AN ASSESSMENT OF SUSTAINABLE URBAN GREENERY PLANNING IN THE CHANGING CLIMATE OF PORTO-NOVO AND PARAKOU IN THE REPUBLIC OF BENIN

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PhD/SPS/FT/2019/11132

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (PhD) IN CLIMATE CHANGE AND HUMAN HABITAT

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DECLARATION

I hereby declare that this thesis titled: "***An Assessment of Sustainable Urban Greenery Planning in the Changing Climate of Porto-Novo and Parakou in the Republic of Benin***" is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has duly been acknowledged.

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Federal University of Technology
Minna, Niger State

Signature & Date

CERTIFICATION

The thesis titled "**An Assessment of Sustainable Urban Greenery Planning in the Changing Climate of Porto-Novo and Parakou in the Republic of Benin**" by: AKAKPO, Bokon Alexis (PhD/SPS/FT/2019/11132) meets the regulations governing the awards of the degree of PhD of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation

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ABSTRACT

Cities in developing countries in Africa and notably many cities in Republic of Benin are still scarcely informed about the growth trend and its influence on the extra changes for further sustainability needs. The patterns of urbanisation are causing multiple problems to urban green spaces (UGS) and the holistic management and planning are crucial for urban sustainable environment. The aim of this study is to generate both quantitative and qualitative information on urban green landscape of studied cities in order to support the sustainable development through land use planning. Three multi-date satellite imageries, “Satellite Pour l'Observation de la Terre” (SPOT) 4 of 2000, SPOT 5 of 2010 and Google Earth Pro V 7.3 images (Landsat/Copernicus) of 2020 were used to generate data and examine occurred changes over two decades time. Google Earth Landsat/Copernicus images in 2022 were digitalized to extract data from individual layer of different categories of UGS. Ripley function was applied to assess pattern and distribution of UGS and landscape metrics were computed to quantify UGS configuration. Monthly satellite derived Normalized Difference Vegetation Index (NDVI) series were also collected using Google Earth Engine open-source while observed air temperature (AT) were obtained at National Meteorological Agency to examine seasonal variation of NDVI and a simple linear regression was applied to show the relationship between AT and NDVI. Questionnaires were used with 800 interviewees to assess resident perception on the existing greenery spaces, the prerogative for environmental safeguard, and the determinant of resident’s willingness for urban greenery improvement. The results showed the built-up areas exert incredible pressure on non-built-up areas in the both cities except on water body class. Crop lands were the most threatened in the cities (around 24 per cent and 46 per cent were respectively converted to built-up areas in Porto-Novo and Parakou). An average of 40 per cent of city bushes were also under threat in Parakou from 2000 to 2020. A significant difference (p-value ≤ 0.000) between UGS categories that were all in the aggregative distribution within cities was found. Furthermore, no significant linear trend (p-values > 0.05) was found, and NDVI was decreasing from 2000 to 2011 (0.21 to 0.19) and increased up (0.19 to 0.23) until 2020. In addition, a significant difference (p-value < 0.001) was shown between climatic seasons and the periods of January to March and April to June showed the lowest values (0.137 and 0.145) of NDVI respectively in Porto-Novo and Parakou. It was also found a positive correlation ($r = +0.56$ and $+0.76$) between annual mean AT and NDVI during the dry seasons respectively in Porto-Novo and Parakou. Moreover, around 80 per cent of existing urban greeneries are mostly located in the core of the town and the state of the density and diversity of these greenery areas were differently perceived in the borough of each city. The main benefits lost from urban greenery were air quality (45.25 per cent) for Parakou and cooling effect (74 per cent) for Porto-Novo and the causes of these losses depended also on the cities and the districts within the cities. Public participation was perceived to be low (> 85 per cent) and the institutional cooperation with local communities, educational level and knowledge on greening main impacts must be improved to foster the involvement of people in urban greenery development. The effective enforcement of urban land use policies and the update of urban planning to climate change effects are recommended for each city. Decision-making should also establish specific strategies or actions for the development, improvement or conservation of each UGS configuration categories. Smart urban management of water availability such as greenery irrigation should be helpful for ensuring the sustainable urban surface temperature mitigation. It was also suggested the enhancement of resident commitment for urban green space improvement and development through the operative institutional cooperation.

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LIST OF ABBREVIATIONS AND ACCRONYMS

ANOVA	: Analysis Of Variance
AT	: Air Temperature
CORINE	: COoRdination of INformation on the Environment and represents a pan-European database of the European environmental landscape
COVID-19	: Coronavirus Disease-19
EEA	: European Environment Agency
ENVI	: Environment of Visualizing Images
FAO	: Food and Agriculture Organization
GIS	: Geographic Information System
GPS	: Global Positioning System
IBM	: International Business Machines
IGN	: Institut National de Geographie
INSAE	: Institut National de Statistique et d'Economie
IPCC	: Intergovernmental Panel on Climate Change
LULC	: Land Use and Cover
LUD	: Land Use Dynamic
LST	: Land Surface Temperature
MCVDD	: Ministry of Living Environment and Sustainable Development
MDGLAAT	: Ministry of Decentralization, Local Governance, Administration and Territorial Planning
MPDEPP-CAG	: Ministry of Prospective Development and Public Politic Assessment-Governmental Action Coordination

NDVI	: Normalized Difference Vegetation Index
NIR	: Near Infrared Radiation
NO_2	: Nitrogen Dioxide
O_3	: Ozone or Trioxygen
PAG	: Programme d'Action du Governement
PDU	: Plan de Développement Urbain
PM10	: Particulate Matter (Diameter of 10 micrometres)
SO_2	: Sulphur Dioxide
SNK	: Student-Newman-Keuls
SPOT	: 'Satellite Pour l'Observation de la Terre', Satellite for Earth Observation
TM	: Thematic Mapper
UGS	: Urban Green Space
UHI	: Urban Heat Island
UK	: United Kingdom
UN	: United Nations
US	: United State
USD	: United State Dollar
USGS	: United States Geological Survey
VIS	: Visible Infrared Spectroscopy
°C	: Celsius Degrees

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The adaptation to the increasingly effects and impacts of the changing climate is not only a critical but also a costing challenge to humanity. An understanding assessment by Intergovernmental Panel on Climate Change (IPCC) showed the effective changes of natural systems, and these changes are assigned to anthropogenic climate change driven and the influences which all can actively made lower ecosystem and services functioning, thus impacting settlement and its human subjects (IPCC, 2014, 2018). As stated by many authors, landscape dynamics implying transformation of original space and features into cities have threatened divers the process of nature and ecology (Ramachandra and Aithal, 2012 ; Aithal *et al.* (2017). It is therefore recognized that the change in climate has a drastic impacts on urban settlements than on rural areas (IPCC, 2018). These impacts can then spread well beyond the physical consequences of climate change on these areas. With regards to this case, changes in climate can have a significant impact on the supply of services, goods, as well as energy to cities areas. Furthermore, the extent of these impacts can be mitigated through effective local planning and governance (United Nations (UN)-HABITAT, 2016).

Cities are complex ecosystems that are mostly affected by ecological consequences of uncontrolled urban growth that can be briefly summarized as increasing urban heat, degradation of air, water and soil cycles and quality, trouble in land use and land cover, loss of biodiversity, change in climate as well as transport congestions and social vices (Siddiqui *et al*., 2018). To address these challenges, inter-disciplinary research must be drawn up from science of climate, planning based on environment and design by working together with social and technical framework to assess climate hazards, vulnerabilities, and adaptation responses. (Carter *et al*., 2015).

The problem to achieve urban sustainable development is an important challenge for adaptative planning, because of the speed of environmental degradation and climate impacts particularly within these places (Wamsler *et al*., 2013; Scott *et al*., 2016). Therefore, the current patterns of urban expansion have created serious problems for natural resources and the quality of life. Also referring to the context of sustainability, great attention has been given to the role of urban landscape behaviour (Masnavi, 2007; Siddiqui *et al.*, 2018) and its dependence on the state and evolution of the growth of city. Although built-up areas in cities and towns are increasing over the world, they are still and highly depended on nature through ecosystem services and goods provisions from natural ecosystems in order to support viable function for its people (Scott *et al.*, 2016; Russo and Cirella, 2020). To this end, urban green infrastructure (urban forests, wetlands, parks, street trees, small gardens, green roofs, and walls) that is the hybrid of greenery and built systems is therefore adopted as strategy to adapt and mitigate climate change as well as providing good quality of life in developed counties (European Environment Agency (EEA), 2009; UN-HABITAT, 2016; Scott *et al*., 2016).

However, there is growing evidence of a decline in urban and natural areas. particularly the green spaces because of the development event in the world, especially in the cities of Asia and Australia cities as well as at small scale in European and North American environments (Haaland and van den Bosch, 2015). The situation of the loss of greenery in urban area can be mostly supported by greening features clearance (urban gardens and road trees) to lead housing, area of industries and bare infrastructure off to other greening measures. Despite this, recent research has discovered an overall rise in greening places in cities in Europe of west, but a decrease in Europe at East. (Kabisch and Haase, 2013; Kabisch *et al.*, 2016). Thus, the city of Berlin (Germany) is then the good example where despite higher density of its inhabitants, it shares very high rate (46 per cent) of urban greenery areas across the whole city (Kabisch *et al.*, 2016; Russo and Cirella, 2020). In North America, percentage of green infrastructure with a high rate of green spaces has been increased in many cities in response to concerns about sustainability in urbanized landscapes.

According to the findings of the urban footprint study of Geotab in 2019 (www.geotab.com/press-release/greenest-cities-in-america), Atlanta is the city in the United States that has the greenest space per person, with 1,023 square feet per person. Dallas comes in second place with 870 square feet, followed by Portland with 856 square feet. In Canada, four major cities (Ottawa, Toronto, Saskatoon and Calgary) have improved their development planning from typical green planning to green infrastructure that promotes ecological connectivity (Dupras *et al.*, 2015). It can be also noted that cities in Asia have not been spared the green space development event. Indeed, because of the quality of its green spaces through the green infrastructures, Hong-Kong has been branded as green city (Chan and Marafa, 2014; 2017).

It has been agreed that urban green infrastructures and its ecological services conceptualization are often recognized in terms of predominantly western perspective. For example, to reconcile urban resilience in or to face to climate change impacts and food scarcity, the cities of Vancouver (Canada) and Berlin (Germany) have adopted the enhancement of edible green infrastructure (Russo and Cirella, 2020). In Latin America, many cities' development plans have been shaved in order rhyme to local climate adaptation strategies. It is the examples of Havana (Cuba), Mexico (Mexico), Quito

(Acuador), Rosario (Argentina) which cities are synonymous with urban agriculture (Food and Agriculture Organization (FAO), 2014). If implemented accurately, the design of urban greenery places and future urban trends could have a significant impact on the larger urban and peri-urban ecology of cities (Russo and Cirella, 2020). As conclude by O'Farrell *et al*. (2019) and Girma *et al*. (2019), the well planning for the retention and the maintenance of urban greening infrastructure is more required as a key feature for the sustainability and well-being in cities.

The Question is to understand what is the state of African towns and cities in regard to greening development. Thus, several authors have reported the poor distribution of urban greeneries within cities and towns in Africa. They are globally uneven, non-aesthetic and increasingly under pressure (Cilliers *et al.*, 2013; Zakka *et al.*, 2017). Studies of Mensah (2016) and Narh *et al*. (2020) have stated that the green spaces and city's parks in Kumassi in Ghana are globally being depleted and now shift in the poor state. Indeed, a priority should be given to their restoration because of their importance in terms of ecosystem services for the quality of life in this city. Related observations were made in Nigeria when there is the loss of city's greenery by conversion of planned vegetation areas to other built land in many northern region cities (Zakka *et al.*, 2017). In South Africa, a paucity of knowledge around urban green space has been recorded and planning to easy the provision of ecosystem services is grossly inadequate (Schäffler and Swilling, 2013). Moreover, many factors contribute to green space development in African cities. The study of Ajewole *et al.* (2019), has identified many of those factors including the Sex, Marital status, and average monthly income. It must be so noted that the failure of institutional coordination in planting, protecting and managing urban green areas is the additional reasons for the loss of greenery in African cities (Girma *et al.*, 2019; Narh *et al.*, 2020).

In the Republic of Benin, the situation on greening spaces of many small and large towns has not been clearly understood and explored, although the life quality within towns depends mainly on the green features size and quality (Osseni *et al*., 2015; Teka *et al*., 2017). In fact, any urban settlement in Benin Republic is traditionally greenly established, while rapid urbanisation is driving to the loss of natural green areas in many cities in the country like it is the case in other African countries (Girma *et al.*, 2019; Narh *et al.*, 2020). The study of Teka *et al*. (2017) on urban forestry has shown a shortness of urban green space in Cotonou with the street trees poorly diversified. It would have been also understood that very few research works were done in this country despite the high interest accorded to green space development for sustainable living conditions in these areas.

The city of Porto-Novo and Parakou, located in different climatic zones, are the example of challenges cities in the country in terms of environmental and climatic events and economical potentialities due to their urbanisation. The weakness of green space in an expanding urban area is source of urban heat island, flooding events, air pollution, disturbance of carbon, nitrogen and water cycle that cause climate change effects, the loss of aesthetical and ecotourism in the city (White *et al*., 2017). Urban green space are additionally agreed to help people in cities to overcome physical and mental anxiety and stress, and to enhance human behaviour and traits. (Anguluri and Narayanan, 2017). Urban green space is consequently a crucial component of urban design, and its importance for maintaining the natural character and sustainability of the city environment may be particularly appreciated.

As a crucial component of urban planning and climate change adaptation measures, urban greenery should be prioritized, the integration of these areas in the planning document of cities should be based on accurate information such as their state, amount, composition, typology, spatial distribution, functioning importance and factors of their conservation and suitable management strategy. The focus of this study is to set the relationship between expanding built-up areas and urban greenery in order to contribute to sustainable urban planning for the selected cities in Republic of Benin.

1.2 Statement of the Research Problem

Urbanisation, (increasing concentration of population in towns and cities, (Cobbinah and Darkwah, 2016)) is still a tangible phenomenon that strongly influences the health of environment by altering urban ecological processes (Andersson, 2006; Cilliers *et al.*, 2014; Cobbinah and Darkwah, 2016; Lu *et al.*, 2019). This depletion of the urban environment can not only have harmful effects on the functioning of ecosystems, but it also presents high health risks for city dwellers (Lu *et al*., 2019). It is agreed that, urban areas and cities are vulnerable to global sustainability despite the raising of it population (Li *et al*., 2016). Since, about 65 per cent of population in the world will live in urban areas by the year 2030 (UN-HABITAT, 2016).

In Africa, cities already have high numbers of people and will continue to be at the centre of the mass of rural migration due to its multiple opportunities (Xu *et al.*, 2019). Therefore, although these areas are the drivers of global ecological transformation (McPhearson *et al.*, 2015), they are also the sensible areas of the most of responses from this world transformation that mostly relate to the increasing of air temperature or heat flow, changed water cycles as flooding, water and air pollution, shortages of house yards, resource and biodiversity loss (Li *et al.*, 2009; Masoudi *et al.*, 2019). Indeed, there is an increasingly interest to a green urban environment which can reduce such issues and strategies to promote urban sustainable development have already been enacted by the majority of developed countries through developing the green infrastructures (urban forests, wetlands, parks, street trees, small gardens, green roofs, and walls) in cities (Heubes *et al.*, 2012; Kabisch *et al.*, 2016; Anguluri and Narayanan, 2017; Russo and Cirella, 2020). The development and planning of urban greeneries can affect simultaneously strategies of mitigation and adaptation of climate change effects.

