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Urban Ecosystem Services and Determinants of Stakeholders' Perception for Sustainable Cities Planning in Cotonou (Benin)

Assouhan Jonas Atchadé [1,2,*], Madjouma Kanda [2], Fousseni Folega [2], Joanes Atela [3], Marra Dourma [2], Kperkouma Wala [2] and Koffi Akpagana [2]

[1] Regional Centre of Excellence on Sustainable Cities in Africa CERViDA_DOUNEDON, University of Lomé, Lomé 01BP1515, Togo
[2] Laboratory of Botany and Plant Ecology (LBEV), Faculty of Sciences, University of Lomé, Lomé 01BP1515, Togo
[3] African Research and Impact Network (ARIN), Nairobi P.O. Box 53358, Kenya
* Correspondence: assouhanjonas94@gmail.com

Abstract: Anarchic urbanization and land artificialization expose urban ecosystems and ecosystem services (ES) to threat. Urban ecosystems and trees play a crucial role in improving urban environments, and their management depends on the perceptions and preferences of urban residents. An assessment of the socio-ecological factors determining the perception of the actors allows for the proper design and planning of ecological urban policies and urban adaptation to climate change. The objective of this work was to determine the key determinants (factors) of urban stakeholders' perceptions of ES in generating socio-ecological information for planning and preservation of ecosystems in Cotonou municipality. In this way, we assessed the perception and discriminating variables of the different stakeholders of urban ES provided in the city of Cotonou. Thus, 381 city dwellers were individually interviewed after statistical sampling. Focus group discussions with the stakeholders also made it possible to highlight the ES provided in the different land use units (LU). The results show that 73.23% of the city dwellers agreed that they were aware of ecosystem services. The hierarchical classification shows two homogeneous groups of perceivers with ethnicity, age, and education as statistically discriminating sociological variables ($pv < 0.001$). Urban dwellers in the city of Cotonou perceived more SEs in the cultural and regulatory services category significantly ($pv < 0.001$; v-test > 3). The principal component analysis (PCA) reveals the varying availability of ES according to the different LU in the city. It will be worthwhile to apply this study in the processes of decision-making in climate and environment policy planning for sustainable cities in Africa and all over the world because it adds scientific value.

Keywords: urban ecosystem services; perceptions; socio-ecological analysis; urban adaptation planning; sustainable cities; Cotonou

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1. Introduction

Anarchic urbanization and land artificialization expose ecosystems and urban ecosystem services (ES) to the threat of dysfunction and disappearance [1,2] (Mensah et al., 2020, United Nations, 2018). African cities are particularly affected with spontaneous, uncontrolled, and environmentally damaging urbanization, making it difficult to sustainably manage large African cities today [3]. In Benin, a West African country, the urbanization rate galloped from 11% in 1960 to 40% in 1990, and then, from 42% in 2005 to 44% in 2015 [4]. Moreover, in future projections, more than half of Benin's population will live in cities by 2025, with an estimated urban population rate of 56.2 percent. This situation will lead to more sanitation problems, pollution, and congestion of public spaces. While balancing the need for urban growth with the functioning of biodiversity in addition to the provision of ES remains a major concern in an approach to perpetually improving the quality of the living environment in high concentration areas [5,6]. Urban ecosystems and

trees play a crucial role in improving urban environments, and their management depends on the perceptions and preferences of urban residents [7,8], which is why the notion of a green city has become a shared ideal nowadays and the availability of socio-ecological data are very important in urban climate change mitigation and adaptation planning and city management for sustainable urban development.

Urban ecosystems, in some cases, facilitate societal needs through exchanges of goods and services classified into four categories: provisioning, regulating, supporting, and cultural services [9,10]. Their function of conserving biological diversity and maintaining ecological balance across regions of the world, forests, and urban trees contribute to human development in the current context of climate change and sustainable development through the provision of goods [11–13]. Urban trees also offer a variety of social and cultural benefits, including recreational opportunities, aesthetic value, and potential inspiration for the arts and other creative endeavors [14,15]. Furthermore, urban trees ameliorate the thermal environment of surroundings, and provide cooling. Ecosystem Services (ES) is a conceptual tool that integrates the relationship between humans and nature [16,17]. This tool contributes to the implementation of concrete policies and practices for the sustainable use of all ecosystems [18–20], and an assessment of the socio-ecological determinants of stakeholders' perceptions enables the proper design and planning of green urban policies, ensuring sustainable urban development. Every ES assessment should be initiated by a social approach to consider the perceptions of local stakeholders [21,22], as ensuring optimal provision of ES on which humans depend is essential to integrating the perceptions of all stakeholders into strategies and decisions for sustainable management of social-ecological systems. Sociocultural SE assessment uses research methods from the social sciences (e.g., interviews), values SE in non-monetary terms (e.g., perceptions), and explicitly makes stakeholders the focus of the research [23,24]. Sociocultural valuation of ES also identifies differences in perceptions among stakeholder groups and prioritizes ES to facilitate provider ecosystem planning and ensure policy relevance [25,26].

