorente M, Palomo I, Casado-Arzuaga I, Del Amo DG, Gómez-Baggethun E, Oteros-Rozas E, Palacios-Agundez I, Willaarts B, et al. 2012. Uncovering ecosystem service bundles through social preferences. PLoS One. 7(6):1–11. doi:10.1371/journal.pone.0038970.

McKinney ML. 2002. Urbanization, biodiversity and conservation. Bioscience. 52(10):883–890. doi:10.1641/0006-3568(2002)052[0883:UBANDC]2.0.CO;2.

Ministerio de Medio Ambiente y Desarrollo Sostenible. 2019a. Barranquilla se convertirá en la primera ‘Biodiversidad’ del Caribe colombiano. https://www.minambiente.gov.co/bosques-biodiversidad-y-servicios-ecosistemicos/barranquilla-se-convertira-en-la-primera-biodiversidad-del-caribe-colombiano/.

Ministerio de Medio Ambiente y Desarrollo Sostenible.b. 2019b. Biodiversidades. Asuntos Ambientales sectoriales y urbanos. Bogotá. https://www.dnp.gov.co/Crecimiento-Verde/Documents/ComiteSostenibilidad/Presentaciones/Sesion1/4_Iniciativa_biodiverciudades.pdf

Mukherjee N, Sutherland WJ, Dicks L, Hugé J, Koedam N, Dahdouh-Guebas F. 2014. Ecosystem service valuations of mangrove ecosystems to inform decision making and future valuation exercises. PLoS One. 9(9):9. doi:10.1371/journal.pone.0107706.

Naidoo R, Gerkey D, Hole D, Pfaff A, Ellis AM, Golden CD, Herrera D, Johnson K, Mulligan M, Ricketts TH, et al. 2019. Evaluating the impacts of protected areas on human well-being across the developing world. Sci Adv. 5(4):1–8. doi:10.1126/sciadv.aav3006.

Of Barranquilla A. 2012. Territorial ordering plan. 2012-2032. Technical support document.

Oh B, Lee KJ, Zaslawski C, Yeung A, Rosenthal D, Larkey L, Back M. 2017. Health and well-being benefits of spending time in forests: Systematic review. Environ Health Prev Med. 22(1):1–11. doi:10.1186/s12199-017-0677-9.

Padilla JC, Lizarazo FE, Murillo OL, Mendigüa FA, Pachón E, Vera MJ. 2017. Epidemiología de las principales enfermedades transmitidas por vectores en Colombia, 1990-2016. Biomedica. 37:27–40. doi:10.7705/biomedica.v37i0.3769.

Palomo I, Martín-López B, López-Santiago C, Montes C. 2011. Participatory scenario planning for protected areas management under the ecosystem services framework: the Doñana Social-Ecological System in Southwestern Spain. Ecol Soc. 16(1):23. doi:10.5751/ES-03862-160123.

Palomo I, Felipe-Lucia MR, Bennett EM, Martín-López B, Pascual U. 2016. Disentangling the pathways and effects of ecosystem service co-production. Adv Ecol Res. doi:10.1016/bse.acrr.2015.09.003.

Paudyal K, Baral H, Keenan RJ. 2018. Assessing social values of ecosystem services in the Phewa Lake Watershed, Nepal. For Policy Econ. 90:67–81. doi:10.1016/j.jforpol.2018.01.011.

Peng J, Tian L, Liu Y, Zhao M, Hu Y, Wu J. 2017. Ecosystem services response to urbanization in metropolitan areas: thresholds identification. Sci Total Environ. 607–608:706–714. doi:10.1016/j.scitotenv.2017.06.218.

Pereira E, Queirós C, Pereira H, Vicente L. 2005. Ecosystem services and human well–being: a participatory study in a mountain community in Northern Portugal. 10:1–26. http://www.ecologyandsociety.org/vol10/iss2/art14/.

Prévote AT, Cheval H, Raymond R, Cosquer A. 2018. Routine experiences of nature in cities can increase personal commitment toward biodiversity conservation. Biol Conserv. 226:1–8. doi:10.1016/j.biocon.2018.07.008.