Furthermore, urban greenery positive change can reduce Urban Heat Island (Huang *et al.*, 2018), urban flooding (Bai *et al.*, 2018; Maragno *et al.*, 2018; Li *et al.*, 2020), contribute to air-noise pollution mitigation (Liu and Shen, 2014; Anguluri and Narayanan, 2017) and microclimate regulation (Heidt and Neef, 2007; Raheem and Adeboyejo, 2016). It is also recognized that the development and good management of urban green infrastructure contribute enormously to the aesthetic of the city and the enhancement of ecotourism activities (Ajewole *et al.*, 2019; Narh *et al.*, 2020). However, the capacity of urban greenery in mitigating and adapting to these effects depends on their category, configuration, composition and spatial pattern (Liu and Shen, 2014; Huang *et al*., 2018; Fu *et al*., 2022).

Many West African cities, particularly in developing countries, lack sufficient understanding of their expansion and urban sprawl, and the associated impacts on future development expenditures. (Xu *et al.*, 2019). Thus, they remain to be understood about their sustainability. Unlike extensive studies in Europe, the United States, Singapore, China, and India, there is limited research on urban development in African cities (Cilliers *et al*., 2014; Cobbinah and Darkwah, 2016; Xu *et al*., 2019). The rapid and extensive urban development in these areas poses risks to natural resources, health, safety, social cohesion, individual rights, and increasing poverty. Existing studies on urban dynamics and sustainability are primarily focused on South Africa (Cilliers *et al*., 2014; Cobbinah and Darkwah, 2016) and Ethiopia (Girma *et al*., 2019), leaving West African cities poorly addressed. The lack of data on urban dynamics in West African cities hinders holistic management and planning for sustainable development.

Cities in the Republic of Benin are undergoing uncontrolled urbanisation, expanding without consideration for the surrounding natural environment. Efforts to enhance the quality of public and private spaces involve incorporating sustainable city models. This includes the creation of green infrastructure such as parks, gardens, interstitial spaces, and street trees to integrate nature and vegetation into urban development. (Haaland and van den Bosch, 2015). Effective use of green infrastructure in urban planning depends on vegetation density and aesthetic appeal. City managers and land planners recognize the need for knowledge to ensure optimal management of green spaces (Osseni *et al*., 2015).. Despite this, residents may not fully grasp the importance of green areas for their well-being. These needs encompass factors like floristic composition, size, shape, distribution, and factors influencing the attractiveness of green spaces. Urban nature planning is acknowledged for its potential to preserve biodiversity and improve urban life quality. In cities like Porto-Novo and Parakou in Benin Republic undergoing restructuring, ecological aspects are often neglected in development approaches. Addressing these needs is crucial for maintaining, increasing, and managing green spaces, especially where their significance is not fully recognized in urban planning. Scientific and technical considerations are integral to the development and monitoring of green spaces in these cities.

Porto-Novo and Parakou in the Republic of Benin are facing adverse environmental and climatic changes despite planning efforts. Porto-Novo, in particular, has high levels of air pollution, with a notable increase in aerosol loading between 2000 and 2011 (Emetere *et* *al*., 2018). In Parakou, allergic rhinitis is attributed to house dust and air pollution (Flatin *et al.*, 2018). Both cities experience elevated temperatures, reaching up to 40 °C in Parakou, contributing to unfavourable living conditions (Falolou *et al*., 2020; Lanmandjèkpogni *et al*., 2019). Additionally, they suffer from severe flooding and soil erosion, with Porto-Novo consistently impacted by disasters linked to flooding and soil loss (Ministry of Prospective Development and Public Politic Assessment Governmental Action Coordination (MPDEPP-CAG), 2019). Parakou, especially in its northern region, faces an annual risk of flooding disasters due to rainwater and overflow from the Okpara river (Livangou *et al*., 2018). The challenging environmental situations in these cities underscore the urgency for comprehensive measures to address climate-related issues and improve overall urban resilience

The study envisages to enhance academic understanding of the sustainability of green spaces in cities, with the goal of informing planning practices and updating the skills of planning professionals. The motivation stems from the need to prepare for the impact of climate change on cities and to control the rapid growth of urban areas. Uncontrolled city expansion, often accompanied by insufficient incorporation of green spaces into urban planning, can lead to issues like heat flow, recurrent flooding, air pollution, and urban ugliness. These disturbances negatively affect people's lifestyles and the overall sustainability of urban areas. Haaland and van den Bosch (2015) emphasize that the destruction of urban green infrastructure has adverse effects on sustainable development. Therefore, the study advocates for the development, management, and integration of green spaces into city growth plans to contribute to positive urban development. However, it acknowledges the necessity of preliminary information and the involvement of various stakeholders before implementing such projects.

The following research questions must be answered to enhance development of urban environment in these cities.

1- How does urban rapid growth impact natural environment of the two cities?
2- What are the pattern and distribution of urban greenery spaces in each city?
3- How does urban greenery vary in year seasons and the relationship with land air temperature regulation in the two cities?
4- Which factors do influence the development of urban greenery spaces?

1.3 Aim and Objectives of the Study

This study aims at generating both quantitative and qualitative data linked to the state as well as urban greening dynamics within cities to support the sustainability in these cities through the planning of land use in Benin. Thus, its objectives are to:

1- Assess urban land use and land cover (LULC) dynamics,
2- Examine the pattern and distribution of urban green spaces in these cities
3- Evaluate the vegetation seasonal variation and the correlation with land air temperature in the cities
4- Assess stakeholder's perception in urban green spaces development in cities.

1.4 Justification for the Study

Porto-Novo and Parakou in Benin Republic are respectively the second and third ranking cities with special status in the country. They also have been included in the scope of emerging city by the government (Allio and Schut, 2013; Programme d'Action du Gouvernement (PAG), 2016). They encourage the high economic development in these different regions of the country, give job opportunities and deliver public services, like high level of education, health and transport that create changes in living standards and lifestyles (PAG, 2016). The development of urban greenery areas may serve an essential part in the construction of ecological towns by improving the overall quality of the urban environment as well as the aesthetic appeal of urban settings. It has been agreed that improving urban greeneries is an essential means and strategy for preserving urban ecosystem wellness, improving the way people live through climate mitigation and adaptation, encouraging an integrative human-nature connection, and eventually achieving sustainable cities. This study contributes to improvement of policy guiding for the sustainable development of cities in Benin Republic, thus urban planners in the Ministry of Living Environment and Sustainable Development; decision makers at National and Districts level, Non-Governmental Organizations (NGO), International institutions that work for urban development.

In terms of improvement in the performance of city managers and urban planners to adapt to current climatic impacts, it goes beyond the scientific issue, as the needs of knowledge for optimal management and balanced urban greenery infrastructures in each city of interest. As a result, specialists in various cities must discover which design and operation strategies would work best for the acquisition, restoration, and preservation of urban vegetation and other greenery in cities in their unique areas. This entails addressing issues at the urban landscape level relating to the optimization of territorial arrangement of urban greenery for operational focus defined in relation to the needs of each city, because regular patterns and distribution should imply regular patterns of ecosystem services produced to urban people.

City dwellers sometimes ignore the importance of greenery spaces to better protect them. These needs are often expressed in terms of category of greenery infrastructure, floristic composition as factors in attracting city dwellers to greenery spaces and climate change mitigation. This study provided clear understanding on seasonal variation of urban vegetation index and implication in land air temperature reduction. Thus, regarding to climate location, city's decision makers could scientifically choose the climate-tailored urban vegetation cooling strategies in the perspective of climate change.

Additionally, students and researchers of national universities and research institutes are also the potential beneficiaries of the study. Giving city forestry an independent political status may have stimulated the rise of scientific needs in urban forest management, arboriculture, horticulture, urban forestry economics, and urban forestry legislation in numerous colleges and research institutions throughout the country or Africa, resulting in the need for future study. It is indeed evident that this study on urban greenery spaces development with a view to improving climatic adaptative strategies and the quality of life in urban areas will not only create awareness of city dwellers and stakeholder decisions but also encourage the opening of new specialties and courses in our universities for the extension of frontiers of knowledge.

The reduction of urban green space areas in profit of built-up areas was found from 2000 to 2020 in each case city. This finding could constitute the object of knowledge of awareness and support to decision making in this field. The pattern and distribution characteristics of urban green space classes would serve knowledge guideline for town planning and policies for urban landscape development with regard to climate change adaptation (ecological functions distribution, equitability as well as equity). A work also assessed the impact of seasonal variability of urban greening on land temperature dynamic. Furthermore, the conclusion may have implication on urban management of water availability such as greenery irrigation which would be more helpful for ensuring the sustainable urban surface temperature mitigation. Therefore, knowledge for multidisciplinary importance in urban green space development should be highlighted and made its attention in universities.

Moreover, as the work assessed the factors that determine people involvement in green space improvement, this study could have the interesting policy implication on the priority axis for urban greenery development. The study showed that institutional cooperation with local communities, educational level and knowledge on urban greenery importance must be improved to foster higher involvement of people in urban green space development. Finally, the findings should contribute to a guideline setting for policymakers, urban planners and managers, cityscape architects, and projects of urban sustainability regarding the urban greenery in the Republic of Benin.

1.5 Scope and Limitation of the Study

1.5.1 Scope of the study

The land use and cover dynamics assessment to understand urban greenery spaces evolution was from 2000 to 2020. This temporal range has been chosen because the changes in urban areas in terms of land greening is rapid due to urban expansion and the deficiency of town greenery space design and management strategy, (non-clearly stated and followed) and then the important differences can be observed during this period in both cities. The research takes into account the administrative area of each city. The city of Porto-Novo and Parakou have been considered because their particular status of city in the country. They are respectively the second and third important cities. In terms of their climate, ecology, social, ethnical and cultural aspects, the two cities are quite different, and this would aid the identification of the nature of sustainability that can be practiced in the two cities. In terms of content, this research on urban greenery development focuses on all green infrastructures (urban forests, wetlands, parks, street trees, small gardens, green roofs, and walls, wetlands and water body, and agricultural small lands) because they emphasis is on ecosystem services provision and especially climate change effects adaptation strategies.

1.5.2 Limitations of the study

By taking distance between people because of Coronavirus Disease 19 (COVID-19) situation affected data collection especially private houses and gardens. Meteorological data mainly used for the city of Porto-Novo were from meteorological station of Cotonou (around 40 kilometres from Porto-Novo). This may have influence on the reliability of the conclusion made in this case. The study faced also the restriction of updated urban master plan and document availability. This constituted a limitation in this work because of the impossibility to compare current observation to the documented planning.

Finally, Google Earth Pro Landsat images used for land occupation dynamics in 2020 do not have exactly the same image characteristics of satellite to observe Earth "*Satellite Pour l'Observation de la Terre*" (SPOT) Four and Five images used for 2000 and 2010. This can induce a lack of concordance in the output maps.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual and Theoretical Framework

This chapter discusses some concepts and theories related to urban expansion, urban green space, planning development and sustainability, environmental sustainability, and sustainable development. These concepts and theories will be helpful for achieving the objectives set out in this study.

2.1.1 Conceptual framework of the study

The contemporary debates are mostly heightening around the relationship between nature and city especially for anticipating impacts of changing climate effects in the cities. Therefore, Tan (2017) had underlined that a well urban planning with the integration and development of greenery strongly leaded to urban environmental sustainability as well as sustainable development of a city. So, in this study the central concepts are clustered into two main categories including: One) - the independent variable as urban greenery planning and urban greenery spaces development which include garden city, eco-city, smart city, greening city and compact city. Two) - those of the urban environmental sustainability and sustainable development. The concept frame with the link between independent variables (urban greening planning and green space development) and dependent variable (environmental sustainability as well as sustainable development) has made the link to climate change since urban areas are the most sensitive to climate change effects. The figure 2.1 shows the conceptual framework of the present study.

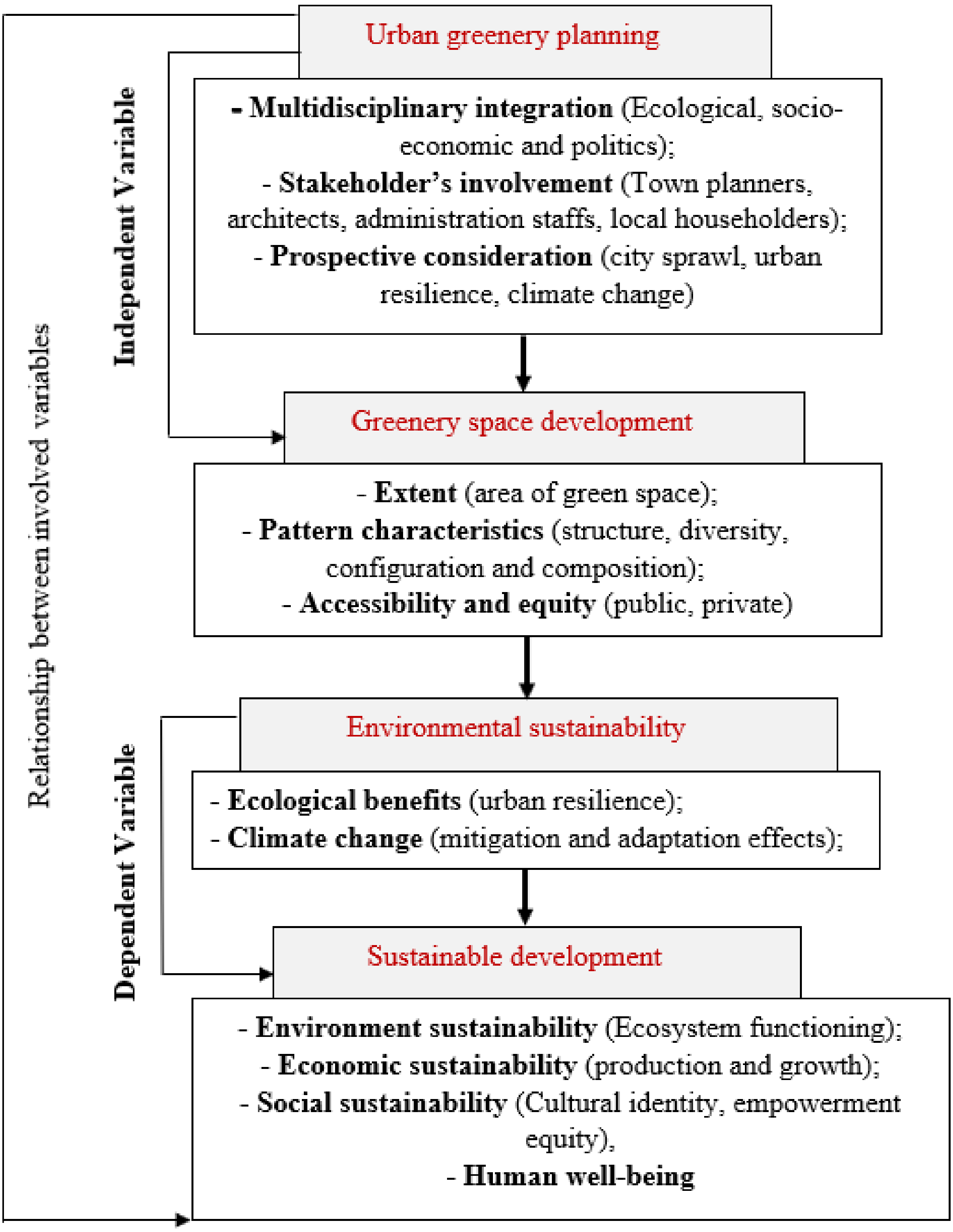

Figure 2.1: Conceptual Framework of the Study.

Source: Author's fieldwork (2021)

2.1.2 Urbanisation and climate adaptation

Urbanisation can be generally defined as the process that replaces "non-urban areas" by "urban areas". According to (Murayama and Estoque, 2020), the definition of the concept can depend of academic perspective. But in most of cases, urbanisation is the increase of the population in a city, with the expansion of urban area and infrastructure (Guo *et al.*, 2022). Therefore, in West Africa, urbanisation is reflected to a rapid process resulting from strong demographic growth and intense internal migration to cities (Walther et al., 2020). In Benin Republic, urbanisation is seen in the anarchic and rapid development of cities due to demographic pressure, the predominance of horizontal housing and the weak policy of land planning (Yaya *et al.*, 2018). Thus, urbanisation is reflected in this study by the expansion of urban sprawl over time.