A few studies on urban forestry and ecosystem services in Benin have addressed stakeholders' perceptions of ES in recent years; however, the collection and analysis of information on the determinants and discriminants of perception and specific ES present in urban land use units is scarce, and furthermore, remains a priority in terms of availability of data on urban socio-ecological systems. Ecosystem studies that generate urban data are conducive to urban environment policy planning [27]; thus, the primary purpose of the present study is to fill this gap in our research area. In a context where extreme weather conditions and global warming impacts are sabotaging economic, social, and environmental development efforts in cities, nature-based solutions—or ecosystem-based adaptation (EbA) integrating ecosystem services—are the go-to recourses in urban planning. Therefore, the determinant variables of perception and the specific ES preferred by urban actors need to be investigated so that their contributions to ecological policy planning catalyzing climate change adaptation in urban societies are fully recognized. This article contributes to a greater understanding for generating socio-ecological information involving ES for urban climate adaptation planning and preservation of ecosystems in Cotonou municipality. More specifically, the study is positioned firstly on the perception of ES and the associated social determinant variables and, on the other hand, on the different ES present in each land use unit which are perceived by citizens in the city of Cotonou.

2. Materials and Methods

2.1. Study Area

The city of Cotonou is in the south of the Republic of Benin between 6°20′ and 6°23′ north latitude and 2°22′ and 2°30′ east longitude. It is bordered to the north by Lake Nokoué, to the west by the Commune of Abomey-Calavi, to the east by the Commune of Sèmè-Kpodji, and to the south by the Atlantic Ocean (Figure 1). The city covers an area of 79 km^2 [28].

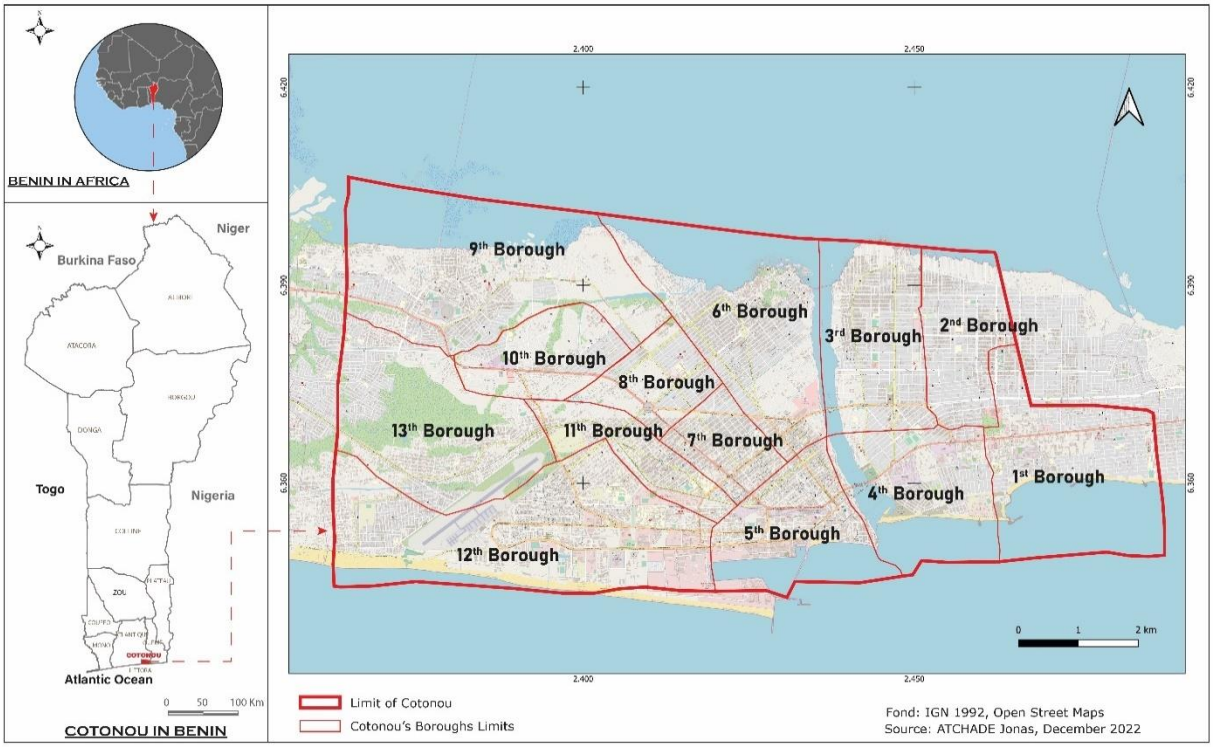

Figure 1. Location map of the research area.

