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*Original Research*

# Residents' perceptions of the role of urban green spaces to climate resilience in the city of Niamey, Niger

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## Abstract

*The city of Niamey like other African big cities is vulnerable to climate change which affects the health and well-being of residents. The urban green spaces which provide solution are increasingly threatened by the urbanization phenomenon. Although the residents maintain the greenery across the Niamey city, there is a lack of data on the role of urban green spaces in boosting the urban climate resilience. Therefore, this study attempts to close this gap by investigating the perceived role of urban green spaces to the climate resilience by the residents in the city of Niamey. To do so, we interviewed randomly 385 households for collecting socio-economic and environmental data. In addition, climate resilience index was estimated via principal component analysis to capture the perceptions of respondents' resilience to climate shocks. The results from the econometric model showed that urban green spaces through their services influence positively the climate resilience at 1% level. Therefore, the respondents who are near to the urban green spaces are more likely to be climate resilient. Furthermore, the respondents that perceived the regulating (17.44%) and cultural services (66.92%) tend to be significantly more resilient to climate change than those who perceived provisioning services (15.64%) at 1% level. In light of these results, the public authorities should scale up the urban green spaces across the city to make them more accessible to dwellers.*

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## Résumé

*La ville de Niamey, comme d'autres grandes villes africaines, est vulnérable au changement climatique qui affecte la santé et le bien-être des habitants. Les espaces verts urbains qui apportent une solution sont de plus en plus menacés par le phénomène d'urbanisation. Bien que les habitants entretiennent la verdure à travers la ville de Niamey, il y a un manque de données sur le rôle des espaces verts urbains dans le renforcement de la résilience climatique urbaine. Par conséquent, cette étude tente de combler cette lacune en examinant le rôle perçu des espaces verts urbains dans la résilience climatique par les habitants de la ville de Niamey. Pour ce faire, nous avons interrogé au hasard 385 ménages afin de collecter des données socio-économiques et environnementales. En outre, l'indice de résilience climatique a été estimé par le biais d'une analyse en composantes principales afin de saisir les perceptions de la résilience des personnes interrogées face aux chocs climatiques. Les résultats du modèle économétrique ont montré que les espaces verts urbains, par le biais de leurs services, influencent positivement la résilience climatique au niveau de 1 %. Par conséquent, les personnes interrogées qui sont proches des espaces verts urbains sont plus susceptibles d'être résilientes au changement climatique.*



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*En outre, les répondants qui perçoivent les services de régulation (17,44 %) et les services culturels (66,92 %) tendent à être significativement plus résilients au changement climatique que ceux qui perçoivent les services d'approvisionnement (15,64 %) au niveau de 1 %. À la lumière de ces résultats, les autorités publiques devraient développer les espaces verts urbains à travers la ville afin de les rendre plus accessibles aux habitants.*

## 1. Introduction

The world is becoming increasingly urbanized with currently 56% of urban population which is expected to be 65% by 2050. Africa and Asia are urbanizing much faster than the other continents, with Africa being the most rapidly urbanizing (United Nations, 2018). This rapid urbanization reduces the agricultural and natural land cover, which combine with the increase in consumption of fossil fuels, and increase in the growing infrastructural needs and waste disposal sites, make the urban areas more vulnerable to climate change (Nero et al., 2019). In this region, climate change is one of the greatest challenges with a significant impact on ecosystems, expressed in terms of the decrease in urban ecosystem distribution (Geest et al. 2019). Thus, building urban resilience defined, according to the 100 Resilient Cities program, as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience" (Keane & Grant-smith, 2014) is crucial. However, its measurement calls for the appropriate indicators, which include the service delivery and regulatory functions of urban spaces with the municipal planning processes, communication systems, business environment, and structural and infrastructure-related factors (Bahadur, Aditya & Pichon, Florence, 2016). When data are unavailable, the subjective decision from directly the people's perception is solicited for selecting the components/dimensions instead of choosing the components with the risk of leaving out key elements (Winderl. 2014).

The city of Niamey, as an emblematic example of a fast-growing West African city (Rossi, 2019) is located in the Sahel region where the climate is characterized by low rainfall and high temperatures and the land use planning is inadequate leading to the increase in the flood-prone areas occupation (Hungerford & Moussa, 2017). For example, in 2017, the flooding affected 1,083 people and destroyed 60 houses and the affected households were estimated to be low resilient (Pointers, 2017). The number of victims increased in 2020 with 119 809 affected people over 52% of its total area (Tarchiani et al., 2021). Additionally, this land occupation leads to the loss of urban vegetation such as green belt and street trees (Hungerford & Moussa, 2017), with already few urban parks (Banon et al., 2021). As a result, Dime and Nakoari (2021) revealed that anthropogenic deforestation is the leading cause of environmental disruption noticed in terms of heat waves, floods, drought, and high winds in Niamey City. In this regards, promoting and developing urban green spaces through efficient management and robust monitoring and evaluation become warhorse to the authorities to increase their benefits and ensuring the cities' climate resilience, as revealed in the National Forest Plan (FAO, 2021).

Defined consensually among ecologists, economists, social scientists, and planners as: "public and private open spaces in urban areas, primarily covered by vegetation, which are directly or indirectly available for the users" (Haq, 2011), the urban green spaces are one strategy to enhance urban resilience (Meerow et al., 2016). They play a crucial role in providing solutions



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to the effects of climate change (Geest et al., 2019). Directly, they increase the general health and the happiness, and indirectly they reduce noise, urban heat island effects, crime rates, and improve air quality (Ma et al., 2019). These benefits translated into ecosystem services reduce the vulnerability of urban communities (Pauleit et al., 2017, Staddon et al., 2018). Indeed, the evidence showed that the urban green spaces through their services contribute to the climate resilience Clarke et al., (2019) in Chicago city, New York City, and Baltimore city/USA, Cabral et al., (2017) in the European cities, Camps-Calvet et al., (2017) in Barcelona/Spain, Derkzen et al., (2017) in Rotterdam City/Netherlands, (Zhang, 2019) in the City of Guangzhou/China, Nero et al., (2019) in Kumasi city/Ghana, Adegun, (2021) in Lagos city/Nigeria, and Anderson, Patiño Quinchia, (2022) in the African cities. These studies examined the structure of the urban green spaces and mostly used the urban forest measurement approaches such as the dendrometric measurement and the use satellite data. However, this study should contribute to the ongoing debate on the role of urban green spaces to the climate resilience by combining the following approaches such as climate resilience index estimated via Principal Component Analysis and econometric modeling. As a result, this study attempts to close the aforementioned gap in the city of Niamey by investigating the contribution of urban green spaces to the climate resilience defined in this study as capacity of people and systems to sustain and improve their livelihood and development opportunities and wellbeing despite the climate change effects (Tanner et al., 2015).