Urbanisation conditions the occupation of greenery spaces that are a key element in climate adaptation strategies (Li *et al*., 2019; Croce and Vettorato, 2021). Climate adaptation generally means putting together strategies and actions to prepare for both current and projected hazardous events, trends or disturbances of climate change (Commission European, 2021). Thus, to improve climate adaptation in urban areas, this study involves assessing the development of urban greenery spaces through urban greenery planning and sustainability. Therefore, the concept of climate adaptation in this document is more close to nature based solutions for adaptation where greenery space development occupies a fundamental place (Kabisch *et al*., 2017).

2.1.3 Urban greenery planning, greenery development and sustainability

The concept of greenery in city can be understood as environmentally friendly in relation to city development. According to (Shen *et al.,* 2018), different layers such as urban planning and design can be included in this concept without forgetting any stages in its implementation. So, a greenery planning and green space development in urban area can be comprehensive as environmental strategies that aim to environment quality improvement and make rapid progress towards climate resilience and sustainability. After more, multi-disciplinary approach such as socio-economical, ecological and political approaches must be involved for urban design and planning.

Cities are the areas which are experiencing too many effects of climate change, while the developed and well-planned urban greenery spaces, have an exceptional contribution in climate change adaptation and mitigation (Kithiia and Lyth, 2011). It can recognize that the development of an urban greenery space is related at its extend, its diversity in terms of configuration, species composition, and its accessibility and equity (Sánchez *et al.*, 2018). Therefore, the functions and benefits from urban greenery spaces are inextricably linked to their pattern characteristics that are in relationship to the exigence of socio-economy and policy for town development (Xu *et al*., 2016; Zhang and Tan, 2019). The sustainable urban greenery is link closely to its management, protection, renewal and urban policy towards their existence (Kimengsi and Fogwe, 2017; Cobbinah *et al.*, 2021). Furthermore, the distribution and composition of urban greenery spaces are essential in the adaptation strategy of cities in the face of climate change (Sánchez *et al*., 2018).

2.1.4 Environment sustainability and sustainable development

In response to growing worries about the influence of development methods on the state of the environment, the notion of "sustainability" has been developed in the early 1970s. (Dizdaroglu, 2013; Chan and Lee, 2019). The discussion over sustainability began in 1972, with the United Nations Stockholm Conference on the Human Environment.

(Cilliers *et al*., 2014). As a result, the term "sustainability" can relate to the preservation of the environment and its services while still meeting human needs. (Wu, 2014; Peng *et al.*, 2015). Sustainability can be the ability of some places that resources can endure forever. Thus, it can be a way of living with less using of active resources. In this scenario, the idea of ecological sustainability in towns and cities includes the resilience and sustainable growth demands of urban regions, as well as how to execute resilience-oriented policies (Russo and Cirella, 2020). Zhang and Li (2018) defined urban sustainability as the proactive method of forming a city without jeopardizing the growth of neighbouring regions and assisting in reducing the negative consequences of development through synergistic interaction and mutual evolution of city subsystems. As a result, environmentally friendly land use (green planning and green space development) is required to regulate natural processes and control the extent of human activities.

Various urban development theories that focus on the nature-based approach can be widely understood under Green Planning (Garden City and Green Planning/Green Urbanism). These theories emphasize the need of preserving the nature-city link and the various advantages that this relationship provides to the evolution of cities, which is critical for the theoretical foundation of this study. An analysis of these theories is provided here to investigate the link amongst urban greenery spaces and environmentally friendly urban growth, which has gotten less attention in urban greenery literature. Every of the listed and closed ideas provides a unique design or way of thinking about how a nature-based approach might be incorporated into urban planning. This feeds into the empirical analysis of the study of the various approaches that can be taken to improve the development of urban greenery spaces. It is the case of the statement such as eco-city, green city, liveable city or smart city.

However, each of these approaches can have a specific aspect that can be interesting for our study. As example of green city, San Francisco is North America's greenest city. In Asian continent, it is agreed that Singapore has been advanced in the concept (Shen *et al*., 2018). The principles of green city are listed as greening resources; social greening system; greening spaces; friendly waste, transportation and building. This study seemed to understand the aspect of how the study areas behave in relation to green spaces. It was just this aspect of green city the work searched to clarify.

But speaking of eco-city, it can be defined as a figure of speech that covers a wide range of urban-ecological models aimed at achieving urban sustainability (El Ghorab and Shalaby, 2016). This concept means more the ecologically healthy that do not talk about the full sustainability of a city (mix of social and economic aspects). However, it was agreed that the ecological health of a city can be the base of the remain aspects (social and economic aspects) of its sustainability (Tang, 2011). Only environmental aspects were taken in this study. The quantity and structure of town greenery places and their relation with climate resilience were especially the concerns reached by the study.

The liveable city, as for it, can be described as an urban system which creates a physical, social and mental wellbeing thus allows a personal development of the inhabitants, it would be about a charming and desirable urban space which can offer a cultural and perhaps sacred enrichment. These key principles are equity, dignity, accessibility, usability, participation and empowerment (El Ghorab and Shalaby, 2016). This study did not concern equity, dignity, accessibility and usability of urban friendly spaces. It was particularly friendly space characterisation (temporal variation and trend, pattern and distribution, impacts on surface temperature and people perception on the current state and their opinions on greenery development).

When the concept of smart city is grounded mostly on high technology. Thus, this sort of city employs a variety of electronic methods and sensors to collect knowledge and data in a variety of domains, including the economics, the environment, transportation, and administration, in order to enhance the city's infrastructure and offerings (Shen *et al*., 2018). The cities of the current study are traditional. The features of smart city were no longer found in these cities. Therefore, the study cities are far from smart city.

In this document, the findings were on the trend of different land use and cover classes from 2000 to 2020; pattern, configuration and distribution of urban vegetations spaces in 2021; impacts of seasonal variability of urban greenery on surface temperature mitigation and citizens opinions and participation in greenery improvement. These aspects may have mostly approached the concept of eco-city that look especially for ecological healthy in urban areas. Thereby, the relationship of nature and city regard to changing climate adaptation and abatement concept can be mostly improved by the planning and the development of greenery spaces in the selected towns in Benin Republic.

2.2 Theoretical Framework

First, the study made reference to the theory of Garden city, introduced by Ebenezer Howard (1850 to 1929). Key landmark city idealistic concepts, including Charles Fourier's dream settlements (dubbed "phalansteries"), Ernest Callebach's fiction "Ecotopia," and Le Corbusier's concept of "La ville verte" (the green city), emphasized the need of preserving the natural environment. Garden City's emergence has been aided by Green Planning concepts such as the greenbelt, green heart, green finger, greenway/wedge, and green roof. These many models have proven various methods for designing and preserving urban vegetation. Acknowledging that the model of Garden City started with the problem of overcrowding in the industrialized settlements in the half of

20th century. This vision have been made of a circular new city which was distinct into several wards as neighbourhoods in order to accommodate up to several thousands of people working as well in the city (Sharifi, 2016). It can be agreed that the density of the population in each ward of the model would be low, the employment and other economic activities would be held at the long of central avenue of the city and the ownership patterns would be carried off on the private. However, what would be the issue of the composition of the population? There, to cooperatively manage the city's affairs and actively participate to civic activities, the model of Garden City envisioned a socially the mixed population in different wards of the model (Gillette, 2010; Sharifi, 2016). This Garden City theory would be related to how the green spaces were patterned and distributed in the study cities. If the green spaces are planned or not. This theory should be helpful to understand the types of natural environment to conservate in urban area and their dynamic over the time.

As the same principle to integrate and preserve nature into city, Green Urbanism or Planning is most a political appellation of theme. As a result, green urbanism provides direction for policies and programs that seek to create new urban areas with the goal of safeguarding the natural urban environment by fostering the rise of socially and environmentally sustainable urban neighbourhoods (Lehmann, 2020). While, regarding to Yu *et al.* (2020), the green urbanism perspective has evolved and is very important in the evaluation of sustainable development. It means that this perspective can cover some subsystems such as environmental sustainability, social sustainability and economical sustainability. However, it has been agreed that the main idea of the concept "Green Urbanism", was to make sustainable the environmental matters in a urban settlement basing on triple zero principle skeleton (zero use of fossil-fuel energy; zero wastes production and zero carbon emissions) (Lehmann, 2020). Basing on green urbanism theory, the suggestion may be made to central and local government and partners in sustainable development to foster urban zoning creation or the creation of new cities with the guarantee of real sustainable development.

To some extent, the growth of new urbanism reflects the government's and the public's desire to iron out urban greening in order to reduce future disorder in cities (Youzhen and Longlong, 2012). Sharifi (2016) studying the evolution of movements from Garden City to Eco-urbanism concept, has concluded that the evolution of theories, which have the same principle, depends on the gradual consideration of the different dimensions of the concept of durability. That, the main aim is the mix of the natural and built. Therefore, in order to make in relation the future cities and environmental sustainability, Riffat *et al*., (2016) have described the exciting innovations already being introduced in cities as well as those which could become reality in the near future. In this case, the place of development of greenery spaces has been highlighted by starting on the pioneer of urban planning with green development (Garden city theory) (Scott *et al*., 2016). The modelling and applying of digital Garden city using Geographic Information System (GIS) has already been carried out (Yuan *et al*., 2013). Recognizing that these models or theories are heavily focused on developed countries, their significance in guiding effective land occupancy, preserving the natural environment, and encouraging environmentally friendly urban land, as well as their inclusion into the planning agenda in many developing countries, may have an impact on the sustainability of many developing cities, including Porto-Novo and Parakou in the Republic of Benin.

2.3. Review of Related Studies

Urban land covers are changing more radically over a short time moment than elsewhere due to relentless processes of urbanisation. Spatio-temporal changes of urban green environment is therefore a common phenomenon under rapid urbanisation.

To assess the dynamic of town friendly space in response to rapid urban growth and greening policies, from 1992 through 2009, Zhou and Wang (2011) employed a holistic strategy to describe the changing layouts and intensities of urban greenery in Kunming, China. This method addressed the spatial differences of greenery space patterns obtained from concentric and directional landscape evaluations, followed by landscape measurements. The change strengths for the research area as a whole, the concentric belts, and the directional segments were then computed for both time frames from 1992 to 2000 and from 2000 to 2009 to investigate the variance of the green space change rate in the city. This method has achieved to the result that the both policies of greening and speed urbanisation have been reported for the method of the change of green space. Thus, among urban green space, land use types like agriculture land were gradually taken away and fragmented by urban extension, especially in the outer belts of the city. According to the land of forest, a relatively moderate loss rate has been encountered comparing to agricultural land.

In contrast, the recovery of grassland in the last decade has been aided by greening policies. (Zhou and Wang, 2011). Therefore, Karanam and Babuneela (2017) used the Normalized Difference Built-up Index to instinctively depict urban areas using Landsat. Thematic Mapper (TM) imagery with the goal to demonstrate changes. This approach has a significant benefit due to the unique spectral sensitivity of built-up regions and various land covers. In addition, it is a suitable substitute to existing approaches for mapping built-up areas rapidly and objectively. To create a false colour composite image, the raw image from United States Geological Survey (USGS) Earth Explorer is stacked with all seven bands. The classification was made by defining five to seven classes by varying the pixels of formation. Initially, a smaller number of training pixels were defined for the Landsat thematic mapping data and an overall assessment of the accuracy, kappa statistics are carried out. The image was categorized differently by increasing training pixels for different classes, and kappa statistics were used to evaluate accuracy across all classes. (Karanam and Babuneela, 2017).

It has been accepted that quantifying urban spatial variance in green space patterns, as well as comprehending pattern change through time, are critical for directing future greening planning and policies to promote sustainable urban growth (Zhou and Wang, 2011). Therefore, Xu *et al.* (2016) identified a clear association between urban green space, spatial pattern, and ecosystem services. Their research discovered that, with the exception of the shape configuration characteristic, many spatial variables of urban green spaces have influenced their ecosystem service value as contained in land value.

Similarly, green areas should occupy from 2.20 per cent to 13.40 per cent of the total urban area in order to effectively enhance their ecosystem service potential. Furthermore, they should be positioned between 50 and 550 metres from other changes, with green space patches distributed so that each patch occupies more than three per cent but less than 62.50 per cent of the overall green space (Xu *et al.*, 2016).

These findings would be highlighted later by (Zhang and Tan, 2019) who studied that urban green infrastructure and health wellbeing depend on the scale of analysis and the way green infrastructures are assessed. Regarding to using a population-based household survey with 1000 respondents, these researchers have collected data on self-reported health and perception and utility pattern of urban green space. The interest of the study has been found in the taken into account of many parameters for the health state perception. Hence, their findings revealed that, while all urban green space measures examined were favourably connected to mental health at different stages, canopy cover had the highest connections with mental health at all dimensions. Then, 400 and 1600 metres are the minimum and maximum spatial scale levels at which urban green space and health have substantial connections, with the greatest benefit (Zhang and Tan, 2019). However, other studies have already stressed the role of urban greening space in climate change adaptation measures.

The contribution of urban green space to urban heat reduction and many other social, physical and environmental benefits has been examined on the largest urban centre in North Karnataka, India (Anguluri and Narayanan, 2017). They have quantified urban green area by using satellite images through Normalized Difference Vegetation Index. The analysis of green space was conducted not just by per-capita green available for each inhabitant of the city, but also by the proportional green index. They also acted to understand about the surface temperature and its correlation with the green cover areas. The method's strength is the use of an extremely high resolution (Geo Eye) image, which allows the segmentation method to extract features from the image. But it is agreed that the findings have concerned only physical availability of green space. Hence, the results have related the very high impact of urban greenery of the temperature in this city.

Presumably, these findings are likely comparable to those of Li *et al.* (2013), who explored the impact of spatial resolution on the link across land temperature and green space spatial layout. Thus, using three spatial resolutions including 2.44 metres, 10 metres and 30 metres based respectively on QuickBird, SPOT and Landsat TM for the images, the spatial distribution pattern of urban green infrastructure was examined with landscape measurements. Land warmth, which includes land temperature, was extracted from the thermal band of Landsat TM imagery. Thus, the Pearson correlation coefficient and Pearson correlation analysis based on census tract as the explicit unit were used to evaluate the link between land heat and the spatial profile of green areas (Li *et al.*, 2013).

It can be assumed that these findings were similar to those found by Li *et al.* (2013), when they were assessing the spatial resolution effects on the link among surface temperature and spatial configuration of greenery spaces. Thereby using three levels of spatial resolutions of 2.44 metres, 10 metres, and 30 metres respectively from QuickBird, SPOT, and Landsat TM for images, the pattern of spatial distribution of urban green infrastructures was examined with landscape metrics. Land Surface Temperature was extracted from thermal band of Landsat TM imagery. Thus, the relation between Land Surface Temperature and spatial arrangement of green space was estimated by Pearson correlation approach (Li *et al.*, 2013). Indeed, the findings revealed that landscape measurements of green space varied according to geographical resolution. As a result, greater spatial resolution images might more correctly define the spatial pattern of green area. Similarly, the association between land surface temperature and green space abundant was consistently negative, but the positive correlation between land surface temperature and greener space spatial layout varied by spatial resolution (Li *et al*., 2013).

Concerning urban flooding mitigation strategies, green spaces in urban areas played very great role. Therefore, GIS-based multicriteria evaluation method is powerful to prioritize areas to site friendly verdant infrastructure to abate urban flooding hazard by planning green components (Li *et al.*, 2020). The authors concluded that developing urban green structures including urban green spaces, should always be an important strategy for environmentally friendly planning for adaptation due to its high effectiveness in reducing rainwater runoff and ensuring the city's long-term viability and resilience.