Administratively, the city of Cotonou comprises 13 arrondissements subdivided into 144 neighborhoods. Its population is 679,012 inhabitants according to the general population and housing census [4].

The climate is humid subequatorial, with two dry seasons (mid-November to mid-March, and mid-July to August) and two rainy seasons (mid-March to mid-July, and September to mid-November). The average annual rainfall is 1200 mm, with 700–800 mm in the long rainy season and 400–500 mm in the short rainy season [29]. The average temperature in the coastal zone is 26.8 °C with extremes of 36.6 °C and 16.5 °C. The average relative humidity in Cotonou is 84%. The hydrographic network consists of Lake Nokoué and the Atlantic Ocean. The types of soil encountered include sandy soils, ferruginous soils, and hydromorphic soils [11]. All these characteristics favor plant development. The current urban matrix of the city offers a wide range of types of artificial and natural environments and vegetation ranging from totally unvegetated environments in the city centers to wooded private parks in residential areas to spontaneous vegetation in abandoned estates in the neighborhoods to fallows, plantations, ponds, marshes, and swamps in the peripheral areas of the city [30].

2.2. Sampling and Data Collection

2.2.1. Sampling

For the exercise of understanding the levels of perception and knowledge of the various stakeholders (city dwellers, authorities, and executives of the Ministry of the Living Environment and Sustainable Development, urban planning and forestry departments, municipal agents, etc.) on ecosystem services, qualitative data were collected through techniques based on surveys and interviews (focus group) with the targets mentioned above in the city of Cotonou.

Questionnaires and interview guides were developed and used for this purpose. The data were collected over a period of four months (March–June 2022). The interviews were

conducted in the 13 districts according to the sampling method based on [31] and are shown in Table 1.

$$n = \frac{U^2 \times P(1-P)}{d^2}$$

n is the number of respondents for each borough; P is the proportion of individuals in each borough calculated from the headcount of each borough and the headcount of the entire city; U (0.975)2 $\approx$ 1.96 is the quantile of a standard normal distribution for a probability value of 0.05; and d is the marginal error set at 8%.

Table 1. Samples of people surveyed by district of Cotonou.

Districts of Cotonou	Population	Proportion P	Sample (n)
1st Borough	59,962	0.085362262	30
2nd Borough	61,668	0.090820192	37
3rd Borough	69,991	0.103077707	35
4th Borough	36,357	0.053543973	19
5th Borough	20,039	0.029511997	17
6th Borough	75,336	0.110949438	40
7th Borough	27,535	0.040551566	31
8th Borough	32,420	0.047745842	19
9th Borough	57,691	0.084963152	30
10th Borough	38,728	0.057035811	26
11th Borough	34,879	0.051367281	19
12th Borough	97,920	0.144209528	47
13th Borough	68,486	0.100861251	41
Total	679,012	1	381

2.2.2. Data Collection

Prior to the individual interview, based on the literature (MEA, TEED, and the work of other authors), proposed ES in urban settings were identified. Then, preliminary work was done with the city's urban management teams, in this case urban planners, environmentalists, and municipal planners. This preliminary work made it possible to validate the urban ES from the literature, but which are proposed and exist in a local context (the city of Cotonou). From there, the questionnaires were developed according to the targeted objectives. In the field, the vernacular language was used for those who did not understand the language of the interview. We also used local translators and informants to translate and explain the interview for the city dwellers. A total of 381 people were interviewed in the city according to the number of people in the different districts. To achieve this, the verbal agreement of the respondents was obtained before the start of each interview. Respondents who did not speak French were listened to with the help of local translators, each respondent was subjected to a semi-structured interview at the level of the respective districts and focus group interviews were conducted in the administrative services and in the residences of municipal councilors (district managers). The main headings of the data collected for this purpose were:

- Socio-cultural characteristics (socio-cultural group, gender, age, activities, and level of education);
- Knowledge of the concept of ecosystem services and the different categories and sub-categories according to the Millennium Ecosystem Assessment [32] classification (provisioning services, regulating services, supporting services, and cultural services). This involved the categories and subcategories of ecosystem services classified by the Millennium Ecosystem Assessment. Each category is described. For example, provisioning services have been described in six (6) subsections (food, wood and bioenergy, medicinal, fibers, art materials, and no plant food resources).

In addition, focus groups were held with the different stakeholders in charge of urban area management. This focused on the identification of ecosystem services offered in the

different land use units (LUs) defined with these stakeholders according to the objective to be achieved.