## 2. Materials and Methods

### 2.1. Area of the study

The City of Niamey as the administrative and political capital of the Niger Republic is the largest in Niger due to the high rural exodus caused by the opportunities for jobs (Issoufou and Lecumberri, 2017). With the birth rate of 7.5 children by women in Niger, its population was multiplied by 34 from about 30,000 inhabitants in 1960 to 1,026,849 in 2012 i.e. at the scale of fifty years (INS, 2012). According to the projection demographic of Niger (2012-2024), the city is currently the most populated city of the country with 39% of Niger's urban population (INS, 2019). It becomes a multi-ethnic city with a diversity of national and foreign communities, notably Zarma-Sonrai, Hausa, Fulani, Tuareg, Kanuri, and others, dominated by Zarma followed by Hausa. It also hosts many national neighborhoods countries such as Benin, Mali, Burkina Faso, and Nigeria. The households in this city, generally engage in informal economic activities with modest gains and limited public support for their livelihood (Issoufou and Lecumberri, 2015). These informal economic activities are the characteristic of West African cities' usual economic activities dominated by commerce which is maintained by clerical work (INS, 2012). In addition, they practice the urban agriculture such as cabbage, tomato, carrot, sweet pepper including husbandry highly considered as important livelihood activity which consists of cultivation of cash and food crops throughout the year either under rain-fed or irrigated conditions (Moussa et al., 2019).

Niamey has an extended area of over 552.27 km², an urbanized area of 255 km2. It has in total a land area estimated at 3,933 hectares (INS, 2012). It is located between latitude 13°20'-13°35' N and longitude 2°00'-2°15' E in western Niger (figure 1). The climate is the semi-arid in the Sahelian region characterized by the mean annual rainfalls of 550 mm per year and the temperatures range monthly between 32.5°C in January (coolest month), and the 40.9°C in April (Warmest month) (Garba & Abdourahamane, 2023). The city observes usually only one



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rainy season per year which occurs between May and September. It is also embedded in the Tillabéri region (red line) and divided into two by the River Niger (Rossi, 2019). The most important part of the city is located on the left bank of the river with many districts divided into the commune I II III IV while on the right bank, there are few districts located in the commune V (figure 1).