The same conclusion has been laid by Maragno *et al.* (2018) even though the different approach has been used. They applied an ecosystem services approach to greenery in cities to deeper comprehend the water flow management method for reducing flooding in urban settings. Three indices: Amount of runoff reduced by existing green infrastructure, runoff reduction coefficient and vulnerability index were tooled to analyse the flood reduction demand. Apart from land temperature and floods prevention, investigations on the interaction between urban green spaces and purification of air and climate control utilities have been focused.

It was the circumstance of the consequences of urban park architecture on the supply of air purification and climate regulation utilities in Almada, a city on Portugal's western coast (Vieira *et al.*, 2018). Various metrics, indicators of microclimatic impacts, and air pollution levels were employed. Lichens are diverse, and contaminants accumulate in them. Functional features relating to nutrient and water requirements in lichens were utilized as surrogates for vegetation's ability to filter air pollutants and regulate climate, and so provide air purification and climate-control ecosystem services, respectively. They also used high spatial resolution, which enables for thorough spatial planning for ecological service optimization. This methodology yielded data indicating that vegetation types with a more complex structure and a lack of control had a greater capacity to perform ecosystem services such as air filtration and climate regulation. If it is acknowledged that urban green space development has the greatest impact on urban growth, it has also been agreed that these spaces require more upkeep and monitoring due to their configuration and composition.

The work of Osseni *et al.* (2015), has been worried on this state of affairs through the use of GIS in urban friendly space management in Porto-Novo, Republic of Benin. They have been based on field survey to analyse the mode of management and attractivity characteristics of green infrastructure in the urban areas. Because, according to the authors, GIS is a tool strongly used to evaluate these relationship (Osseni *et al*., 2015). However, there are other constraints often in order of conflicts among stakeholder that can hinder this development. Wagner *et al.* (2019) performed a home survey to analyse how local residents and administration perceive them using environmental service analysis to assess the ecological potential of selected metropolitan regions in Germany. Interviews were also performed to detect potential conflicts between stakeholders (politicians and administrative personnel). As a result, stakeholders assessed and perceived land use planning processes differently for green space.

In summary of the different points of view obtained through the various papers, it can be retained that urban landscape dynamics have the important changes on urban green spaces which have in turn impacted the sustainable environmental development of these areas. The numerous metrics green spaces descriptions are very important to understand because of their influences on the services served by these areas in terms of the mitigation and adaptation to the increasing urban heat island effects, flooding vulnerability and air pollution in many cities worldwide and especially in Africa. It is realized that very few works have been performed in retail on the cities of Porto-Novo and Parakou despite the existence of environmental issues (Flatin *et al*., 2018; Livangou *et al*., 2018; Falolou *et al*., 2020). The green spaces inventoried in Porto-Novo were limited at public squares, gardens and wooded esplanades and for which the numbers of trees available the species diversity are relatively weak (Osseni *et al*., 2015). These results would be insufficient for the good decision taking for good planning in these cities. Information on the functions and spatial pattern as well as the exhaustive of urban greenery areas are obvious for an effective planning (Taylor and Hochuli, 2017). Because, according to Anguluri and Narayanan (2017), to benefit and accommodate the many advantages of urban green spaces, urban sustainable development should take into account the spaces, proportion, distribution, configuration and types of current and further green spaces in their processes for adapted planning.

2.4 Examples from Other Regions/Countries

The study has some examples as methodological support to supply A scientific standard for preserving green spaces and promoting healthy urban development in Porto-Novo and Parakou in the Republic of Benin (West Africa). To assess land use and land cover in 202 European cities, Kabisch and Haase (2013) used raster data of COoRdination of INformation on the Environment and represents a pan-European database of the European environmental landscape (CORINE) of years 1990, 2000 and 2006. The image resolution of this raster data was 100 metres × 100 metres. For our study, the image resolution should be high because of the shrinkage of the study areas in comparison to Kabisch and Haase (2013). These authors considered all vegetated areas with land area superior to 25 hectares as urban green spaces. In this context, these spaces comprised urban parks, vegetated cemeteries, botanical or zoological gardens, city squares but not included city gardens. The provided green infrastructures, including city gardens and incorporating water bodies and marshy lands, were duly taken into account. The authors also mentioned some insufficiencies related to low resolution raster data (Only size units of at least 25 hectares can appear on the map), no availability of CORINE raster data for the three years in some countries such as United Kingdom, Finland, Greece and Romania. However, despite the disadvantages, authors used CORINE data because of the availability of data for the three years in maximum cities that can allow comparison between cities.

Data on annual variations in urban land cover, such as percentage, were analysed using descriptive statistics. In this manner, they employed the weighted average of yearly values to prevent having land cover changes influence smaller towns more than a change of the same size in a bigger town (Kabisch and Haase, 2013). The results of the research were displayed using charts, graphs, and maps. As a result, favourable regional changes were largely acquired in Western and Southern European cities, and Western European cities appeared to have greater values of urban green space values between 2000 and 2006.

In 2016, Kabisch *et al.* (2016) evaluated the presence of urban green areas in 299 European cities based on land use type and urban resident statistics in 2016. Green space availability, in the author's opinion, is not the same as green space accessibility. In a GIS investigation, the researchers used land use and land cover statistics. These data are derived from the European Urban Atlas land cover database from the European Environment Agency (www.eea.europa.eu/data-and-maps/data/urban-atlas). At the moment, imagery from satellites with a spatial resolution of 2.5 metres are accessible in the 27 countries that make up the European Union. In addition, because 2006 was the most recent year available, our analysis employed urban atlas data from that year. To prevent overlap with the cities in the urban atlas, the study concentrated mostly on the centre city (Kabisch *et al*., 2016).

Four steps were followed for spatial availability of urban green space by the authors. Therefore, the one concerned the identification of Urban Green Space (UGS) (area ≥ two hectares) category. Between the distance of 500 metres and 300 metres, the vegetated areas included only urban green areas and forest areas class with a minimum size of two hectares were selected. Unfortunately, the authors excluded the class of croplands, the semi-natural lands and the marshy lands because of providing low recreational value (Kabisch *et al*., 2016). In this study, these excluded classes as urban green spaces were regarded as they have the potential to contribute to climate change adaptation and mitigation (Scott *et al*., 2016). Authors have also buffered each green space and intersect with one-kilometre square grid to calculate area of the urban green space within buffer for each grid cell. Finally, map of cells with available urban green space per capita was gotten for each core city.

Two cities were used as the case study by authors. There are Berlin (Germany) and Lodz (Poland) where authors found the raisons such as the largest cities respectively in Western and Eastern Europe, socio-economic change after 1990 that impacted urban land cover and shrinkage of the population causing industrial decline with the conversion of brownfields into new green spaces.

Tables, maps and charts were used to present the results. The authors discovered that supply values in Southern European cities are under average. According to the history of these cities, they interpreted this discovery by the low woodland and vegetation. They also explored the prospects and constraints for developing markers for green space availability by comparing the results using different datasets and threshold settings. Finally, conclusions were reached about the availability of greenery in cities as an interest indicator for managing urban complexity so as to improve human wellbeing in a town. Furthermore, they stated that urban green areas are merely one component of the complex socio-ecological interconnections that take place within cities.

To appropriately quantify the cooling effects that urban green areas may offer to city dwellers, the study by Huang *et al.* (2018) will be heavily relied upon. This study aims to investigate the assessment of cooling effects in urban green spaces on the Heat Island phenomenon, comparing the summer and winter seasons in Harbin city, northeast China. To achieve this aim, the study attempted to determine the urban heat wave variation trend of the city during the two seasons; to quantify the relationship among the spatial distribution of urban green infrastructure and the urban heat island intensity; and understand the relationship between the morphology (area, perimeter and shape factors) of urban green space and its cooling effect. It can be hypothesized that these research questions are close to those of our research project. In effect, the images from Landsat five TM with a resolution of 30 metres have been downloaded at 2007, 2011 and 2015 accordingly in summer and winter period. In addition, the images have been taken when the cloud cover was low than two per cent and the data process was applied by using the ENvironment of Visualizing Images (ENVI) 5.1 and ArcGIS 10.3. The urban green spaces in this study area were located by the interpretation of screen visual after radiometric calibration, atmospheric correction, geometric correction. For the accuracy of the classification, the green infrastructure assessment was carried by field control work. Thus, more than 95 per cent were found as the accuracy of the classification.

Therefore, land temperature and heat wave intensity were quantified by applying some relevant relationship as well as formula (Huang *et al*., 2018). Following that, urban vegetation was extracted using the Normalized Differential Vegetation Index (NDVI) which is calculated as $NDVI = (NIR - VIS / (NIR + VIS)$. As a result, NIR denotes the reflectance of near-infrared bands, while VIS denotes the reflectivity of visible bands. The NDVI value ranges from one to zero, and when it is too close to zero, it depicts ground covers comprised of bare rock or dirt. When the NDVI number is too near to one, it represents plant-covered terrain. Furthermore, they have used the quadrant division methodology to analyse the shifting rules of the city's level of urban warmth wave.

It was discovered that three major parameters, including the area of green spaces, the circumference, and the shape factor of greener spaces, influence the cooling impact of greenery. Huang *et al.*, (2018) investigated such factors in the summer and winter. They have also concluded that the less complex of factors is the shape of urban green space that induces the more evident fresh air effect. Furthermore, friendly spaces provide great wide cooling effect in the summer than it was in the winter. However, there is a certain spread of cooling effect in winter, although it is even less important in comparison to the event in summer. Finally, no matter whether the season, there was basically a negative relationship among NDVI value and urban heat island effect. Indeed, these findings could serve as a model for a practical procedure for the layout of urban parks with the goal to effectively limit the heat effect of cities in this region of China. The examination of this study will help us very much to understand how to oriented the content of our research project in way that its results will be very helpful for green space improvement in order to maximize the benefits from the urban green spaces in our local cities.

A recent study by Hwang *et al.* (2020) was examined. This study, once carried out in some fast-growth cities of continent of Asia, has aimed to extend the usefulness of urban green spaces by solving accessibility issues to greenery by the poor (inequity associated to green spaces). Agreeing that less usage and accessibility to the green spaces could constitute a driver for their non-development and suddenly impact urban sustainability (Hwang *et al*., 2020). The choice of this study as the case study may bring novel insight on these aspects in our study. The study has especially assessed the quantity (describing the physical characteristics) and the distribution (in relationship with urban land value) of urban green spaces and follow by the relationship with the distribution of socioecological benefits. Some of those points such as physical characteristics and pattern distribution have already be expected in our project.

However, some views such as relationship between pattern and land value, usage and accessibility of urban green space will constitute the new angle of the study that should be boarded. Geospatial data were used to see the correlation was between urban green spaces provision and distribution of inequity associated to their usefulness. To analyse data, these authors have evaluated landscape metrics and linear regression has been performed. It can be recognized that these methods were convenient to achieve the set goal. Therefore, the findings were that the city's districts with lower value of land had dense vegetation and high coverage mainly associated to a large amount of unmanaged greenery. They finally concluded to find the ways to enhance the asset from the use of unmanaged urban green areas as a social and ecological benefit for poor citizens and highlight the practical impacts of introducing their results into policy making and urban planning towards the including ecological cities built. Our research project will strongly be interested about these findings because the city of Porto-Novo and Parakou seemed to have the same characteristics as Mumbai and Jakarta in regard to the worth status of people.

2.5 The Overview and Key Issues of the Study

The urban areas look to be fundamentally in opposite to the country's areas. Therefore, after their creation, they develop and start to encroach on the nature and quickly push it back. Further, it replaces vegetated landscapes with mineral, anthropogenic and artificial landscapes. While, although at the time of fast urbanisation, there is no concern on the retreat of nature, but at the time that the need for green spaces in city become reality, it now pushed planners to review their principles. Indeed, the concept of urban green spaces and the growing interest on ecosystem services are often predominantly perspective for cities and their broader social, economic and environmental challenges. So, throughout the history of cities, urban green spaces have traditionally had functions of representation, well-being or urban hygiene (Russo and Cirella, 2020). Likewise, the increased urban density has leaded to increased pressure on green urban areas and pose a risk to the attractivity and quality of life of towns and cities. As cities continue expanding and more inhabitants migrate into previously congested regions, what must be undertaken to change our cities into pleasant places to reside? Thereby, since industrialisation took hold in the 19th century, so the gap between urban and rural grew greater, people in western countries (developed countries) were the first civilization to recognise the benefits of rural features within a city. In Addition to the challenges due to urbanisation, the induced-climate change impacts put urban areas in much higher risk as well as other profound societal and environmental changes (UN-HABITAT, 2016).

It must be recognized that the green spaces in urban areas play so much roles to mitigate and reduce the challenges regarded to urbanisation and climate change. For example, several studies have concluded that city greeneries decrease pollutants and can diminish a phenomena known as the urban heat island effect, which relates to the warmth confined in built-up areas (Kong *et al*., 2014; Liu and Shen, 2014; Maimaitiyiming *et al.*, 2014; Huang *et al.*, 2018). However, despite multitude roles and benefits those urban greeneries supply to cityscapes, statistics have proved that these areas are in decline in many cities around the world. For example, the average of 30 per cent of greenery space have been lost by taking many cities as case and this lost may be due to the rapid built-up (Kabisch and Haase, 2013; Kabisch *et al.*, 2016). In North America, it can be admitted that the similar observation has been found with more than 1 million hectare of urban green areas converted to built-up areas (McDonald *et al.*, 2010; Narducci *et al.*, 2019). Furthermore, it agreed that the worst situation was found in Asian cities because of the higher rate of urban growth (Dutta, 2012; Estoque and Murayama, 2015). The situation is especially pressing in Africa, where research has revealed that most urban greenery zones in major towns have been unduly destroyed to create way for diverse human activities. Hence, in Ghana and using the city of Kumasi as case study, Mensah (2014), has found that green space in this city is suffering from rapid deterioration. Likewise, Badmos *et al*. (2018) have estimated the net loss of urban green spaces at six per cent from 2009 to 2015 in Lagos, Nigeria. These situations of loss and depletion of greenery spaces in cities create a lot of panic especially at current times when the ecological conditions become more and more complicated in association to the serious impacts of changing climate with growing density in cities.

Cities in Benin Republic, like many cities around Africa, are faced with the imperative of reconciling urban development and the protection of environment and green spaces. Urban development is an important factor of prosperity for the cities, but nowadays, a phenomenon of massive expansion disturbs their balance. A good governance of greenery spaces for their sustainable development constitute a need in regard to urban sustainability (Mensah, 2015; Zakka *et al*., 2017; Girma *et al*., 2019). For this purpose, it important to identify different stakeholders involved in this matter. These stakeholders must be clearly defined in order to be able to establish relevant and advantageous relationships and organization that will make the process of their effective management credible. Likewise, in order to have a complete initial view on greenery space, it is advisable to supplement its knowledge base by an inventory of existing actions and available actions. First of all, it is important to identify all the actions currently existing within the municipality and contributing to the process of good management of municipal greenery spaces. This is evidence, because cities are more often in control of municipality. Then, it may be an environmental policy adopted by the city, an awareness campaign to reduce the use of phytosanitary products, a master plan for land use, festive events highlighting nature in the city. In addition, an inventory of available means of action must be carried out. Indeed, ignorance of all the available levers of action leads to inertia. However, many regulatory and legislative mechanisms and tools of the local, municipal and national governments give real power to the municipality. Also, at the municipal level, many regulations derive from the law on land use planning and development. Thus, these legislations are the most targeted and the most conducive to concrete actions. For example, they deal with the felling of trees or other greening, the protection of the river banks, the vegetating, the urban development plans or even town planning document. It is also essential that the management of greenery spaces in cities be carried out with consultation in order to benefit from the useful and available knowledge and expertise. Moreover, the approach undertaken can be supported by the creation of partnerships recognized during the identification phase. It is about working with conservation organizations that can offer relevant support, whether it is funding or expertise.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

This work builds on two cases study cities (Porto-Novo and Parakou) tidied up along south-north gradient across the territory of Benin. The cities vary in their urban form, climate pattern and socio-economic characteristics

3.1.1 Geographical location and map of study

The area of the study covered two cities in the Republic of Benin, Porto-Novo, the capital of Ouémé Department and Parakou, the capital of Borgou Department in the south eastern and northern eastern parts of Benin Republic respectively. Porto-Novo is located between 6°26’ and 6°31’ north latitude and between 2°34’ and 2°45’ east longitude (Figure 1.1). It is housed in the south-east of Benin (Vigninou, 2010). Porto-Novo is divided into five districts and encompasses an area of 5,241.15 hectares.