2.3. Data Processing and Analysis

Using Excel 2016 (MicroSolft Office 365), the collected data were entered and formatted in accordance with the format; R.4.1.2. software was used to perform all the processing and analysis. The axes of these statistical treatments were the descriptive statistics of the socio-demographic parameters (ethnic group, level of education, age, and gender), the hierarchical classification on multivariate component analysis (Hierarchical cluster analysis to distinguish similar group) to group the respondents on a similar perception of the Ecosystemic Services, the principal component analysis (PCA) to describe the relationship between the Ecosystemic Services and the units of land use (US) and the Generalized Linear Model (Poisson type binomial errors) and the descriptive statistics of the groups obtained (Me: Mean, CV: Coefficient of Variation), respectively, to test and describe the variation in the number of services cited by user group.

3. Results

3.1. Socio-Demographic Profiles of Respondents

Analysis of Table 2 reveals that the Fon (32.63%), Adja (17.63%), and Goun (13.68%) ethnic groups are, respectively, the most represented, while the Peulh (2.10%) and Betamarides (2.63%) are the most underrepresented of the urban population interviewed in the city of Cotonou. Men are almost 3 times (72.37%) the number of women (27.63%) interviewed, along with Adults (75.53%), followed by the elderly (17.37%) and youth (7.11%). As for the level of education, 34.21% and 32.89% of the urban residents surveyed had, respectively, reached secondary and higher education levels, while 13.68% had no level at all.

Table 2. Characteristics of socio-demographic parameters.

Variables	Modalities	Numbers	Frequency (in %)
Ethnic's group	Adja	67	17.63
	Bariba	18	4.73
	Betamaride	10	2.63
	Fon	124	32.63
	Goun	52	13.68
	Mahi	31	8.15
	Peulh	8	2.10
	Tchabè	33	8.68
	Yorouba	37	9.74
Level of education	None	52	13.68
	Primary	73	19.21
	Secondary	130	34.21
	Superior	125	32.89
Age	Adult	287	75.53
	Older	66	17.37
	Young	27	7.11
Gender	F	105	27.63
	M	275	72.37

In the Table 2, we mean young as people from 18 to 35 years old; adult as people from 35 to 55; and older as those from 55 years and beyond.

3.2. Local Perception of Ecosystem Services by the Populations of Cotonou

3.2.1. Degree of Perceptions of Ecosystem Services as a Function of Sociological Variables

Table 3 illustrates the assertions of the 381 sampled city dwellers on their knowledge of ES in the city of Cotonou. From this illustration, 73.23% of respondents claim to have significant (<0.001) knowledge of ES in the city of Cotonou. Of the lot, 79.84% of those with higher education level and 26% of those with secondary education level declared to

be significantly aware of what the ES offered. The same response was also significant for 66.67% of the elderly and 51.40% of adults. Older people perceive SEs better than younger people. The perception is significant among 80.00% of Fon, 20.00% of Yoruba, 51.32% Adja, 18.56% Bariba, and 19.64% Mahi. Approximately half of the men and 32.23% of the women, while acknowledging the existence of SE, did not make a significant statement.

Table 3. Knowledge statements on ecosystem services in Cotonou.

Socio-Demography	Answers	Percentage (%)	*p*-Value
Global	Yes	73.23	<0.001
Education = Superior	Yes	79.84	<0.001
Education = None	Yes	13.08	0.005
Education = Primary	Yes	21.12	0.001
Education = Secondary	Yes	26.00	0.033
Age = Older	Yes	66.67	<0.001
Age = Adult	Yes	44.60	<0.001
Age = Young	Yes	32.00	0.005
Ethnic.Groups = Fon	Yes	80.00	<0.001
Ethnic.Groups = Yoruba	Yes	20.00	<0.001
Ethnic.Groups = Adja	Yes	51.32	<0.001
Ethnic.Groups = Bariba	Yes	18.56	<0.001
Ethnic.Groups = Betamaride	Yes	15.78	0.002
Ethnic.Groups = Goun	Yes	18.23	0.025
Ethnic.Groups = Mahi	Yes	19.64	<0.001
Ethnic.Groups = Peulh	Yes	21.00	0.008
Ethnic.Groups = Tchabè	Yes	35.12	0.002
Gender = Female	Yes	32.23	0.025
Gender = Male	Yes	52.15	0.053

It is clear from this analysis that the reception of ES in the city of Cotonou is influenced by the level of education, ethnicity, and age class. Sex or gender did not significantly influence this perception.