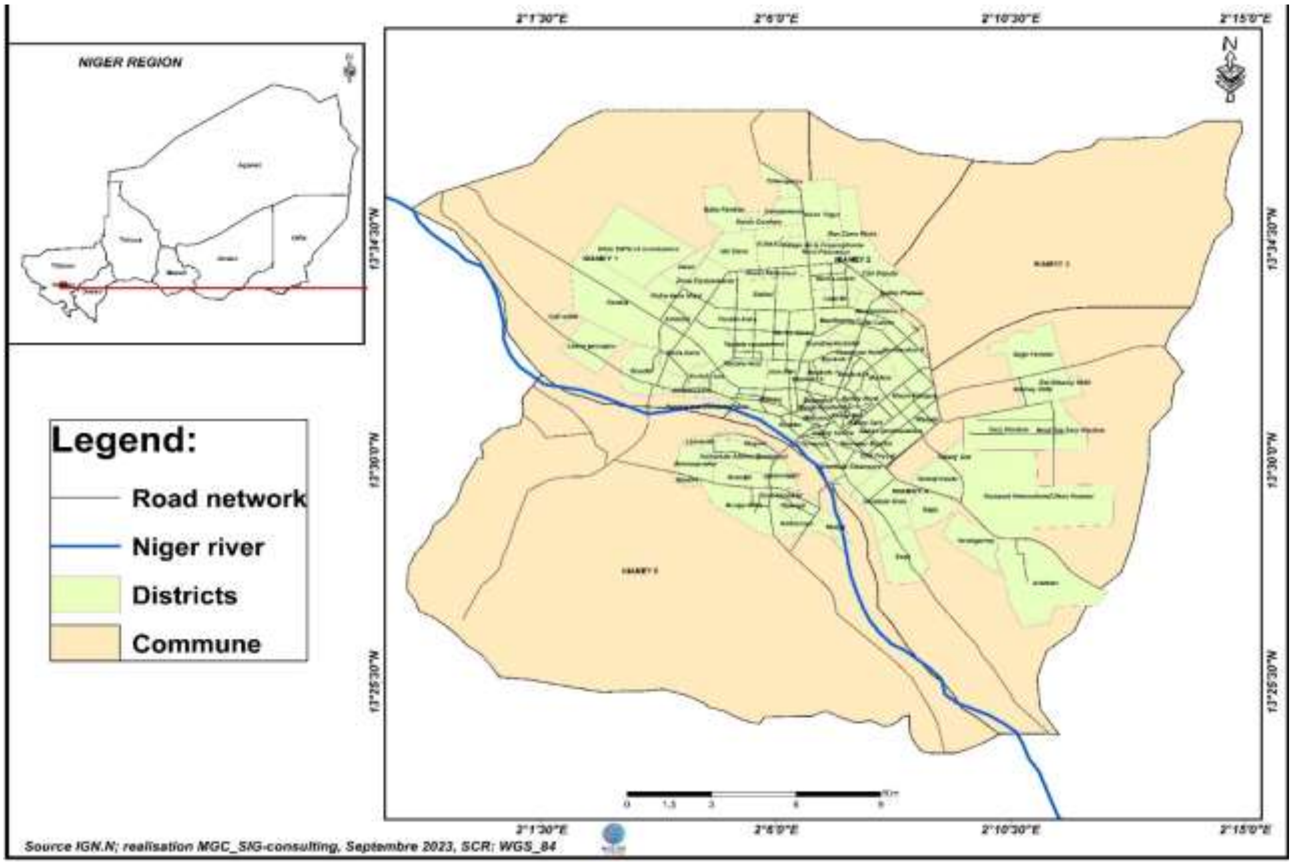


**Figure 1.** The localization and the structure of Niamey city (MGC_SIG, 2023)

## 2.2. Data collection

The primary data were collected based on the structured questionnaire consisting of close and open-ended questions in July 2021 across Niamey city. The survey was conducted by a group of students by using the Opendatakit (ODK) software with the smartphone in local language and French. The survey was also conducted during the weekdays in order to find the heads of households who are responsible for the most daily expenditures. This idea allows for minimizing the information bias and potential hypothetical biases. The heads of households are considered in this study to ensure the respondents are residents of the specific district. In addition, the stratified random sampling method was used first to select the districts within the five (5) municipalities (I, II, III, IV, and V) and then the residents within each district selected and interviewed (Maazou et al., 2024). This selection is based on the projection demographic of Niger 2012-2024 (INS, 2019) resulted from forth census (RGPH, 2012) conducted in 2012 by National institute of statistics. According to this projection, the Niamey's population which was 1,026,849 inhabitants in 2012 projected at 1,365,927 inhabitants in 2021 (Maazou et al., 2024).



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**Table 1:** The distribution of Niamey's population by Commune. Source: (INS, 2019).

| Commune | I | II | III | IV | V | Total |
|---|---|---|---|---|---|---|
| **Population** | 276,335 | 336,292 | 215,046 | 363,318 | 174,936 | 1,365, 927 |
| **Percentage of Niamey's total population** | 20.43% | 24.62% | 15.74% | 26.61% | 12.80% | |

In addition, the sample size is determined using the proportion method for the representative sample developed by Cohran (1963, 1975). As the population is large, the sample size is given by the formula: $n = \frac{t^2(p)(1-p)}{(p)^2}$ where $t$ is the confidence level (value found in the statistical tables consisting of area under the normal curve); $p$ is the proportion of citizens that have the attribute of interest i.e., those who perceived at least one ecosystem service in the population and e is the margin of error (the level of precision). However, we do not know the proportion p; so, it is quite common to take 0.5 as a maximum variability in the population to have a more conservative sample size which may be larger than if the variability of the population attribute is truly used (Singh, 2014). Therefore, by using 95% confidence level, the sample size is estimated at $n = \frac{(1.96)^2(0.5)(0.5)}{(0.5)^2} = 385$

This sample size was split out into five (5) communes according to the percentage of population by commune (table 1). Therefore, 79 (20.43%*385) respondents were selected in Commune I, 96 (24.62%*385) in Commune II, 61 (15.74%*385) in Commune III, 103 (26.61%*385) in Commune IV, and 46 (12.80%*385) in Commune V. In the first step, the districts selected using random numbers generator software (RNG) were Plateau, Koubia, Bobiel, Ryad, and Koira Kano in Commune I; Koira tadji, Lazaret, Banizoumbou, Dar-es-salam, Boukoki, Cite deputé in Commune II; Madina, Kalley Nord, Cité Fayçal, Banifandou in Commune III; Saga, Talladjé, Niamey 2000, Aeroport, Route fillingué, Pays bas, and Gamkalley in Commune IV; and Lamorde, Kirkossey, Nogarey in Commune V. In the second step, 16 respondents were randomly selected per district based on the method of pace between the households. The pace of 10 was taken from the household of the district chief (Maazou et al., 2024).

### 2.3. Data analysis

In order to assess the contribution of urban green spaces to climate resilience, the climate resilience index was estimated via PCA based on the subjective approach as applied by Jones, (2017) according to the availability the data at the city level. In addition, the econometric model, mainly the partial odds logistic regression model, the relaxing ordered logistic regression model, was applied to verify this association according to the nature of the dependent variable (climate resilience). Indeed, the ordered logistic regression is a suitable and the most commonly used model for regressing ordinal-scaled outcome variable providing highly interpretable coefficients. For this analysis, the Stata 16 software was used.

#### 2.3.1. Climate resilience index



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From the data survey, the PCA was run and the results were reported in tables (2) and (3) below. Table (2) indicates that the proportion of variance explained declines while the cumulative proportion of variance explained increases. The three (3) capacities explained respectively 82.8%, 10.6%, and 6.6% of these variations. Additionally, the proportion of the variance explained by component 1 added to the variance explained by component 2 gives the resulting cumulative proportion of the variance explained. Thus, the three associating components contribute to a cumulative variation of 93.4% using an eigenvalue cutoff of 1.000. The eigenvalues represent the different values that explain the factorial axes, explained respectively up to 2.484, 0.318, and 0.197 by the components 1, 2, and 3.

**Table 2:** Principal components, eigenvalues, differences between the eigenvalues, proportion of variance explained, and the cumulative. (Source: Field survey (2021) )

| Component | Eigenvalue | Difference between eigenvalues | Proportion of variance explained | Cumulative |
|---|---|---|---|---|
| Comp1 | 2.484 | 2.166 | 0.828 | 0.828 |
| Comp2 | 0.318 | 0.120 | 0.106 | 0.934 |
| Comp3 | 0.197 | . | 0.066 | 1.000 |

It is noticed that the first component has the highest eigenvalue equal to 2.35, greater than 1 explaining 82.8% of the variance. Therefore, the variables (capacities) under this first component contribute respectively up to 0.592, 0.572, and 0.568 to the principal component axis, which depicts the first eigenvector. As a result, the overall resilience score is estimated by combining the first eigenvector with the three associated capacities of the leading principal component (table 3).

**Table 3:** Principal components (eigenvectors/factors scores). (Source: Field survey (2021))

| Variable | Comp 1 | Compo 2 | Compo 3 |
|---|---|---|---|
| Anticipatory capacity | 0.592 | -0.057 | -0.804 |
| Adaptive capacity | 0.572 | -0.673 | 0.469 |
| Absorptive capacity | 0.568 | 0.737 | 0.366 |

According to Jones, (2018), the climate resilience index is generated from overall resilience scores derived from the linear combination of these three capacities by dropping the components that contribute less. The quantiles categorized these overall resilience scores into three groups: low score category, medium score category and high score category. The first category, considered low resilience, has the scores varying from 1.718 to 4.06, corresponding to 33.59% of the sample. The second category, considered medium resilience has the scores



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varying from 4.06 to 5.215 and correspond to 35.64%. The last one, as high resilience, has the scores varying from 5.2157 to 6.9272, corresponding to 30.77%.