About regional capital of northern part of the country, the city of Parakou is far away by 407 kilometres from Cotonou (the first big city of the country) and covers 6,662.76 hectares. It is located between the northern latitudes 9°15’ and 9°27’ and east longitude 2°31’ and 2°45’ (Figure 3.1). The city has grown at a rate varied by decade, from the 1930s to today.

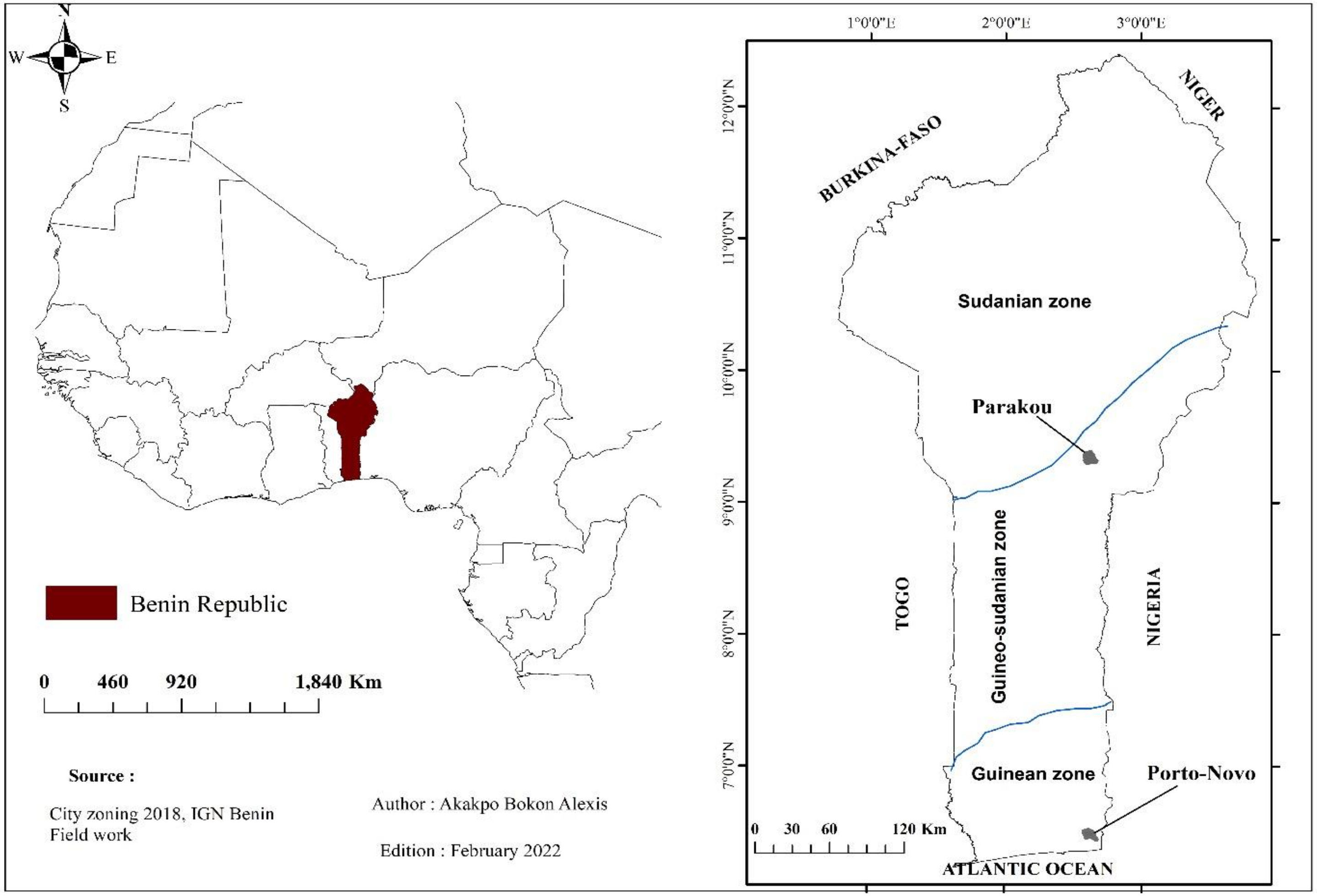

Figure 3.1: Map of the Location the Cities of Porto-Novo and Parakou in the Republic of Benin (West Africa)

Source: Author' fieldwork (2022)

3.1.2 Climate

3.1.2.1 *City of Porto-Novo*

Porto-Novo has a humid tropical climate or a subtropical climate. The average temperature is 28 °C. The warmest month is March (32 °C), and the coolest month is August (24 °C). (Figure 1.2) The rainfall pattern consists of two wet seasons and two dry seasons of varying lengths. It usually rains from March to July (the "big rainy season") and September to November (the "small rainy season"). Annual precipitation is anticipated to be 1200 millimetres per year (Houngla *et al.*, 2019). The seasonal cycle has been disrupted throughout the last two decades. Then, adaptation to climate change is critical for the resilience of this municipality's activities.

3.1.2.2 *City of Parakou*

The climate in Parakou is tropical dry, with a wet season (May to October) and a dry season (November to March). From May to October, the temperature range is low, with temperatures averaging around 25 °C (Figure 1.2). It is recorded daily thermal amplitudes that are more evident during the months of December to January (period of harmattan) (35 °C to 40 °C in the early afternoon and 10 °C to 15 °C at night). The average annual rainfall reported at the synoptic weather station of Parakou is roughly 1170 millimetre per year, with the most of it falling between July and September (Miassi and Dossa, 2018; Lanmandjèkpogni *et al*., 2019)..

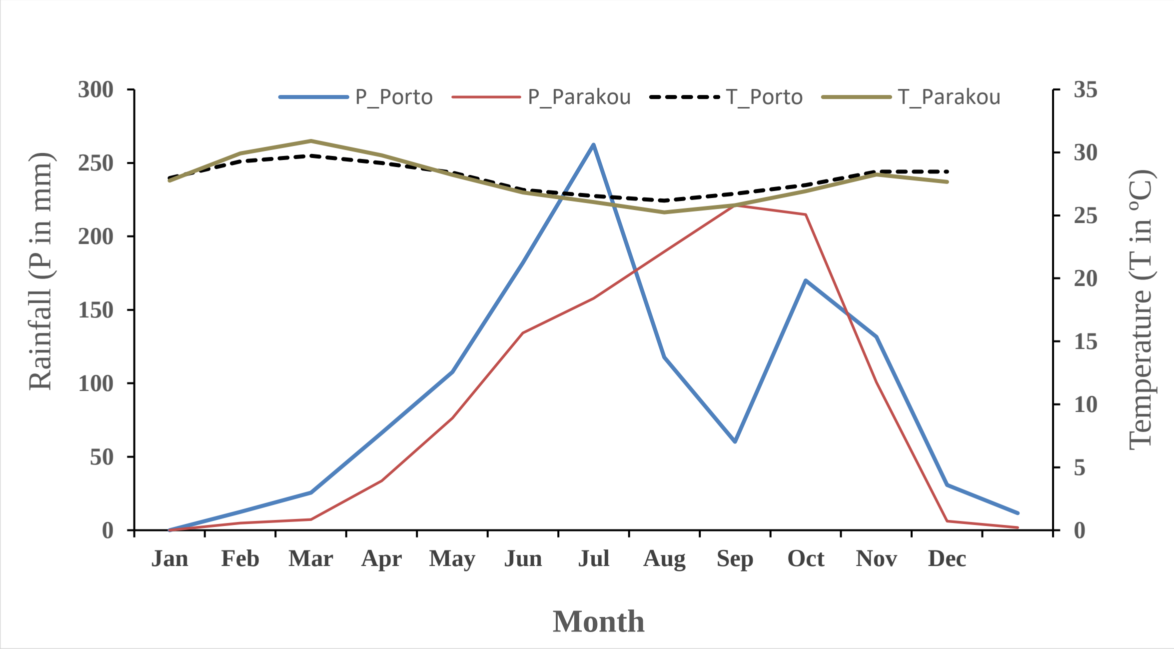

Figure 3.2: Trend of Monthly Average Rainfall and Temperature of Study Areas Between 2000-2020

Source: National Meteorological Agency of Benin Republic and Author's fieldwork (2022)

3.1.3 Soil, vegetation and hydrology

3.1.3.1 *City of Porto-Novo*

The city of Porto-Novo is situated in amphitheater at a median elevation of 29 metres on the Sakété plateau, which gradually rises away from the lagoon and is dominated by the soils weakly ferrallitic sections of the Continental Terminal bare land plate and hydromorphic soils. The principal rivers that can be found within the city are the Boué, Zounvi, Donoukin, and Aguidi (Figure 1.3). Geomorphologically, Porto-Novo is part of the coastal sedimentary basin, which includes three plateaus known as the plateau of southern Benin: the plateau of Kétou, the plateau Sakété, and the plateau Allada (Dansou and Odoulami, 2018). At the level of this coastal geological basin, plateau soils, Lama depression soils, valley soils, and seashore zone soils can be differentiated. The natural vegetation is almost non-existent in this area. But outside of a few forests' witnesses, the crop and fallows, the palm plantations and most degraded savannahs that spot the green landscape can be met in Porto-Novo (Figure 1.4).

3.1.3.2 *City of Parakou*

In contrast to Porto-Novo, the city of Parakou, the region stands out from a pedological point of view by the predominance of tropical ferruginous soils, of significant thickness due to low erosion (Figure 1.3) (Miassi and Dossa, 2018). The cover of vegetation observed in the municipality of Parakou is dominated by wooded savannahs. However, tree plantations and gallery forests are mostly observed in urban area of the city (Figure 1.3). It is characterized by the presence of the plant species like *Tectona grandis*, *Gmelina arborea*, *Parkia biglobosa*, *Blighia sapida*, *Diospyros mespiliformis* and *Butyrospermum paradoxum*. The lowlands of the city are marshy meadows of savannahs, bamboo bushes (*Bambusa Arundinacea*). Moreover, there are some trees in several homes that provide diverse functions to the owners. Parakou is crossed by streams or tributaries from the right bank of Okpara. The waters of the area of Alaga are dumped in Ouémé. It can be understood that these streams are subdivided at infinitum and remain dry from January to May.

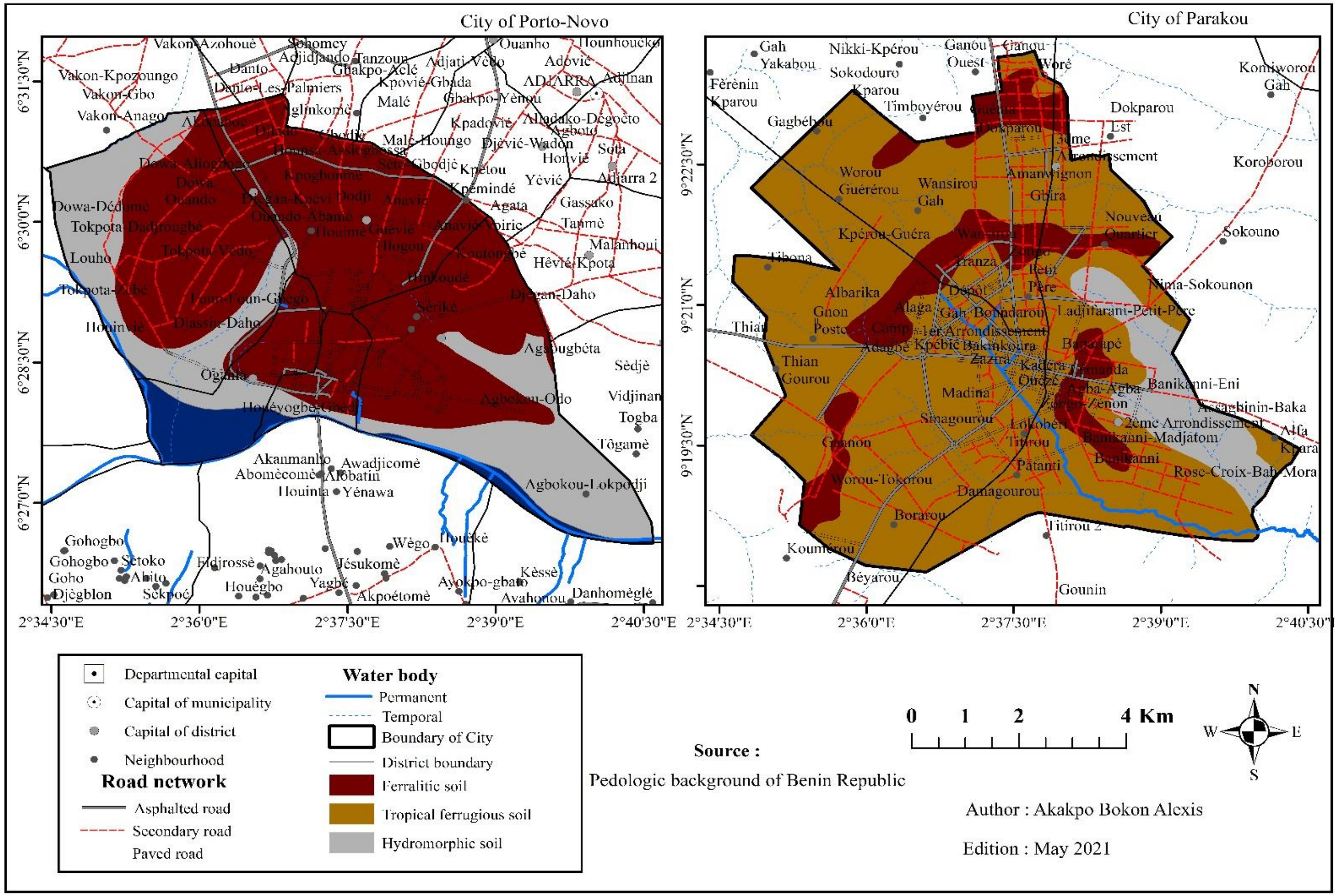

Figure 3.3: Soil Characteristics of the Study Areas.