3.2.2. Socio-Ecological Analysis of Perception of Categories and Subcategories of Ecosystem Services

The analysis in Table 4 reveals the relationship between the socio-demographic variables (gender, age, ethnic group, and education) and ecosystem services (provisioning, regulating, cultivating and supporting) perceptions used for the discrimination of parameters and the description of different homogeneous groups of respondents. This highlights the correlations between the socio-demographic variables and the perception of ecosystem services with sufficient precision on the two groups of perceivers.

Table 4. Description of homogeneous groups of respondents using the most discriminating socio-demographic criteria.

Services and Socio-Demography	Cla/Mod	*p*-Value	v.Test
First group of respondents (GR1)			
Socio-demographics			
Education = Superior	79.84	<0.001	8.25
Age = Older	66.67	<0.001	2.97
Ethnic groups = Fon	80.00	<0.001	3.77
Procurement Services			
Food	60.68	<0.001	8.04
Wood bioenergy	65.53	<0.001	6.62

Table 4. *Cont.*

Services and Socio-Demography	Cla/Mod	*p*-Value	v.Test
Medicinal use	54.43	<0.001	3.85
Use fibers	78.75	0.004	2.91
Art materials	74.34	0.003	2.97
No plant food resources	74.10	0.002	2.67
Regulation Services			
Air purification	57.32	<0.001	3.48
Reducing extremes	58.68	<0.001	8.08
Anti-erosion role	80.21	0.015	9.42
CO_2.assimilation	50.98	<0.001	13.61
Shading	81.08	<0.001	5.88
Temperature regulation	71.36	<0.001	6.23
Cultural Services			
Inspiration	59.80	<0.001	7.38
Natural beauty visit	65.71	<0.001	6.85
Relaxation	51.08	<0.001	5.68
Entertainment	51.69	<0.001	4.23
Support Services			
Refuge animal species	71.26	<0.001	13.25
Species evolution maintenance	72.80	<0.001	13.10
Second group of respondents (GR2)			
Socio-demographics			
Ethnic Groups = Yoruba	80.00	<0.001	3.77
Age = Adult	55.40	<0.001	3.70
Education = None	86.92	<0.001	3.60
Education = Primary	78.88	0.001	3.25
Education = Secondary	64.00	0.005	2.80
Age = Young	68.00	0.005	2.72
Procurement Services			
Food	47.06	<0.001	8.04
Wood bioenergy	38.39	0.001	3.62
Medicinal use	41.88	<0.001	3.85
Use fibers	17.67	0.004	2.91
Art materials	30.30	0.003	2.97
No plant food resources	23.90	0.011	3.67
Regulation Services			
Temperature regulation	31.67	<0.001	6.23
Air purification	26.15	0.013	2.48
Shading	42.00	<0.001	5.88
Anti-erosion role	36.85	0.015	2.46
Reducing extremes	23.65	<0.001	8.08
CO_2.assimilation	16.29	0.001	13.61
Cultural Services			
Inspiration	44.52	<0.001	3.38
Natural beauty visit	19.41	0.031	2.85
Relaxation	39.00	<0.001	5.48
Entertainment	33.08	0.001	2.99
Support Services			
Refuge animal species	36.64	<0.001	13.25
Species evolution maintenance	33.85	0.041	2.10

Cla/Mod: percentage of all city residents surveyed who recognize the presence/existence of a specific ES and belong to a cluster; ***p*-value**: level of significance of the analysis, **v-test**: measures the association between variables and groups. It reveals which variables are positively or negatively associated with clusters. When the **v-test est > à 3**, this indicates the significance of the analysis.

The first group of perceivers is made up of 79.84% of the literate (higher level), 66.67% of the elderly, and 80.00% of the Fon ethnic group. The procurement services most significantly (pv < 0.001; v-test > 3) recognized by individuals in this group are: food, wood bioenergy, medicinal use. Within this category, wood bioenergy (65.53%), is the most cited

subcategory of services. The most significantly (pv < 0.001; v-test > 3) recognized subcategories of regulatory services are: air purification, reducing extremes, CO_2 assimilation, shading and temperature regulation. The subcategories of services such as shading (81.08%) and temperature regulation (71.36%) are, respectively, the most rendered services according to the citizens of this homogenous group. The same table shows the different subcategories of cultural services that are significantly recognized by the citizens of the group. These are inspiration, natural beauty visit, relaxation, entertainment, among others. Natural beauty visit (65.71%) is the most cited service in this category. For support services, it is refuge for species (71.26%) and species evolution maintenance (72.80%).