### 2.3.2. Partial Proportional odds model

According to the nature of the dependent variable (climate resilience), the ordered logistic regression is a suitable and the most commonly used model for regressing ordinal-scaled outcome variable. This model has an advantage to provide highly interpretable coefficients. As the proportional odds model, the ordered logistic model describes an observed ordinal outcome variable Y consisting of three (3) categories: 1 if low resilience, 2 if medium resilience and 3 if high resilience, which is function of the latent variable $Y^*$. Thus, the empirical equation for proportional odds model is given as follows:

$$\ln\left(\frac{\Pr(Y_i \leq j/x_i)}{\Pr(Y_i \succ j/x_i)}\right) = \lambda_j - x\alpha \text{..........with}(1 \leq j \leq J)\text{..........}(eq:1)$$

The probability of the respondents to be low, medium, and high resilient is given by:

$$\Pr(Y_i = j \mid x_i) = F(\lambda_j - x\alpha)\text{............................................}(eq:2)$$

Where, $x$ is a vector of explanatory variables such as the demographic and socio-economic characteristics of the respondent $i$, and climatic and geographic characteristics of the area of the respondent $i$, $\alpha$ is a vector of unknown parameters to be estimated, and $\lambda_j$ denote the cut points associated with the $j^{th}$ category.

The ordered logistic model considers low, medium, and high level of climate resilience to have the same slope except the intercept. For that, the parallel lines assumption must be check following the Brant's Wald test (1990) as a post-estimation test. When the parallel lines assumption is violated, thus, the generalized ordered logistic model or partial proportional odds model relax this assumption across sample. By modifying the equation (eq:2) through the partition of into a subset, the ordered logistic regression model (proportional odds model) becomes the partial proportional odds model by which some coefficients are the same for all the climate resilience level i.e., they respect the parallel lines assumption while some other are allowed to differ by j climate resilience i.e., they violate the assumption (Fullerton, 2009). Thus, the partial proportional model is expressed as follow:

$$\ln\left(\frac{\Pr(Y_i \leq j/x_i)}{\Pr(Y_i \succ j/x_i)}\right) = \lambda_j - x\alpha - z\eta_j \text{.......with}(1 \leq j \leq J)\text{........}(eq:3)$$

Where $x$ and $z$ are the vectors of exogenous variables, is a cutpoint, $\lambda_j$ is the vector of the coefficients of the variables that meet the parallel lines assumption and $\eta_j$ is the vector of the coefficients of variables that do not meet the parallel lines assumption.

The specified model is given by:

$$Y_i = \alpha_0 + \alpha_1 Age_i + \alpha_2 Gen_i + \alpha_3 hhd\_size_i + \alpha_4 Mar\_status_i + \alpha_5 Educ\_level_i + \alpha_6 Income_i + \alpha_7 Work\_status_i + \alpha_8 \text{Occupancy\_status}_i + \alpha_9 \text{District\_status}_i + \alpha_{10} E\cos\text{\_services}_i + \alpha_{11} C\lim ate\_shock_i + \alpha_{12} \Pr ox\_publ\_green_i + \alpha_{13} \text{Life\_satisf}_i + \varepsilon_i \text{..........................................................................................}(eq:4)$$



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### 2.3.3. Expected sign of the explanatory variables of the model

Empirically, Jones, (2018) revealed that the climate resilience is influenced by age, marital status, gender, education, occupation status, status of the area, life satisfaction, climate shocks, and households' status. The evidence from Sub-Saharan African cities revealed that access to essential services such as water, electricity, health care, education, housing and transportation, soc ial networks, employment, the ownership of productive assets, and the building of flood-barriers influence the urban climate resilience (George, 2019). The characteristics such as age, gender, income, and health status of the urban population are also factors that influence the urban climate resilience (IPCC 2015).

**Table 4:** Explanatory variables and their expected sign

| Variables | Code | Label | Expected sign |
|---|---|---|---|
| **Age (Jones et al., 2018)** | $Age$ | Age | - |
| **Gender (George, (2019); Jones et al., (2018))** | $Gen$ | Female | +/- |
| | | Male | + |
| **Household size (George, (2019)** | hhd_size | Household size | - |
| **Marital status (Jones et al. 2018)** | $Mar\_status$ | Unmarried | +/- |
| | | Married | + |
| **Education level (Jones et al., 2018)** | $Edu\_level$ | Unschooled | - |
| | | Primary level | + |
| | | Secondary level | + |
| | | University level | + |
| **Work status (George, 2019)** | $Work\_status$ | Unemployed | - |
| | | Employed | + |
| **Income (George, 2019)** | $Income$ | <100000 | - |
| | | 100000-200000 | + |
| | | 200000-300000 | + |
| | | >300000 | + |
| **Climate shocks (Jones et al., 2018)** | $C\lim ate\_shock$ | High wind | - |
| | | Flood | - |
| | | Heat | - |
| **Occupancy status (Jones et al. 2018)** | Occupancy_status | Tenant | +/- |
| | | Owner | + |
| **District status Marcus, (2010)** | $District\_status$ | Downtown zone | + |
| | | Transition zone | +/- |
| | | Periphery zone | +/- |
| **Ecosystem services (Nero et al., 2019)** | $E\cos\_services$ | Provisioning | + |
| | | Regulating | + |
| | | Cultural | + |
| | | Low | +/- |
| | | Medium | + |



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| | | | |
|---|---|---|---|
| **Life satisfaction (Jones et al. 2018)** | Life_satisf | High | + |
| **Proximity to public green spaces (Braubach et al., 2017).** | $Prox\_publ\_green$ | No | +/- |
| | | Yes | + |

# 3. Results and discussion

## 3.1. Classification of ecosystem services

Widely used to communicate urban green spaces benefits, the ecosystem services must be carefully contextualized about the specific areas and time (Thomas Elmqvist et al., 2013). In the context of this study, ten (10) ecosystem services were identified and classified into three (3) categories, notably provisioning (the products obtained from the ecosystem), regulating (Benefits obtained from the regulation of ecosystem), and cultural (Nonmaterial benefits obtained from ecosystem). Figure 2 below indicates that cultural services dominate these ecosystem services with 66.92 %. As the most widely reported, these cultural services were consisted of shade, aesthetics, and recreation, with 92.74%, 34.65%, and 19.77% of responses. They are followed by regulating services which represent 17.44 % of services. The respondents were asserted that the urban green spaces allow them to infiltrate or intercept rainfall water with 5.9% against floods, reduce heat with 75.91%, and improve air quality with 60%. The provisioning services represent 15.64 % of the services explicitly dominated by food, with 42.18% of the affirmative answers. The respondents also mentioned medicine at 35.11%, aromatic at 10.99%, and wood at 5.63%.