Source: Author's fieldwork (2022)

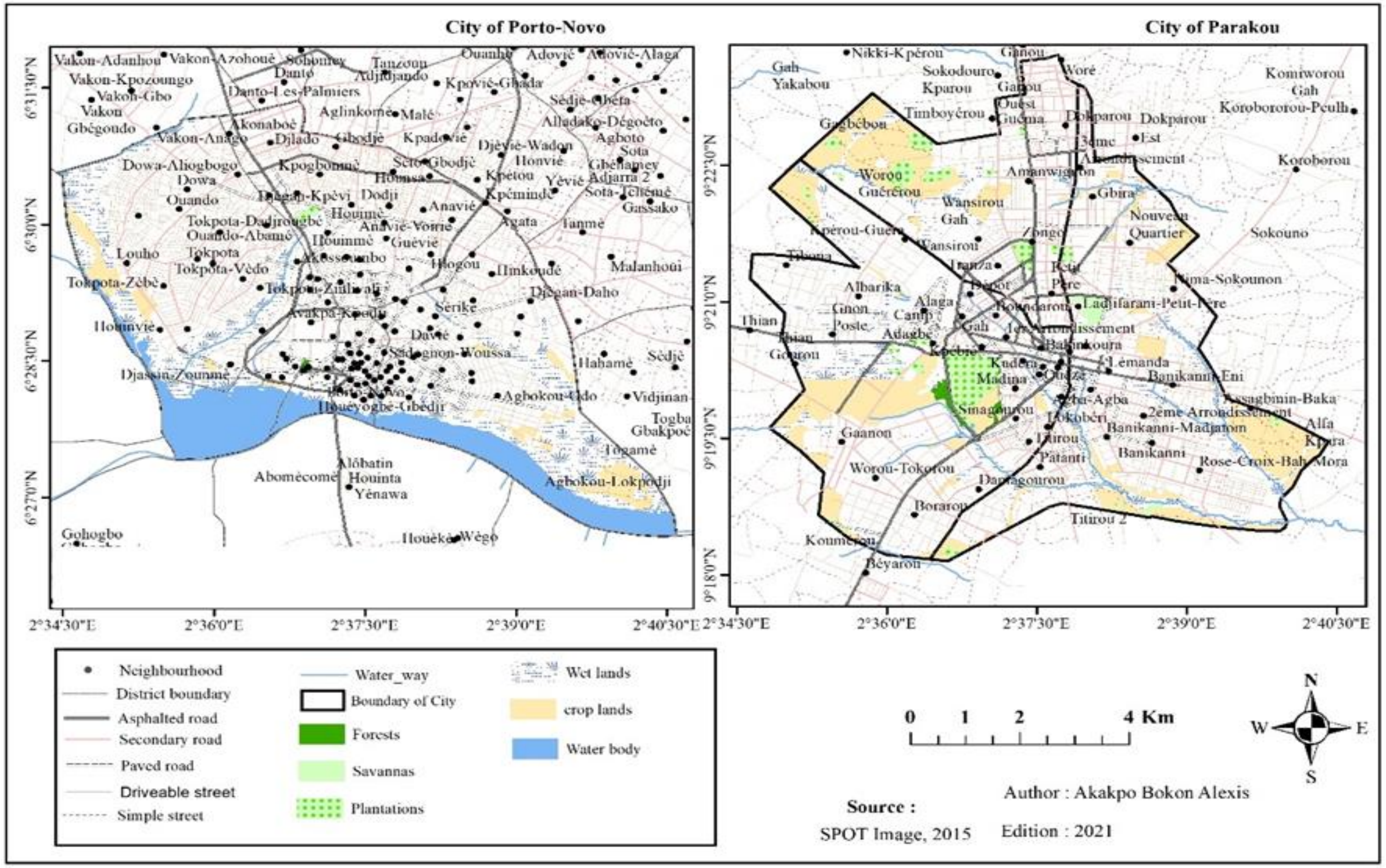

Figure 3.4: Vegetations and Hydrology Characteristics of the Study Areas.

Source: Author’s fieldwork (2022)

3.1.4 Socio-economic activities

3.1.4.1 *City of Porto-Novo*

With a current population of 264,320 inhabitants, the city of Porto-Novo has experienced an increasing population from 1979 to 2013 (Figure 3.5). In addition, the female population has consistently been higher than the male population from 1979 to 2023. This trend of population can be assigned mainly to rural-urban migration, new births and the new classification of urban areas of the city (Benna and Garba, 2016). The economic activities in Porto-Novo are so largely dominated by women who run more than 56 per cent of the economic sectors, particularly in commerce (Vigninou, 2010; Allio and Schut, 2011; Houngla *et al*., 2019). The workforce of the city of Porto-Novo is young, and 54 per cent of business and service entrepreneurs are under 30 years old (Vigninou, 2010). It can, thus be acknowledged that the trade remains the main activity in Porto-Novo because of its proximity of the mega city of Lagos.

3.1.4.2 *City of Parakou*

Parakou's economy is mostly centred on commerce, tourism, crafts, livestock, fisheries, and agribusiness. As a big town with a population of 255,478 inhabitants, the city of Parakou has a rapid growth trend between 2002 to 2013 (Figure 3.5). Also, the female and male populations do not seem to exhibit a significant difference. This population is quite dynamic and home to many market gardeners' farmers, owing to its river system, which includes a great number of streams and shoals, tributaries of the upper side of Okpara (Miassi and Dossa, 2018). Indeed, trade in the city of Parakou is the main activity dominated by the informal in urban outlets where legal and illegal goods from Nigeria and Niger are exchanged.

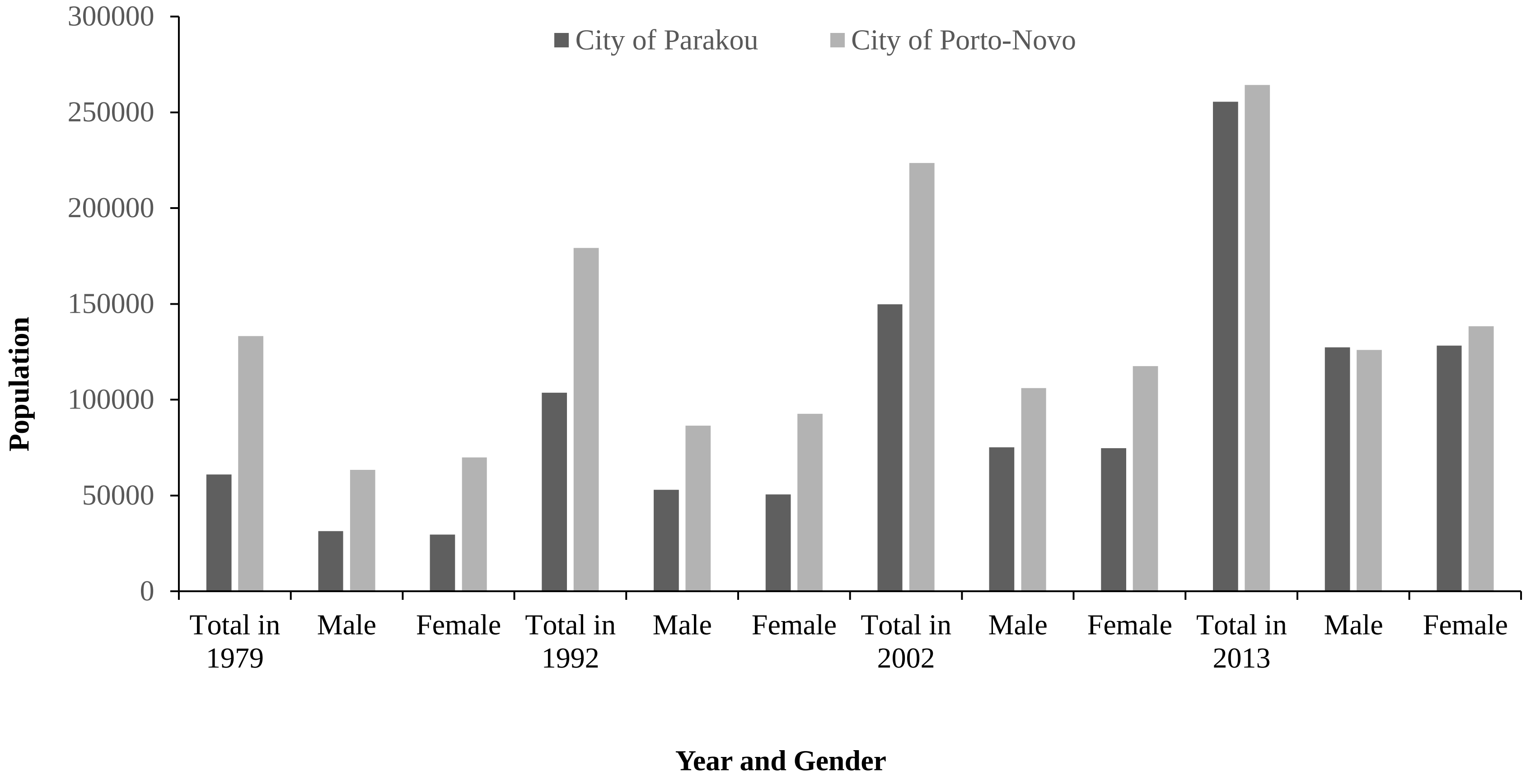

Figure 3.5: Population Evolution in the Study Cities from 1979 to 2013

Source: INSAE (2016)

3.2 Description of Materials

The main material of this study was both urban areas of Porto-Novo and Parakou. The two cities, were served the administrative boundary for data collection. In each of the cities, any green infrastructure that can be identified on remote sensing images was considered as studied items. Therefore, urban green space can be meant as unmanaged and managed network of natural and semi-natural areas; that may be suitable habitat analogues for plant species of conservation interest and deliver a wide range of ecosystem service to the area and people (Itani *et al.*, 2020). These infrastructures are effective, economical, and enhances community safety and quality of life. In the context of this study, the green infrastructure refers to the rain gardens, urban forests, plantations, crop lands, water bodies, marshy lands, mangroves and street and home trees assemblages.

Furthermore, to well achieve the aims of the research, a high precision of Global Positioning System (GPS) (example: GPS-Garmin 64s) was needed. It was used to collect the coordinates data of the studied features and other geographical information during the field works to validate the image classification results. A computer (Lenovo T430s; Intel(R) Core (TM) i5-3320M CPU @ 2.60GHz 2.60 Gigahertz (GHz); Random Access Memory (RAM): eight Giga Byte and Read-only memory (ROM): 180 Giga byte) and the useful software such as ENVI, ArcGIS and QGIS were used for the treatment of images. Statistical software in range of R 4.3.0 (R Core Team, 2022) and Statistical Package for the Social Sciences (SPSS) 23 (International Business Machines (IBM) Corp, 2015) were used for data analysis.

Likewise, a mobile hard driver of two Giga of memory capacity was used for data stock and data save. For field data collection, questionnaires and physical sheets were used.

Questionnaires were made in Kobo toolbox and mobile phones were deployed for survey data recording.

3.3 Description of Methods of Data Collection

3.3.1 Assessment of urban land use and land cover dynamics of the cities

Remote sensing and geospatial data are reliable data sources for understanding land use dynamic (Kleemann *et al*., 2017). Thus, urban land use and cover dynamics were analysed by using spatio-temporal satellite images of the period from 2000 to 2020. This period was justified by the availability and the quality of the satellite images at these periods. Thus, as historical data, a time series spatial data from SPOT 4 and 5 (six metres of spatial resolution) sensors at period of 2000 and 2010 were acquired from Department of Forests, Water and Hunting (Orekan *et al*., 2019). However, according to the period of 2020, Google Earth Pro V 7.3 imageries (Landsat/Copernicus) were used due to its relatively high spatial resolution and its free availability globally.

The survey in offices in charge of urban management and urban planning (decentralized offices of the ministry of Living Environment and Sustainable Development, office of urban planning and management of each town hall and National Institute of Geography) was carried out to generate the base layers of the boundaries of the city and city borough limit in the cities. Existing city maps with ward boundaries were also consulted. Population data were collected from the National Institute of Economy and Statistics (INSAE). The control points (used to register and geo-correct remote sensing data) were acquired employing a GPS and a toposheet survey of the Republic of Benin. The relative vectorial layers such as road network and hydrographic were also collected from the database of National Institute of Geography (IGN-Benin Republic).

3.3.2 Examination of the pattern and distribution of urban green spaces in the cities

The spatial resolution of Google Earth images on the city of Parakou is up to 0.6 metre (Yang *et al.*, 2021; Chen *et al*., 2022), this makes it possible to detect green spaces and visually make the difference. Consequently, using the remote sensed images (Landsat/Copernicus) in 2022 provided by Google Earth Pro V 7.3, the major green areas patches were drawn manually over the whole city area. The month of august in the rainy summer season 2022 was selected for remote sensed images because the coverage of greening spaces at this moment should be more obvious than any other seasons, which is more helpful for visual interpretation. The greening areas covered by an assemblage of trees with clear canopy boundary, or grasses greening areas were used as an individual patch. The visual distinction was also made on the category of green space. Therefore, there was green space as forest (sacred forest and gallery forest), marshy land (greening wetland), tree plantation (example: *Tectona grandis* tree planation, plantation of fruiterer), crop land (Agricultural areas), city bush (unmanaged areas with greenery, old fallow areas, unbuilt lots or any ephemeral bushes), urban garden (public gardens or places with greenery, green road junctions, private gardens or vegetated courtyards) and city trees (street tree assemblages, office tree assemblages or home tree assemblages). The polygons were saved in keyhole markup language data format, and input into ArcGIS 10.3 software for subsequent data calculation of each individual polygon. The data extraction considered the centroid coordinates (X, Y), the area (hectare) and the perimeter (kilometre) of each polygon of urban green space.

100 coordinates were randomly selected and from which the green spaces were located, and field survey was conducted (area measurement) to verify the reliability of the information of green spaces observed from the images. A general regression model was used to carry out the comparison (Appendix A), and the regression slope was 0.90 and

0.89 respectively for Parakou and Porto-Novo. This finding implies that green space information can be really collected using visual interpretation of remotely sensed images.

3.3.3 Evaluation of seasonal variation in vegetation and its correlation with air temperature in the cities

The urban green-stuff importance and productivity is widely characterized by the normalized difference vegetation index (Li *et al.*, 2017, Malik *et al.*, 2020). The data used in this objective included the NDVI image collections and observed land air temperature. Monthly Landsat satellite derived NDVI series were collected on the two cities using Google Earth Engine open-source (www. code.earthengine.google.com).

Regarding to land air temperature, the observed monthly data were obtained at the National Meteorological Agency of Benin Republic at the meteorological station of Parakou and Cotonou from 2000 to 2020. Before being used for any analysis, the temperature data used in this study were rigorously processed for missing values and quality checked. Thus, there were no missing values in land air temperature data from 2000 to 2020 for either of the two meteorological stations studied. Seasonally (three-month period), a transformation of the monthly NDVI and land air temperature (AT) data was achieved through the computation of a mean (m) using the formula:

$m = \frac{1}{n}\sum_{i=1}^{n=3} x_i$, x_i is the monthly value of NDVI or AT (3.1)

3.3.4 Assessment of stakeholder's perception in urban green spaces development

The survey was carried out considering the city boroughs of each city. The number (N) of interviewees was sampled by using the formula of Dagnelie (1998):

$$N = \frac{Z^2 pq}{e^2} \quad (3.2)$$

where z is the value of random statistic found in the tables at 95 per cent and is 1.96; p is the proportion of people able to respond to questions; q is the $1 - p$ and e is, the desired level of precision which is 0.05. In these cities, 55 per cent (p) of residents have at least 15 years old (INSAE, 2016) and can be attributed as interviewees in this study (Gwedla and Shackleton, 2019). Therefore, N was around 380 people for each city. However, in order to increase the representation of the sample of the interviewees (Gashu *et al*., 2019), 20 respondents were added to augment the sample size from 380 to a total of 400 interviewees in each city.

Furthermore, the 400 interviewees of each city were proportionally distributed to the city boroughs or sub-cities based on the inhabitant size of each city borough (Table 3.1). At each public place and urban-related institution, people of 15 years old and older were randomly asked for the interview because already at 15 years old, people can contribute sufficiently to urban vegetation development in the Republic of Benin. Interviews were also made in the randomly selected resident's houses in each city borough where the head of household or an elder of the household was politely asked for the interview after giving the purpose of the visit.

In this context, a semi-structured questionnaire (Appendix B) was used to collect primary data from socio-economic characteristics (age, gender, ethnic, religion, matrimonial, polygamy, school education, residence acquisition, main activity, monthly income, urban and living duration) and variables on stakeholder's perceptions on urban greenery improvement (urban greenery characteristics, urban greenery importance and urban greenery management and planning). Interviews were randomly completed with either female or male using the Kobotoolbox Collect application. At each randomly selected resident, a greeting and the goal of the visit were carefully made to stimulate the willingness to participate in the survey. The visited urban-related institutions were the Departmental Direction of Living Environment and Sustainable Development, Departmental Direction of Planning and Development, Town Agency of Territory Management, Technical Councils of Town Hall, Departmental Direction of Forestry and, Departmental Institute of Geography. At each institution, the introduction and the purpose of the social survey were made and after that, volunteers were interviewed.