The second group of respondents, which is quite different from the first, is made up of 80% Yoruba, 55.40% adults, 86.92% city dwellers with no education, 78.88% with primary education, 64.00% with secondary education, and 68.00% youth. This group reflects mostly younger urbanites (many youths and adults) with very low levels of education (none, primary and secondary). The city dwellers in this homogeneous group have a rather limited knowledge of the categories and subcategories of services mentioned. The services significantly (pv < 0.001; v-test > 3) recognized by individuals in this group are: food (47.06%), medicinal use (41.88%), reducing extremes (23.65%), shading (42.00%), temperature regulation (31.67%), inspiration (44.52%), relaxation (39.00%), and refuge animal species (36.64%).

In a synthetic way, this socio-ecological analysis reveals that most of the interviewed city dwellers perceive the provisioning services of wood bioenergy as the most cited, while in the regulation services, shading and temperature regulation are the two most represented. As for the cultural services category, natural beauty visit is the most cited. Two services of the support services category are widely cited by the citizens. The discriminating parameters of the perception of the different categories and subcategories of ecosystem services offered by plant biodiversity are literacy level, age, and ethnicity. Sex/gender has no influence on the perception of the populations of the studied municipality.

3.2.3. Averages of the Sub-Categories of Services Cited and Homogeneity in the Response of the Groups of Respondents in the City of Cotonou

Across Table 5, the average number of ES cited varies statistically significantly between groups of perceivers (pv < 0.001). Individuals in Group 1 recognized an average of 2 support services, 5 cultural services, 3 provisioning services, and 6 regulatory services. In contrast, Group 2 city dwellers cited 1 support service, approximately 3 cultural services, 3 regulatory services, and 2 provisioning services. The values of the coefficient of dispersion (CV) show that the perception is homogeneous in group 1 compared to group 2. Thus, at the level of the city dwellers in the first group, there is a certain homogeneity (CV < 50%) in the way of perceiving the 4 categories of ecosystem services (support; cultural; regulation; and supply). On the other hand, at the level of the citizens of the second group, this homogeneity is scattered. From this socio-ecological analysis, it appears that regulatory and cultural services are the two categories of ecosystem services frequently encountered by the citizens of the city of Cotonou.

Table 5. Descriptive statistics (Me: mean, CV: Coefficient of variation) and results of the generalized linear model (Poisson with binomial errors) on number of services cited according to group of respondents.

Services	GR1		GR2		Probability
	Me	CV	Me	CV	
Support	1.94	16.47	0.75	81.47	<0.001
Cultural	4.62	13.97	2.85	34.32	<0.001
Regulation	5.65	11.48	3.13	31.51	<0.001
Procurement	3.27	40.92	2.17	73.11	<0.001

The results of the principal component analysis (PCA) indicated that 86.1% of the input information is explained by the first 3 dimensions (axes), which is sufficient to ensure accuracy in the interpretations. On the one hand, ecosystem services such as temperature regulation (SE4), area purification (SE5), shading (SE6), moderation of climate extremes (SE7), inspiration, art/aesthetics (SE8), recreation/relaxation (SE9), and social cohesion (SE11) are positively correlated with the first dimension (axis1) of the PCA (Figure 2). It is found that land use units (LUs)—in which vegetation provides shade, social cohesion, relaxation, and inspiration for the arts, and those in which climate extremes are moderated—temperature is regulated and the area is purified. These ecosystem services in the category of regulating and cultural services are more offered in the land use units (LU) such as administrative zones (LU2), wooded areas, green spaces, urban forests, and cemeteries (LU4) as well as commercial zones including sometimes markets (LU6) in the city of Cotonou. On the other hand, food (SE1), wood, bioenergy (SE2), traditional medicine (SE3), inspiration, art/aesthetics (SE8), spiritual (SE10), and biodiversity maintenance (SE12) services are also positively correlated to the first dimension (axis2) as well as the land use units US1, US3, and US5. This implies that plantations along roads and alleys (US1), plant species in residential areas (US3), and training and learning centers (US5) contribute mainly to the provision of ecosystem services in the category of provisioning, cultural and support services—such as maintenance of biodiversity, provision of medical materials, bioenergy and spiritual and arts services—in the city of Cotonou (Figure 2).