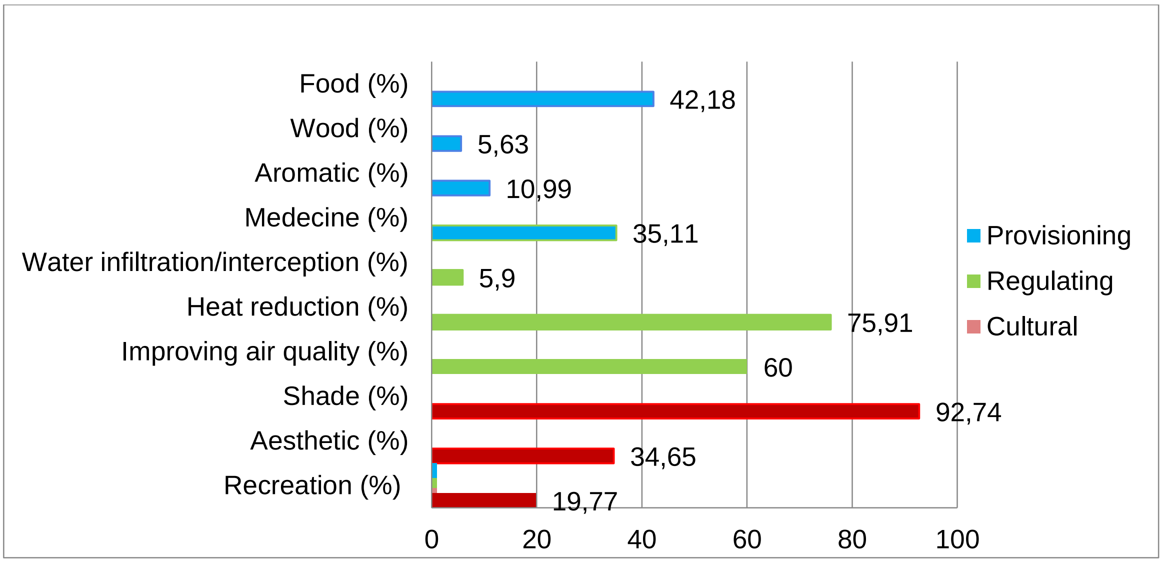


**Figure 2.** Classification of ecosystem services. Source: Authors, 2021



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### 3.2. Self-assessed capacities to climate shocks

The households self-assess their ability to prepare, recover, and adapt to the most reported climate shocks, such as high wind, flood, or heat, across the four (4) Likert scale points from not at all likely to extremely likely. The questions related to the three capacities as defined by Jones (2018) are respectively "If the main shock occurred, how likely is it that your household would be fully prepared in advance?", "If the main shock occurred, how likely is it that your household could fully recover within six months?", "If the main shock was to become more frequent, how likely is it that your household could change its source of income or/and livelihood, if needed?". Figure 3 indicates that 37.95%, 41.03%, and 27.95% of the respondents perceive themselves as highly likely to prepare, recover, and adapt to the main climate shock they experience. Again, 35.13%, 28.97%, and 37.69% of the respondents perceived respectively themselves as very likely to prepare, recover, and adapt to the main climate shock they experienced. However, compared to 18.46%, 21.28%, and 17.69% of the respondents who are not at all likely, 8.46%, 8.72%, and 16.67% of them are respectively very likely to prepare, recover, and adapt to the main climate shock that they experience. Ultimately, most of the respondents perceive themselves as very or extremely likely to prepare, recover, and adapt to the most reported climate shocks. Therefore, as the climate resilience variable derived from the average of these 3 As capacities, it is expected that most of the respondents be resilient to the climate shocks such as violent wind, flood, or heat.

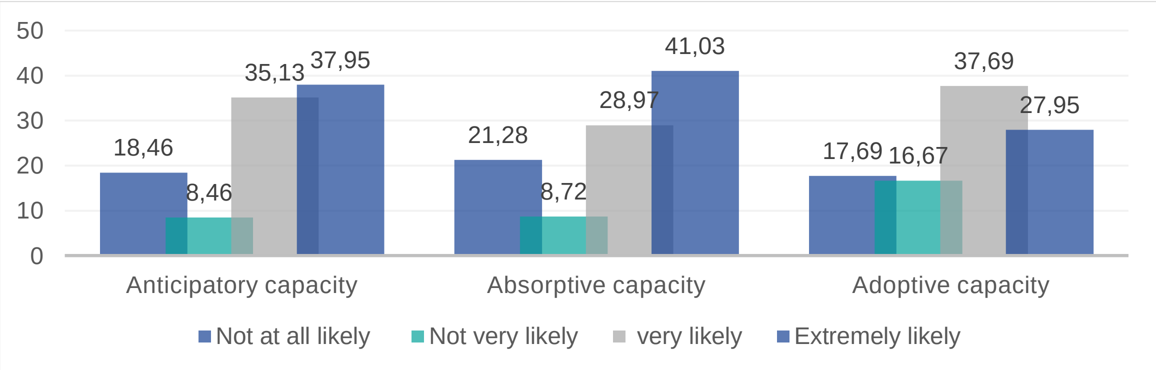


**Figure 3:** Self-assessment of the respondents' capacities to face the climate shocks. (**Source**: Authors, 2021)

### 3.3. Socio-economic demographic characteristics of the respondents

The descriptive analysis shows that the respondents' average age is 45.62 years and the average size of the household interviewed is 6.93 i.e. 7 persons per household.