Table 3.1: Distribution of Respondents Among Urban Districts of Study Cities

City's Borough	Porto-Novo		Parakou	
	Population	Sample Size	Population	Sample Size
1st borough	33,161	50	114,558	179
2nd borough	52,571	79	71,121	112
3rd borough	33,535	51	69,799	109
4th borough	63,306	96	-	-
5th borough	81,747	124	-	-
Total	264,320	400	255,478	400

Source: INSAE (2016) and Author's fieldwork (2021)

3.4 Description of Methods of Data Analysis

3.4.1 Assessment of urban land use and land cover dynamics

SPOT 4 and 5 images were used to classify the urban areas in the cities of study interest for the periods of 2000 and 2010. The images of SPOT four and five have a panchromatic band of 1.5 metre of spatial resolution, and other four multispectral bands of six metre resolution (blue, green, red, near-infrared) (Qian *et al.*, 2019).

Prior to picture categorization, preliminary work on image preparation was completed. The initial processing consists of improving the image quality in order to enable their use. As a result, the acquired scenes were treated to geometric, atmospheric, and radiometric corrections with the goal to improve image quality and make the spatial units look like genuine features.

SPOT four and SPOT five images were subjected to supervised classification. As a result, images were classified using the maximum likelihood approach. This technique can categorize pixels probabilistically by displaying the typical uncertainty gap among the values of the pixels and those of the various practice locations (Orekan *et al.*, 2019).

Following classification, cities selected twenty random places for each land cover class to assess the correctness of each time class using historical maps and Google Earth Pro historical pictures. However, the land cover and use classification for the year 2020 was derived from the digitization of Google Earth Pro images. In this context, the results were validated using the pictures and field observation data. Thus, the confusion matrix was employed to confirm the classification. The resulting matrix was created by contrasting the classification data with the field-testing data (reference data), which needs to be distinct from the classification data. The kappa coefficient, which ranges from zero to one, represents an estimate of the classification's quality.

The percentages of the land cover for each land use and cover class were calculated at the different time period. The change rates were estimated and shown in tables and charts. The transition matrices were provided to show the changing in urban areas and how the green spaces were manifested.

3.4.2 Examination of the pattern and distribution of urban green spaces

The landscape metrics including mean patch perimeter, edge density, mean patch size and shape index of urban green area, were computed to quantify the pattern and configuration of urban green spaces as showed in table 3.2. An analysis of variance (ANOVA) was applied after checking normality and homogeneity of data to examine the significance of land metrics variation in cities. Student-Neuman-Keuls (SNK) test was used using the statistical package “agricolae” to show the means once ANOVA revealed a significant difference.

Moreover, the analysis of the spatial distribution of all green areas and each green areas category was carried out using the spatstat package of R software 4.3.0 (R Core Team, 2022) and Ripley’s K method based on green entity centre distances. Thus, the pair correlation function (Stoyan, 1994) was used to test whether green areas could be considered to have regular, random or aggregative pattern. This function is a normalized measure at average manner where green area was perceived according to an increasing distance (r) within the city (Law *et al*., 2009). The function formular is

$$g(r)=K'(r)/2\pi r \qquad (3.3).$$

The function is established from $\lambda K(r)=E$ (Number of neighbour elements at distance ≤ r); $K(r)=\int 2\pi r g(s) s ds$ (3.4), where, $K'(r)$ is the derivative or second reduced moment of Repley function $K(r)$ (Ripley, 1981).

The calculated function $g(r)$ in a given city and green area category is contrasted to the hypothetical value of the null assumption (randomly pattern of individuals green area). The Monte Carlo approach was employed to test the reliability of the identified pattern. As a result, the null hypothesis's rejection limits are determined in the shape of envelope (Atidehou *et al*., 2022). Furthermore, rejecting envelopes of the null assumption at the level of 0.05 were performed using a total of 500-point trials. The null assumption is rejected for any length r for which the value of $g(r)$ is beyond the simulations' envelope (Atidehou *et al*., 2022). The key to interpretation is as follows:

- $g(r) = 1$ for a random distribution;
- $g(r) > 1$ for an aggregate distribution;

- g(r) < 1 for a regular distribution.

Table 3.2: Landscape Metrics Used to Quantify Green Space Pattern (Adapted from Qian *et al.*, 2019)

Land Metric	Description	Equation
Mean Perimeter (km)	The average perimeter of all green space of each category in the city	$\frac{1}{100 \times n} \times \sum_{i=1}^{n} e_i$
Mean Size Area (Ha)	The average area of all green space of each category in the city	$\frac{1}{10000 \times n} \times \sum_{i=1}^{n} a_i$
Edge Density (m/Ha)	Total length of all edge segments in category of green space per hectare	$\frac{10000}{A} \times \sum_{i=1}^{n} e_i$
Shape Index	Value of the index	$\frac{1}{n} \times \sum_{i=1}^{n} \frac{0.25 \times e_i}{\sqrt{a_i}}$

ai represents the area of patch i, ei represents the length of the edge (or perimeter) of patch i, A represents the total area of the city and n represents the total number of patches.

Source: Author's fieldwork (2022)

3.4.3 Evaluation of seasonal variation in vegetation and its correlation with land air temperature in the cities

linear-trend analyses were performed on annual mean of NDVI and land air temperature using a non-parametric over the time period of 2000 to 2020 (Li *et al.*, 2018). Mann-Kendall test was applied to assess the significance of the trend chats (Mondal *et al.*, 2012).

The analysis of variance (ANOVA) was used after checking normality and homogeneity of data to examine the significance of year-seasons (trimester periods) variation on vegetation index. Student-Neuman-Keuls (SNK) test was applied using agricolae package to make difference in means once ANOVA test was significant.

A simple linear regression was applied to show the relationship between land air temperature and NDVI. R core software version 4.3.0 (R Core Team 2022) was employed for all statistical analyses. The package "ggplot2" was used to create the graphics and plots.

3.4.4 Assessment of stakeholder's perception in urban green spaces development

Frequencies and percentages were interpreted on the socioeconomic data according to each city. The purpose was also to explain the possible significance of the relationship between cities, city boroughs of each city, and the perception of residents on urban greenery variables (location of urban greenery availability, state of density and diversity of the existing urban greenery, benefits lost from urban greenery and the causes of urban greenery loss) and resident's involvement attitudes towards greenery improvement (Gashu *et al.,* 2019; Arabomen *et al*., 2021).

Furthermore, the test of Pearson Khi-square was executed in SPSS 23 software (IBM Corp, 2015) to highlight the dependence between the above urban greenery variables and cities and city boroughs. The Correspondence Analysis (CA) was also applied to show the association between city boroughs, lost benefits, and causes of the loss of benefits for each city by using SPSS 23 software (IBM Corp, 2015).

Finally, a binary logistic regression using SPSS 23 software environment (IBM Corp, 2015) was used to examine the variables that explain people's willingness to get involved in improving urban greenery in each city of the study area. This model supplied an appropriate fit for the binary choice events where the dependent variable can only take two values (Arabomen *et al*., 2021). The dependent variable was respondent participation in greenery development (PGD) by manpower, personal initiative, or financial contribution to improve urban greenery that assumed a value 1 if the response is yes and 0 otherwise. The model was performed using fourteen explanatory variables including the city boroughs, sex of respondent (male or female), interviewee age, marital status (single; married; divorced or widower), religion (traditional; christianism or islam), polygamy (yes or no), education (tertiary; senior high school; junior high school; primary school; literacy or none), residence (owner; free accommodated or rental), activity (agriculture; state employment; private employment; trade; pension; own business or student), income (less than 71.63 United States Dollars (USD); 71.63 to143.25 USD or more than 143.25 USD), duration of stay (less than 5 years; 5 to 10 years or more than 10 years), knowledge of the general impact of urban greenery (yes or no), house greenery existence (yes or no), institutional collaboration with local people (yes or no). The conclusion as the explanatory variable significantly influences dependent variables was gotten if $p \leq 0.05$.

3.5 Description of Method of Data Presentation

Maps, tables and charts were methods under which the results of this research were explained.

3.5.1 Data presentation into maps

Urban land use and cover dynamics were shown into maps to explain the spatial distribution and configuration of different land use and cover units. Therefore, the comparative land use and cover units in each city were displayed by mapping and for each studied period. The study also examined the environment impacts of changes on urban vegetated space pattern, structure and distribution. The results coming from this examination were shown into maps.

3.5.2 Data presentation into tables

In this work, the data of urban landscape metrics was presented into tables. The areas of different land use and land cover units or matrix of transition was shown into tables.

Moreover, the calculated indices values were also stocked into tables. Tables were also used to show the results from statistical analysis.

3.5.3 Data presentation through graphs

Graphs and bar charts were used to indicate the evolution of people perception on urban existing greenery link to the town boroughs. Loss of greenery benefits and its causes were also shown into charts. To impress decision makers, two decades differences in environmental anomalies regarding to greening importance and surface temperature were highlighted in graphs. The seasonal relationships between surface temperature and NDVI according to each city were presented as graphs.

3.6 Outcomes of Research

The study was successful in educating stakeholders on the extent of the influence of rapid urban expansion on greenery availability in each of the example cities. The maps (2000, 2010 and 2020) on urban land use and cover were available for the case cities.

The pattern and the distribution of urban green spaces were known. Several thematic maps were available on these data and could be used for urban planning conception and management. Likewise, the gap or the concordance between the current green space situation and what it should be, may be highlighted in the document.

Comparing Porto-Novo to Parakou, the lacked benefits from green spaces and the factors causing these losses were known. Likewise, the study showed the moments in year when urban green spaces can optimize its impacts in terms of surface temperature mitigation.

Finally, the factors which are influencing (negatively or positively) the improvement of urban friendly spaces in the case cities were known. Therefore, the recommendation was made in the lens of urban greenery improvement in order to increase its impacts these cities.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation and Analysis of Results

4.1.1 Urban land use and land cover dynamics in the cities

4.1.1.1 *Land use and land cover maps of the cities*

The land use and land cover of the city of Porto-Novo (Figures 4.1 and 4.2) and Parakou (Figures 4.3 and 4.4) have been greatly changed during the last two decades (2000 to 2020). Eight land use and cover classes were found included forests (gallery and sacred), plantations (wood and fruit), marshy lands, crop lands (annual and perennial), city bushes, water bodies, bare lands and built-up areas. The built-up areas represent the urbanized areas while forests, plantations, marshy lands, crop lands, city bushes, water bodies can be considered as urban green spaces.

The proportion of crop land and marshy land covers decreased considerably from 2000 to 2020 in Porto-Novo. Concerning forest and plantation covers, the decreasingly changes were found from 2010 to 2020 (Table 4.1). Very weak change was observed in water body cover. However, the proportion of built-up areas was increased during all the study periods (Table 4.1). The Figures 4.1 and 4.2 showed the trend of these changes. The built-up areas represented 67.65 per cent, 68.88 per cent and 70.26 per cent respectively in 2000, 2010 and 2020 (Table 4.1, Figures 4.1 and 4.2). Likewise, water body class was mostly found in Porto-Novo but the city of Parakou lacked this land cover class as showed in figure 4.3 and figure 4.4.

Table 4.2 presented areas and proportions of urban land cover changes in Parakou. The cover of crop land, city bush, forest and plantation classes have decreased from 2000 to 2020. Crop lands decreased from 26.52 per cent to 12.75 per cent, city bushes from 8.30

per cent to 0.74 per cent, forests from 7.29 per cent to 4.51 per cent and plantations 2.11 per cent to 1.93 per cent (Table 4.2). Marshy lands recorded a slight regression during this period (2.50 per cent in 2000, 2.41 per cent in 2010 and 2.07 per cent in 2020). Bare lands did not record change from the period of 2010 to 2020. Moreover, the greatest changes were observed on the built-up areas. Therefore, 53.01 per cent of built-up areas were recorded in 2000, 67.93 per cent in 2010 and 77.86 per cent in 2020 (Table 4.2, Figures 4.3 and 4.4).

Table 4.1: Land Use and Land Cover Classes Used in the Change Analysis of Porto-Novo (Area in hectare)

LULC Classes	2000	%	2010	%	2020	%
Crop Lands	239.15	4.56	181.42	3.46	127.75	2.44
Marshy Lands	797.51	15.22	790.90	15.09	778.70	14.86
Water Body	646.01	12.33	646.01	12.33	646.21	12.33
Built-Up Areas	3545.76	67.65	3610.11	68.88	3682.39	70.26
Plantations	8.85	0.17	8.85	0.17	2.73	0.05
Forests	3.87	0.07	3.87	0.07	3.38	0.06
Total	**5241.15**	**100**	**5241.15**	**100**	**5241.15**	**100**

Source: Author' data analysis (2021)

Table 4.2: Land Use and Land Cover Classes Used in the Change Analysis of Parakou (Area in hectare)

LULC Classes	2000	%	2010	%	2020	%
Crop Lands	1,767.22	26.52	1,043.22	15.66	849.69	12.75
Forests	485.97	7.29	436.22	6.55	300.49	4.51
City Bushes	553.04	8.30	274.00	4.11	49.08	0.74
Built-Up Areas	3,532.26	53.01	4,525.89	67.93	5,187.53	77.86
Bare Lands	16.81	0.25	9.41	0.14	9.41	0.14
Marshy Lands	166.59	2.50	160.70	2.41	137.81	2.07
Plantations	140.87	2.11	213.32	3.20	128.74	1.93
Total	**6,662.76**	**100.00**	**6,662.76**	**100.00**	**6,662.76**	**100.00**

Source: Author' data analysis (2021)

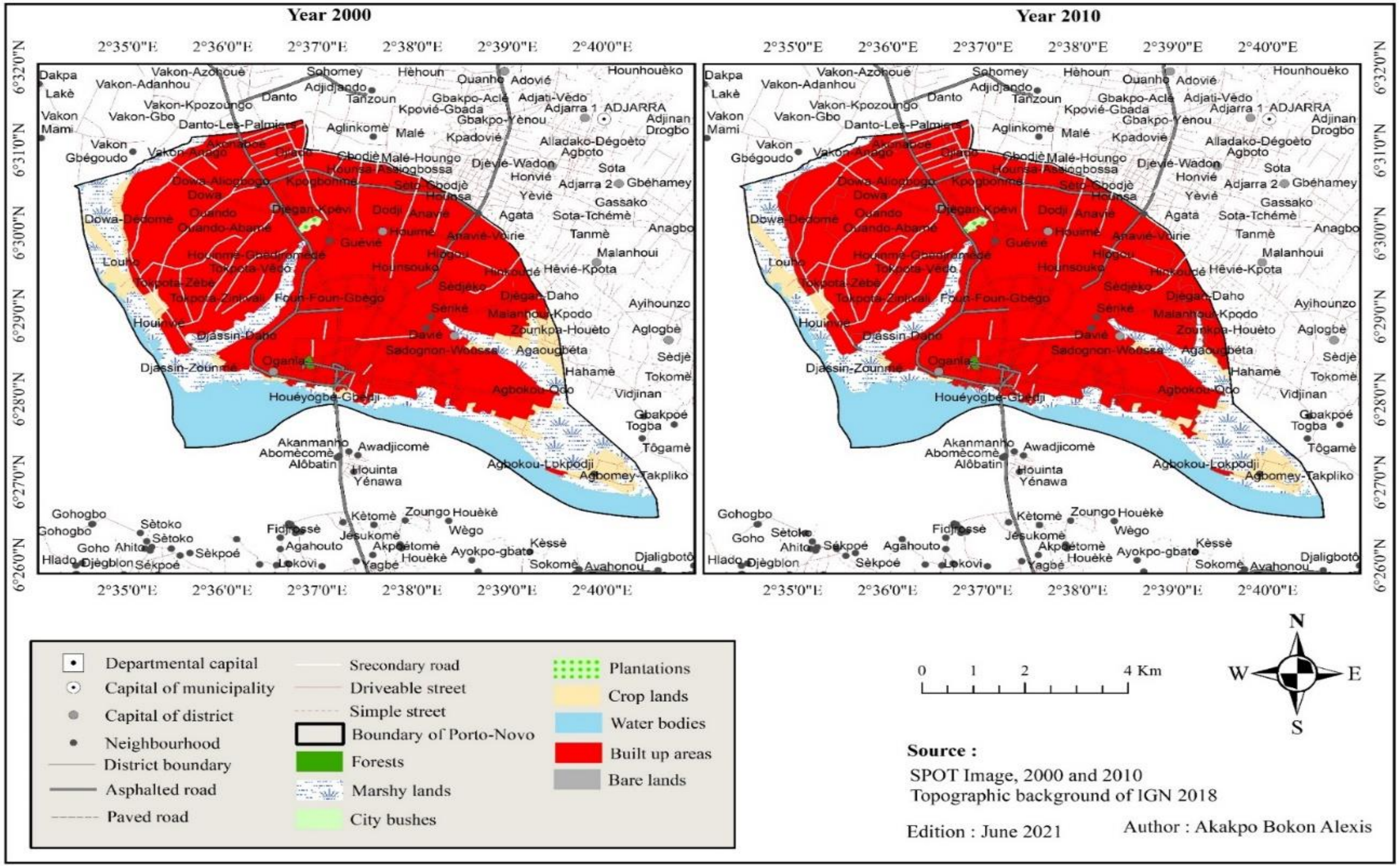

Figure 4.1: LULC Maps of the City of Porto-Novo (2000 to 2010)