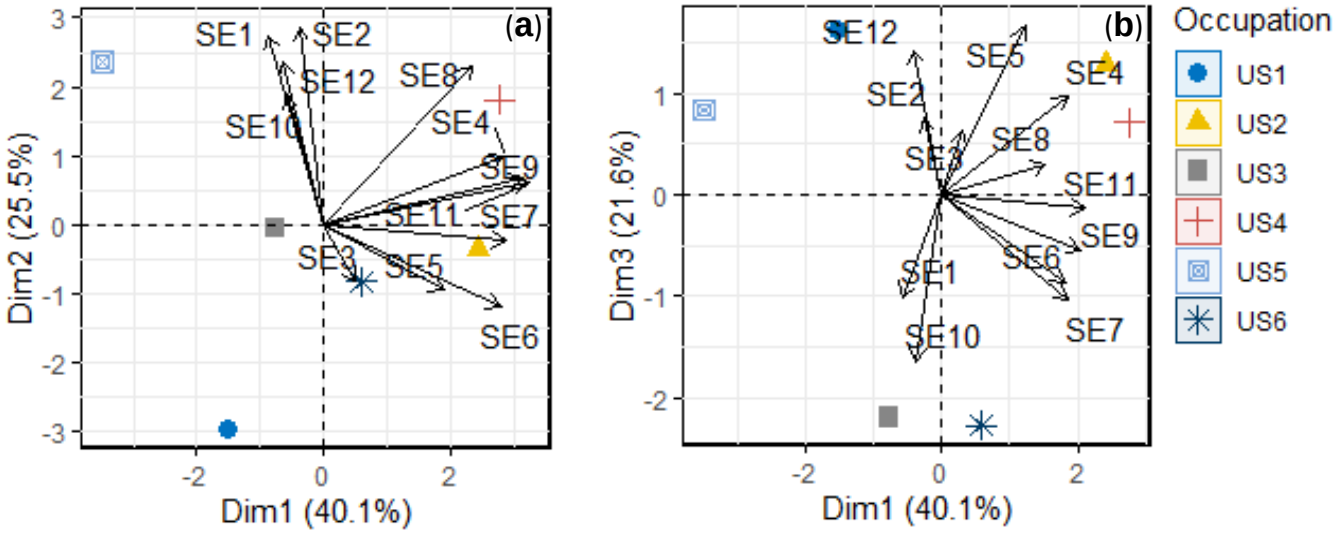

Figure 2. (**a**) the first two PCA axes. (**b**) the first and third PCA axes. Description of the relationships between ecosystem services (ES) and land use units (US) on the three main axes. **Land use units**: **US1**: roads; **US2**: administrative areas; **US3**: residential areas; **US4**: wooded areas: urban green spaces and forests, wetlands, botanical gardens, interstices and cemeteries and peripheral areas; **US5**: institutions (training and learning centers); **US6**: commercial areas: markets, etc. **Priority Ecosystem Services: SE1**: food (fruit, seed, leaves, etc.), **SE2**: Wood, bioenergy, **SE3**: traditional medicine, **SE4**: temperature regulation, **SE5**: air purification, **SE6**: shade, SE7: moderation of extremes, **SE8**: inspiration, art/aesthetics, **SE9**: recreation/relaxation, **SE10**: spiritual, **SE11**: social cohesion, **SE12**: biodiversity maintenance.

4. Discussion

In this study, socio-demographic parameters such as level of education, ethnicity, and age are determining variables for the perception of urban ecosystem services in the city of Cotonou. Among these parameters, the "higher and secondary level of education" and the "ethnic groups" (Fon, Yoruba, Adja, Bariba, and Mahi) are the significant variables which imply the perception of ecosystem services. These results support those of [7] and [33], who revealed that the value of ES to stakeholders varies due to a complex set of factors,

including (i) stakeholders' personal (e.g., age, gender, education, place of residence) and social values (e.g., culture, social network), but also, (ii) interactions between stakeholders and ES associated with use, perception, and knowledge of ES. However, our results did not reveal the influence of gender in the way citizens perceive ES. Authors such as [23,24,34] argued that sociodemographic variables such as "gender", "age", "ethnicity", "social condition", "experience and historical relationship with nature", and "main occupation" significantly influence an individual's perceptions of ES. In the same way, [1] found in Benin that the perception of ES by urban residents of the historic city of Abomey was more correlated with the level of education and ethnicity and social status than other factors. The findings of [1] are reinforced by our research, as social affiliation refers to the different ethnic groups and was found to be a significantly discriminating variable in this study work. In southwestern Ethiopia, men recognized more forest ES than women [26]. In Rwanda, long-term residents identified more forest ES than newcomers [16]. Furthermore, the level of knowledge and education of stakeholders are also important according to [21]. In contrast, the results from research of [11] noted the living environment as the factor influencing the perception of ecosystem services offered by the green spaces installed in the city, Abomey-Calavi, Allada, and Cotonou. This suggests that there are many factors contributing to urban ES perceptions, and this is the source of good preservation and management of urban green spaces.