**Table 5:** Definitions and summary statistics of quantitative variables

| Variables name | Definition | Mean | Std. dev. |
|---|---|---|---|
| **Age** | Discrete/numeric variable representing the age of the respondent | 45.62564 | 12.78609 |
| **Household size** | Discrete/numeric variable: the number of the people living in the household. | 6.93333 | 3.55575 |

In addition, most of the respondents are male (72.05%), married (82.82%) and employed (71.28%). It is noticed that 27.44%, 14.36%, 46.67%, and 11.53% of the respondents earned respectively below 100000 XOF, between 100000 and 200000 XOF, between 200.000 and


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300.000 XOF, and above 300000 XOF per month. Also, 31.54% of respondents have a university level of education, followed by those who have a secondary level with 26.92%, a primary level with 24.62% and unschooled with 16.92% due to the status of political capital of the city.

According to the survey, 58.21% of the respondents have the own house while 41.79% are tenants. The results revealed that 43.08% of the respondents live in the transition zone while 15.38% and 41.54% live respectively in downtown and periphery zone. In these zones, 23.59% of the respondents live for more than 5 years considered as a long-term, 35.90% for less than 1 year considered as court term and 40.51% live for the years between 1 and 5 considered as the medium term. Furthermore, the respondents face mainly three (3) climatic shocks during the last five years such as wind, flood, and heat with respectively 37.69%, 32.05% and 30.26%. These shocks lead to the livelihood lost, the diseases and even the death sometimes and the ability of the respondents to deal with these shocks is derived from the intertwined absorptive, anticipatory, and adaptive capacities. These capacities rely on the means and strategies adopted by the respondents. Among the strategies, there is growing trees, shrubs and grasses to make their homes and districts green for the ecosystem services. Therefore, 66.92% of the respondents perceived the cultural services, 17.44% perceived the regulating services and 15.64% perceived the provisioning services from urban green spaces. In addition, 33.33% of the respondents are low resilient, 34.87% are medium, and 31.80% are highly resilient. Ultimately, 66.92% of the respondents argued that they are highly satisfied, whereas 18.72% argued that they are lowly satisfied with their life, against 14.36% who are moderately satisfied.

**Table 6:** Definitions and summary statistics of qualitative variables. **(Source:** Field survey (2021)**)**

| Variables name | Definition | Variable label | Percentage |
|---|---|---|---|
| **Gender** | Dummy variable 1 if respondent is male and 0 otherwise | Female | 27.95% |
| | | Male | 72.05% |
| **Marital status** | Dummy variable taking value 1 if married, 0 if unmarried | Unmarried | 17.18% |
| | | Married | 82.82% |
| **Education level** | Nominal categorical variable taking 1 if the respondent is unschooled, 2 if primary level, 3 if secondary level, 4 if university level. | Unschooled | 16.92% |
| | | Primary level | 24.62% |
| | | Secondary level | 26.92% |
| | | University level | 31.54% |
| **Work status** | Dummy variable taking 1 if the respondent is employed in full or in part and 0 otherwise (retired, jobless, and housewives). | Unemployed | 28.72% |
| | | Employed | 71.28% |
| **Income per month** | Nominal categorical variable representing the amount that household earns per month taking 1 if below to 100000, 2 if from 100000 to 200000, 3 if from 200000 to 300000, and 4 if 300000 to above. | <100000 | 27.44% |
| | | 100000-200000 | 14.36% |
| | | 200000-300000 | 46.67% |
| | | >300000 | 11.53% |
| **Occupancy status** | Dummy variable taking 1 if the respondent is owner of house where he lives and 0 otherwise (tenant). | Tenant | 41.79 % |
| | | Owner | 58.21% |
| **District status** | | Downtown zone | 15.38 % |
| | | Transition zone | 43.08% |



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ISSN 2673-4494

| | | | |
|---|---|---|---|
| | Nominal categorical variable equals to 1 if the household lives in Downtown zone (districts with complete urban fabrics), 2 if he lives in Transition zone (districts between downtown zone and periphery zone) and 3 if he lives in Periphery zone (districts with incomplete urban fabrics). This variable is defined based on the urban reference plan of Niamey (*PUR* 2009). | Periphery zone | 41.54% |
| **Climate shock** | Nominal categorical variable equals to 1 if household experienced high Wind in the last five years, 2 if he experienced the Flood, and 3 if he experienced Heat. | Wind | 37.69% |
| | | Flood | 32.05% |
| | | Heat | 30.26% |
| **Climate resilience** | Ordinal categorical variable taking 1 if low resilience 2 if medium, 3 if high estimated from subjective approach Jones et al. (2018). | Low | 33.59% |
| | | Medium | 35.64% |
| | | High | 30.77% |
| **Proximity to the public green spaces** | Dummy variable equals to 1 if the respondent is near to public green spaces and 0 otherwise. This variable is defined based on WHO recommendations i.e., being at 15 min walking distance to green spaces to get the benefits. | No | 58.46% |
| | | Yes | 41.54% |
| **Ecosystem services** | Nominal categorical variable taking 1 if Provisioning 2 if Regulating, 3 if Cultural defined according to the MEA (2005). | Provisioning | 15.64% |
| | | Regulating | 17.44% |
| | | Cultural | 66.92% |
| **Life satisfaction** | Ordinal categorical variable taking 1 if low 2 if Medium and 3 if High. It is defined by the social, mental and physical life satisfaction. This variable measures the subjective well-being. | Low | 18.72% |
| | | Medium | 14.36% |
| | | High | 66.92% |

### 3.4. Partial proportional odds model results

The application of the ordered logistic model is under the proportional odds assumption/ parallel regression assumption. This assumption is tested by the Brant's Wald test under null hypothesis assuming that there is no difference in coefficients/odds ratio between the categories. According to the test, was statistically significant at 1% meaning that we can reject the null hypothesis, thereby the parallel regression assumption is violated. We conclude that the odds ratio/coefficients are not equal across the categories. Therefore, we would run a less restrictive model i.e. the generalized ordered logistic model/the partial proportional odds model. For that, the Brant's Wald for the global test was conducted. According to this test, the was not statistically significant even at 10% indicating that the null hypothesis cannot be rejected; thereby the final model does not violate the parallel lines-assumption.