R Core Team. 2013. R: a language and environment for statistical computing. Vienna: Foundation for Statistical Computing.

Raudsepp-Hearne C, Peterson GD, Tengö M, Bennett EM, Holland T, Benessaiah K, MacDonald GK, Pfeifer L. 2010. Untangling the environmentalist’s paradox: why is human well-being increasing as ecosystem services degrade? BioScience. 60(8):576–589. doi:10.1525/bio.2010.60.8.4.

Reyers B, Nel J, O’Farrell PJ, Sitas N, Nel DC. 2015. Navigating complexity through knowledge coproduction: mainstreaming ecosystem services into disaster risk reduction. Proc Nat Acad Sci. 112(24):7362–7368. doi:10.1073/pnas.1414374112.

Reyes-García V, Babigumira R, Pyhälä A, Wunder S, Zorondo-Rodríguez F, Angelsen A. 2016. Subjective wellbeing and income: empirical patterns in the rural developing world. J Happiness Stud. 17(2):773–791. doi:10.1007/s10902-014-9608-2.

Rojas C, Aldana-Dominguez J, Munizaga J, Moschella P, Martinez C, Stamm C. 2020. Urban wetland trends in Three Latin American cities during the latest decades (2002-2019): Conocón (Chile), Barranquilla (Colombia), and Lima (Peru). Wet Sci Pract. 37:283–293.

Rosseel Y. 2012. Lavaan an R package for Structural Equation Modeling. J Stat Softw. 48(2):1–36. doi:10.18637/jss.v048.i02.

Russell R, Guerry AD, Balvanera P, Gauld RK, Basurto X, Chan KMA, Klein S, Levine J, Tam J. 2013. Humans and nature: how knowing and experiencing nature affect well-being. Annu Rev Environ Resour. 38(1):473–502. doi:10.1146/annurev-environ-012312-110838.

Sandom C, Dalby L, Flogaard C, Kissling WD, Lenoir J, Sandell B, Troelsgaard K, Ejrnas R, Svenning JC. 2013. Mammal predator and prey species richness are strongly linked at macroscales. Ecology. 94(5):1112–1122. doi:10.1892/1342-1431.

Santos-Martín F, Martín-López B, García-Llorente M, Aguado M, Benayas J, Montes C. 2013. Unraveling the relationships between ecosystems and human wellbeing in Spain. PLoS One. 8(9):8. doi:10.1371/journal.pone.0073249.