The individuals of the two homogeneous groups significantly perceive in the city of Cotonou the provisioning services (food and medicinal use), the regulation services (reducing extreme weather, shading, and temperature regulation); the cultural services (inspiration, relaxation) and the refuge support service for animal species. These same services have been found in urban environments by [11,15]. Cultural and regulatory services are two categories more perceived with some homogeneity by urban residents in both groups. From the latter, regulatory and cultural services are the ecosystem services most frequently encountered by Cotonou city residents. It has been argued that rural populations perceive provisioning ES more frequently than in urban societies, due to a cognitive disconnect of human well-being from the environment in cities [8,13]. These outcomes in urban social-ecological settings are reinforced by our results. At the same time, other researchers find that rural residents mention that regulatory and cultural ES are more frequently perceived than provisioning ES, because they have an ecological knowledge of the importance of the environment and forest ES [20]. It should be rightly emphasized that the perception of ecosystem services depends on the perceiver and several socio-cultural and ecological dimensions.

From the principal component analysis (PCA), it appears that the land use units (LUs) in which plants serve as shade, there is more social cohesion, relaxation, inspiration for the arts, and furthermore, those places in which climate extremes are moderate, the temperature is regulated along with the purification of the area. These ecosystem services of the category of regulating and cultural services are offered more in the land use units (LU) such as administrative zones (LU2), wooded areas, green spaces, urban forests, and cemeteries (LU4), as well as commercial zones including sometimes markets (LU6) of the city of Cotonou. Since it is known to all today that climate change is increasing the frequency and intensity of extreme environmental events, this poses increasingly important sustainable adaptation challenges to cities, especially those located in coastal areas [24]. Our results, while reinforcing the TEED guidelines, show how nature-based solutions or ecosystem-based adaptation can facilitate city resilience via sustainable urban adaptation planning that integrates the urban ecosystem services offered by urban plant diversity, of which our results revealed. Going in this same direction, [15] had argued that ecological infrastructures such as urban forests, green screens, trees planted in administrative areas, commercial areas, etc., in cities sustainably regulate local temperatures and mitigate the effects of urban heat islands—in fact, they go further by pointing out that the reduction of the city's heat load is one of the most important regulating ecosystem services that trees provide to cities. Similarly, [9] found that urban trees reduce temperature during the hottest

months by providing shade and absorbing heat from the air through evapotranspiration, especially when humidity is low. In the same vein, for [35], water from urban plants absorbs heat by evaporating, cooling the air in the process. The multivariate analyses from our work also show that plantations along lanes and alleys (US1), plant species in residential areas (US3), and training and learning centers (US5), contribute mainly to the provision of ecosystem services in the category of provisioning, cultural, and support services such as maintenance of biodiversity, provision of food, medical materials, bioenergy, and spiritual and arts services in the city of Cotonou. These results are consistent with the work of [6], who report that wood production, bioenergy, and pharmacopoeia services are highly valued by the populations of the city of Grand-Popo in Benin. Biodiversity, ecosystems, and natural landscapes have been the source of inspiration for much of our art, culture, and increasingly, for science [20]. The role that green spaces play in maintaining mental and physical health is increasingly recognized, despite measurement challenges, according to [27,28]. The results of our work expose the role of maintaining biodiversity as a support service reported by citizens in the city of Cotonou. These results are supported by the findings of [19] in that urban systems can play an important role as a refuge for many species of birds, amphibians, bees, and butterflies during their movements.

5. Conclusions

Anarchic urbanization and land artificialization expose urban ecosystems and ecosystem services (ES) to the threat of dysfunction and disappearance. An assessment of the socio-ecological factors that determine the perception of the actors not only allows urban adaptation to climate change but also the proper design and planning of ecological urban policies, which is a guarantee of sustainable urban development in Africa. The results of this research expose the determining variables of the perception of ES by identifying two groups of perceiving stakeholders and reveal the different ES offered by the plant diversity in each occupation unit of the city of Cotonou. The significantly discriminating variables are education level, age, and ethnicity. The two categories of urban ecosystem services most frequently encountered and cited by Cotonou residents are regulatory and cultural services, followed by provisioning and support services. The multivariate analyses show how the occupancy units present in the city offer various goods and services to facilitate the urban adaptation of the citizens and infrastructures of the city of Cotonou in the face of climatic extremes and hazards. This is also to reinforce the production of data for urban planning of green and ecological cities, a guarantee of sustainable urban development in Africa.

These outcomes, while reinforcing the TEED guidelines, highlight how nature-based solutions or ecosystem-based adaptation can facilitate the resilience of cities through urban adaptation planning that integrates the urban ecosystem services offered by urban plant diversity. Our recommendations point to the need to integrate the ecosystem services assessment tool with urban planning in Africa, given the holistic approach that ES promotes for urban resilience regarding weather extremes. There is also a need for future research to broadly consider, beyond adaptation, the mitigation potentials of climate change through green infrastructure in African cities. The limitations of the study concern the underrepresentation of youth in the sampling. Better still, the use of geomatics and cartography tools would have made it possible to highlight the ecosystem services that could be the subject of long-term planning for the sustainability of the city.

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