As less restrictive model, Wald test shows 18 constraints have been imposed to have ten (10) variables that meet the parallel-lines assumption. For these variables, the sign of coefficients or the odds ratio are the same for all the categories and the interpretation is similar to that of the ordered logistic model. Of the thirteen (13) estimated coefficients, nine (9) associated with the variables gender, marital status, work status, education level, monthly income, climatic shock, life satisfaction, proximity to the public green spaces, and ecosystem services have a significant effect on the climate resilience. According to the results, the chi-square likelihood ratio (24) is equal to 116.05 with a p-value of 0.0000. This indicates, under null hypothesis that


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ISSN 2673-4494

the coefficients of the predictors are statistically different from zero. Therefore, the model as a whole is statistically significant compared to the null model without predictors with the value of the pseudo-R-squared which is equal to 0.1356.

For the variables that meet the parallel regression assumption, the sign of coefficients or the odds ratio are the same for all the categories and the interpretation is similar to that of the ordered logistic model (table 7). Therefore, the results showed that marital status is positively and significantly related to climate resilience. This means that the married respondents are more likely to be resilient than the unmarried. According to the results, there is a positive association between the high level of education and climate resilience (Jones, 2018), and also between high income per month and climate resilience. Indeed, the respondents with a high level of education are 2.172 times more likely to be resilient to climate change than the unschooled respondents, given that all the other variables are held constant. This result is expected as highly educated people are well aware of the effects of climate change and more likely to take action against climate change shocks. Indeed, the educated people can change their attitudes and behavior and make informed decisions. Importantly, the respondents with income per month above 300000 XOF are more likely to be resilient to climate change than those with less than 100000 XOF. This is intuitive because respondents with high monthly incomes are supposed to have the means to take action against the climate change effects; for instance, to acquire solar energy to counter the power cut to reduce the heat. Contrariwise, the low-income respondents in the urban area would find themselves facing the climate shocks effects with difficulties in taking concrete actions, especially for some who live in the informal settlements.

As expected, the sign of the climate chocks variable is significantly negative because of the extreme heat and frequent flooding with adverse effects on the dwellers' well-being in Niamey city. Thus, compared to the respondents who experienced the high wind event, the respondents who experienced heat or flood shock are less likely to be resilient. This is due to the city's climate, which is semi-arid Sahelian, characterized by the high temperature which ranges monthly between, on average, 32.5°C in January (coolest month), and the 40.9°C in April (Warmest month) (Garba & Abdourahamane, 2023). Also, the city frequently observes flooding during the rainy season, which affects the dwellers' livelihood making them more vulnerable, while violent wind rarely happens between June and July. In this regard, the urban green spaces, through their services, are seen as strategy tools to boost resilience to these climate shocks. This result is line with the results of Jones (2018).

Ecosystem services provided by the urban green spaces affect climate resilience positively. Indeed, compared to respondents who perceived the provisioning services, those who perceived the regulating and cultural services of green spaces tend to be significantly more resilient to climate change. This result reveals that the role of urban green spaces in reducing the high temperature, the risk of flooding via rainwater infiltration or interception, making the place cooler via evapotranspiration, and improving air quality via the absorption of CO2 while releasing oxygen in the atmosphere. These results are in line with the findings of Clarke et al., (2019), Cabral et al., (2017), Camps-calvet et al., (2016), Derkzen et al., (2017), and Zhang, (2019). Regarding cultural services, this study demonstrated that urban green spaces contribute significantly to recreation and social activities such as playing and meeting, which affect the respondents' health and well-being by making them less stressed. This result is much expected since the households in Niamey city plant trees generally for the shade increasing recreation while reinforcing social cohesion, as found by Hungerford and Moussa, (2016) and for heat



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ISSN 2673-4494

and air pollution reduction through the carbon stocks' ability to ensure the biomass (Moussa et al., 2019, Illiassou et al., 2016). This agrees with the findings of Nero et al., (2019) in Kumasi City, highlighting that urban green spaces contribute to climate resilience by improving air quality, reducing heat waves and flood risk, and improving health and well-being. These results show that the urban green spaces act as Nature-based solutions to climate change for the respondents in the City of Niamey. Thus, they allow facing the power cut, especially during summer, and reduce energy consumption when the energy demand exceeds the supply. Also, they provide oxygen by constituting the carbon sink which improves air quality and residents' health rendering the city more livable. To this effect, the results reveal that the respondents close to public green spaces within 15 minutes of walking distance are 1.753 more likely to be resilient than those far from them. This corroborates the potential of urban green spaces for climate resilience. Indeed, this result is expected since the proximity to the urban green spaces promotes physical activities such as walking, jogging, running, recreational activities, and social cohesion. This makes people near the green spaces more relaxed and less stressed, with a good mood, lower rate of depression, and good health by breathing quality air. This reduces the further cost of illness and thereby increasing their financial capacity. Consequently, they would be more likely to be resilient in the face of perturbations such as environmental extremes, floods, conflicts, or food insecurity (Braubach et al. 2017). Interestingly, the respondents' life satisfaction reflecting their well-being significantly influences climate resilience. Indeed, the respondents who are highly or moderately satisfied with their life are more likely to be resilient to climate change than those who are low satisfied with their life. This is expected as the respondents' happiness should strongly affect their capacity to cope with, adapt, and anticipate climate change, mainly because how people feel about their lives today can help them consolidate the resource to weather the storm tomorrow (Mguni et al., 2010). This positive correlation between life satisfaction and climate resilience has been found by Jones (2018).

Table 8 draws the variables that do not meet the parallel lines assumption, notably gender, work status, and district status which does not significant. For these variables, the coefficients or odds ratio differ from the low, medium, and high resilience categories and their interpretation will be similar to those from the multinomial logistic model. Therefore, the gender variable has a negative and significant effect on the low level of climate resilience. This means that men are less likely to be low resilient than the women. This is expected as women are more vulnerable, according to many studies, especially in African countries where women have traditionally less access to socioeconomic resources (Jones 2018, George, 2019). Concerning the work status, the results effectively show a positive and significant association between work status and climate resilience, but the coefficients decline across cut-points. Meaningfully, the employed respondents are more likely to be resilient than the unemployed, but the effects become much weaker when the climate resilience level moves from low to high. This is expected since the employed respondents are supposed to have a minimum income to ensure their livelihoods during and after the shocks. This change in the effects is probably due to poor working conditions, such as lack of job security and limited support, which many respondents who operate in the informal sector experience. In fact, according to World Bank, (2017), the city of Niamey constitutes the employment opportunities’ place for newcomers who generally engage in the informal sector without job security and often settle in the slums, considered the most exposed areas to climate shocks. These informal settlements are found mainly in the periphery and transition districts with unreliable electricity system and insufficient gutters for draining water.