Schell CJC, Dyson K, Fuentes TL, Des Roches S, Harris NC, Miller DS, Woolfle-Erskine CA, Lambert MR. 2020. The ecological and evolutionary consequences of systemic
racism in urban environments. Science. 369(6510):6510. doi:10.1126/science.aay4497.
Schubert H, Calvo AC, Raucheck M, Rojas-Zamora O, Brokamp G, Schütt B. 2018. Assessment of land cover changes in the hinterland of Barranquilla (Colombia) using landsat imagery and logistic regression. Land. 7 (4):1–24. doi:10.3390/land7040152.
Schultz PW, Tabanico J. 2007. Self, identity, and the natural environment: exploring implicit connections with nature. J Appl Soc Psychol. 37(6):1219–1247. doi:10.1111/j.1559-1816.2007.00210.x.
Schulz C, Martin-Ortega J. 2018. Quantifying relational values—why not? Curr Opin Environ Sustainability. 35:15–21. doi:10.1016/j.cosust.2018.10.015.
Scopelliti M, Carrus G, Adinolfi C, Suarez G, Colangelo G, Lafortezza R, Panno A, Sansi G. 2016. Staying in touch with nature and well-being in different income groups: the experience of urban parks in Bogota. Landsc Urban Plan. 148:139–148. doi:10.1016/j.landurbplan.2015.11.002.
See SC, Shaikh SFSA, Jaung W, Carrasco L.R. 2020. Are relational values different in practice to instrumental values? Ecosyst Serv. 44:101132. doi:10.1016/j.ecoser.2020.101132.
SNEA. 2014. Spanish National Ecosystem Assessment. Ecosystems and biodiversity for human wellbeing. Synthesis of the key findings.
Soga M, Gaston KJ. 2016. Extinction of experience: the loss of human-nature interactions. Front Ecol Environ. 14 (2):94–101. doi:10.1002/fee.1225.
Summers JK, Smith LM, Case JL, Linthurst RA. 2012. A review of the elements of human well-being with an emphasis on the contribution of ecosystem services. Ambio. 41(4):327–340. doi:10.1007/s13280-012-0256-7.
Sutherland JJ, Villamagna AM, Dallaire CO, Bennett EM, Chin ATM, Yeung ACY, Lamotho KA, Tomscha SA, Cormier R. 2018. Undervalued and under pressure: a plea for greater attention toward regulating ecosystem services. Ecol Indic. 94:23–32. doi:10.1016/j.ecolind.2017.06.047.
Sykes O, Demaziere C, Nurse A. 2020. Introduction ‘Green cities’ as urban models: contributing to new urban agendas, but how? Town Plan Rev. 91(4):349–355. doi:10.3828/tpr.2020.20.
Tian Y, Wu H, Zhang G, Wang L, Zheng D, Li S. 2020. Perceptions of ecosystem services, disservices and willingness-to-pay for urban green space conservation. J Environ Manage. 260:110140. doi:10.1016/j.jenvman.2020.110140.
United Nations, Department of Economic Affairs, Population Division. 2019. World urbanization prospects: the 2018 revision (ST/ESA/SER.A/420). United Nation, New York.
Venter ZS, Shackleton C, Van Staden F, Selomane O, Masterson VA. 2020. Green Apartheid: urban green infrastructure remains unequally distributed across income and race geographies in South Africa. Landsc Urban Plan. 203:103889. doi:10.1016/j.landurbplan.2020.103889.
Vilardy SP, González JA, Martín-López B, Montes C. 2011. Relationships between hydrological regime and ecosystem services supply in a Caribbean coastal wetland: a social-ecological approach. Hydrol Sci J. 56 (8):1423–1435. doi:10.1080/02626667.2011.631497.
Von Dohren P, Haase D. 2015. Ecosystem disservices research: a review of the state of the art with a focus on cities. Ecol Indic. 52:490–497. doi:10.1016/j.ecolind.2014.12.027.
Wakita K, Shen Z, Oishi T, Yagi N, Kurokura H, Furuya K. 2014. Human utility of marine ecosystem services and behavioural intentions for marine conservation in Japan. Mar Policy. 46:53–60. doi:10.1016/j.marpol.2013.12.015.
Wei Z, Zhang F, Zhou L, Li Y. 2019. Migration of rural residents to urban areas drives grassland vegetation increase in China’s Loess Plateau. Sustainability. 11 (23):6764. doi:10.3390/su11236764.
WHO. 2017. Urban green space interventions and health. Reg. Off. Eur. Copenhagen. http://www.euro.who.int/en/health-topics/environment-and-health/urban-health/publications/2017/urban-green-space-interventions-and-health-a-review-of-impacts-and-effectiveness-full-report-2017.
Wilson EO. 1984. Biophilia: the human bond with other species. Cambridge, MA, USA: Harvard.
Yang W, Dietz T, Liu W, Luo J, Liu J. 2013. Going beyond the millennium ecosystem assessment: an index system of human dependence on ecosystem services. PLoS One. 8(1):9. doi:10.1371/journal.pone.0064581.
Yang YCE, Passarelli S, Lovell RJ, Ringler C. 2018. Gendered perspectives of ecosystem services: a systematic review. Ecosyst Serv. 31:58–67. doi:10.1016/j.ecoser.2018.03.015.
Zhang W, Ricketts TH, Kremen C, Carney K, Swinton SM. 2007. Ecosystem services and dis-services to agriculture. Ecol Econ. 64(2):253–260. doi:10.1016/j.ecolecon.2007.02.024.
Zimmermann-Teixeira F, Bachi L, Blanco J, Zimmermann I, Welle I, Carvalho-Ribeiro SM. 2019. Perceived ecosystem services (ES) and ecosystem disservices (EDS) from trees: insights from three case studies in Brazil and France. Landsc Ecol. 34 (7):1583–1600. doi:10.1007/s10980-019-00778-y.