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**Table 7:** Estimation results for the variables meeting the parallel regression assumption

| Variables | Coefficients | Odds ratio | Std. error(coef) |
|---|---|---|---|
| **Age** | 0.014 | 1.014 | 0.009 |
| **Household size** | -0.030 | 0 .970 | 0.031 |
| **Marital status** | | | |
| **Unmarried** | Reference | Reference | Reference |
| **Married** | 0.550* | 1.733* | 0.289 |
| **Education level** | | | |
| **Unschooled** | Reference | Reference | Reference |
| **Primary level** | 0.075 | 1.078 | 0.328 |
| **Secondary level** | 0.221 | 1.234 | 0.350 |
| **University level** | 0.775** | 2.172** | 0.382 |
| **Income per month** | | | |
| **Below 100000** | Reference | Reference | Reference |
| **100000-200000** | -0.425 | 0.654 | 0.342 |
| **200000-300000** | 0.293 | 1.341 | 0.285 |
| **300000 above** | 0.995** | 2.704** | 0.419 |
| **Occupancy status** | | | |
| **Tenant** | Reference | Reference | Reference |
| **Owner** | -0.103 | 0.902 | 0.239 |
| **Climate shocks** | | | |
| **Wind** | Reference | Reference | Reference |
| **Flood** | -0.754*** | 0.470*** | 0.262 |
| **Heat** | -0.580** | 0.560** | 0.279 |
| **Life satisfaction** | | | |
| **Low** | Reference | Reference | Reference |
| **Medium** | 0.770*** | 2.159*** | 0.374 |
| **High** | 0..699** | 2.012** | 0.286 |
| **Ecosystem services** | | | |
| **Provisioning** | Reference | Reference | Reference |
| **Regulating** | 1.608*** | 4.992*** | 0.394 |
| **Cultural** | 0.886*** | 2.427*** | 0.312 |
| **Proximity to public green spaces** | | | |
| **Far** | Reference | Reference | Reference |
| **Near** | 0.561*** | 1.753*** | 0.214 |
| **Number of observations** | 390 | | |
| **LR chi2(24)** | 116.05 | | |
| **Prob > chi2** | 0.0000 | | |
| **Pseudo R2** | 0.1356 | | |

Significance levels (P>|z|): * p<0.1; ** p<0.05; *** p<0.01



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**Table 8:** Estimation results for the variables that do not meet the parallel assumption

| Categories | Low resilience | | | Medium resilience | | |
|---|---|---|---|---|---|---|
| | Coef | Odds | Std. error (coef) | Coef | Odds | Std. error (coef) |
| Intercept | -2.109** | 0.121** | 0.870 | 4.072*** | 0.017*** | 0.893 |
| Gender | | | | | | |
| Female | Reference | Reference | Reference | Reference | Reference | Reference |
| Male | -0.537* | 0.584* | 0.293 | 0.264 | 1.303 | 0.299 |
| Work status | | | | | | |
| Unemployed | Reference | Reference | Reference | Reference | Reference | Reference |
| Employed | 1.428*** | 4.171*** | 0.264 | 0.501* | 1.650* | 0.281 |
| District status | | | | | | |
| Downtown | Reference | Reference | Reference | Reference | Reference | Reference |
| Transition | -0.314 | 0.730 | 0.324 | -0.314 | 0.730 | 0.324 |
| Periphery | -0.263 | 0.768 | 0.349 | 0.304 | 1.356 | 0.345 |
| Number of observations | | | 390 | | | |
| LR chi2(24) | | | 116.05 | | | |
| Prob > chi2 | | | 0.0000 | | | |
| Pseudo R2 | | | 0.1356 | | | |
| Reference category (default) | | | High resilience | | | |

Significance levels (P>|z|): * p<0.1; ** p<0.05; *** p<0.01

## 4. Conclusion

The City of Niamey, as most urbanized city of Niger, observes the increase in the demand of land for the dwellings at the expense of the urban vegetation. This situation increases the vulnerability of its dwellers to the climate shocks such as floods, heat, and violent wind. Indeed, the urban green spaces via the provisioning, regulating, cultural, and supporting services are considered as a promising solution to tackle these climate shocks. Therefore, this study aims to investigate the perceived role of the urban green spaces to the climate resilience by the residents. For that, the primary data were collected from 385 respondents across the city of Niamey via stratified random sampling method consisting of selecting the districts at the first stage and the households at the second stage. Furthermore, the econometric model especially the partial proportional odds regression model was used based on the nature of the climate resilience variable. The climate resilience index was estimated via PCA based on the respondents' perception of climate shocks and their capacities to face the shocks. The results show that the respondents who perceived regulating and cultural services from urban green spaces are more likely to be resilient compared to those who perceived the provisioning services. Additionally, the respondents who are near the public green spaces are more likely to be resilient compared to those who are far from these spaces. These results revealed that the ecosystem services from urban green spaces increase significantly the respondents' climate resilience. Furthermore, they revealed that marital status, work status, education level, monthly income, and life satisfaction increase significantly the likelihood of being climate resilient. In contrast, gender, and climate shock decrease significantly the likelihood of being climate resilient.


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The urban green spaces act as a nature-based solution to the climate change effects in the City of Niamey. Therefore, the public authorities (1) should implement an environmental education program in the schools to raise awareness of urban green spaces benefits; (2) should provide and preserve the public spaces intended to the greening to avoid being misappropriated; and (3) should promote the projects aiming to develop the green spaces across the city for accessibility. However, the data used in this paper are self-reported and cross-sectional. Thus, there may be a desirability bias or memory effect, especially some interview questions are related to the respondents' income, and respondents' perception of climate shocks and their capacities to cope with. For the future studies, clear attention must be made on objective approach for the climate resilience index's estimation. Furthermore, the dwellers' perception of public green spaces and their willingness to pay for the related ecosystem services could be assessed.

## Use of generative AI

We declare that there is no use of Artificial intelligent as tool for this research.

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## Conflict of interest

We declare that there is no potential conflict of interest

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