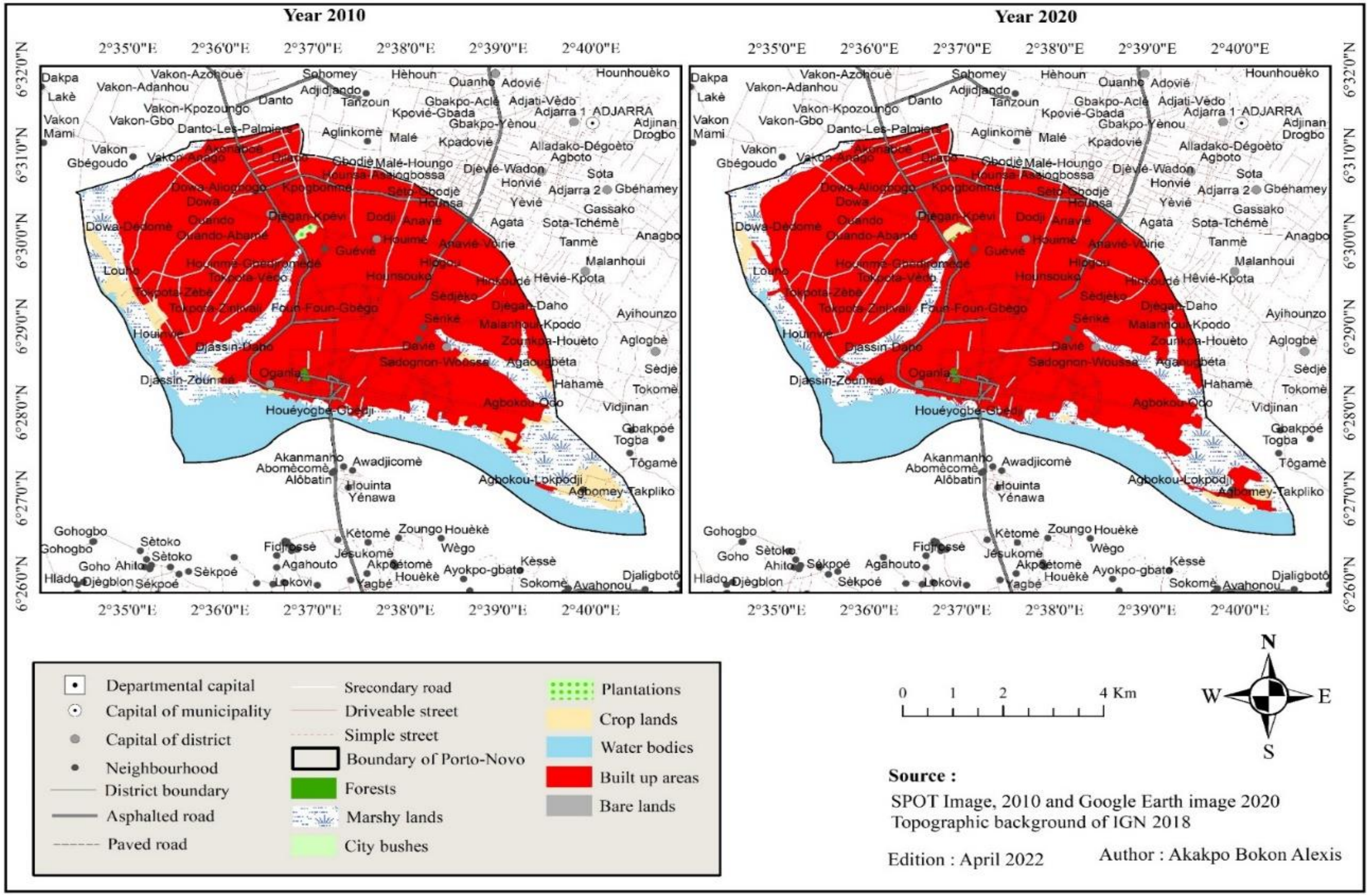

Figure 4.2: LULC Maps of the City of Porto-Novo (2010 to 2020)

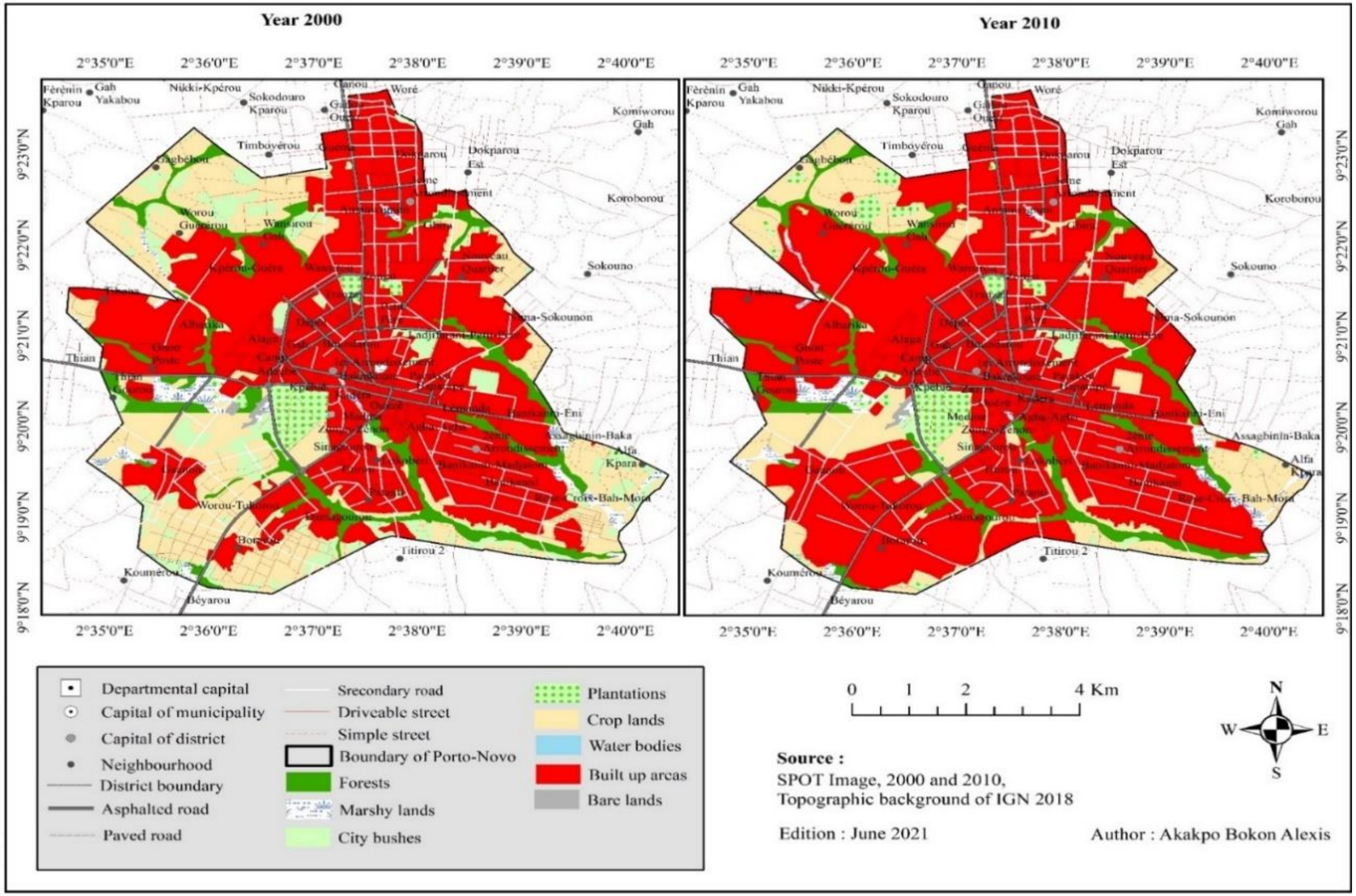

Figure 4.3: LULC Maps of the City of Parakou (2000 to 2010)

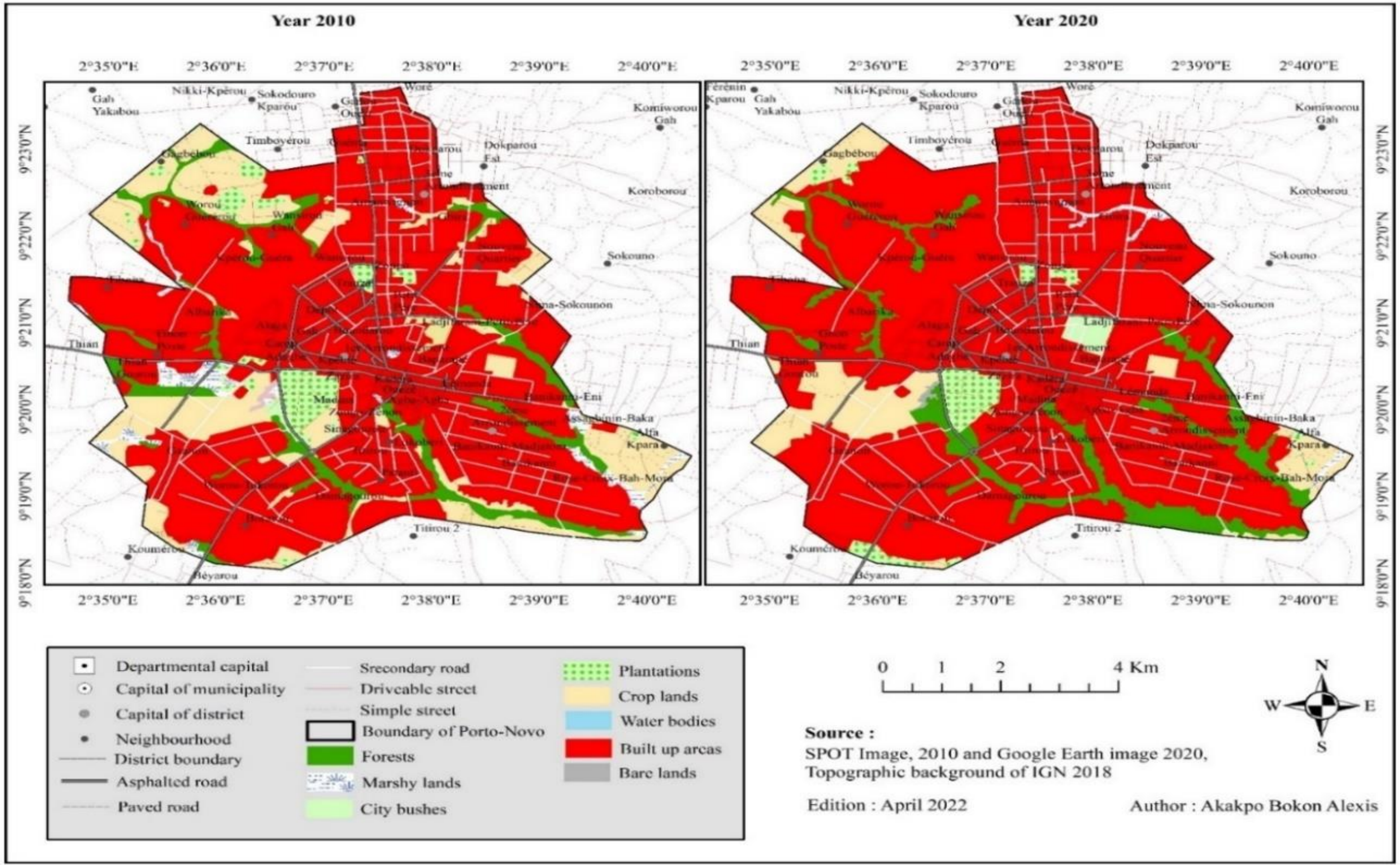

Figure 4.4: LULC Maps of the City of Parakou (2010 to 2020)

4.1.1.2 *Change in land use and land cover in the cities*

The matrices of land use and cover transition of 2000 to 2010 and 2010 to 2020 were used to estimate the land change probability in the cities (Tables 4.3, 4.4, 4.5 and 4.6). In the city of Porto-Novo, water body, forest and plantation showed a total persistence (100 per cent per year) for the period of 2000 to 2010. Marshy land recorded 99 per cent per year of persistence when crop land showed a weak persistence (76 per cent per year). 24 per cent and 1 per cent respectively of the transformed proportion of crop land and marshy land were all transformed into built-up area (Table 4. 7).

Regarding to the period of 2010 to 2020, plantations were greatly under threat with only 31 per cent persisted per year for its area. The loss of 69 per cent were converted to crop land (Table 4.7). Marshy land, forest and crop land presented respectively 97 per cent, 87 per cent and 67 per cent per year for persistence. Thereby, the lost proportions were all transformed into built-up areas (Table 4.7). Moreover, water body did not change.

The findings were different in the city of Parakou. For the period of 2000 to 2010, plantations (99 per cent), marshy lands (96 per cent) and forests (90 per cent) recorded the greatest persistence in the city (Table 4.8). Crop lands and bare lands showed respectively 45 per cent and 53 per cent of persistence rate per year. However, city bush class was the most converted and only 11 per cent of its area remained par year (Table 4.8). The results showed also that at least all the transformed proportions of forest, bare lands, marshy lands and plantations were converted to built-up areas. City bushes were converted into built-up areas (40 per cent), crop lands (39 per cent) and plantation (11 per cent). According to crop lands, 42 per cent were transformed into built-up areas, 12 per cent to city bushes and one per cent into plantation (Table 4.8).

From 2010 to 2020, the city of Parakou showed the greatest persistence of marshy lands (86 per cent). Forests, plantations and crop lands showed respectively 68 per cent, 60 per cent and 54 per cent of persistent rate while city bushes (18 per cent) were highly converted into crop lands (78 per cent) and built-up areas (4 per cent) (Table 4.8). The transformed areas of crop lands were converted into built-up areas (46 per cent) as well as the plantation (34 per cent). Moreover, the forests were degraded by the sprawl of built-up area (21 per cent) and agriculture (11 per cent).

Table 4.3: Transition Matrix Rate of Porto-Novo from 2000 to 2010

LULC Classes	Crop Lands	Marshy Lands	Water Body	Built-Up Areas	Plantations	Forests	Land Rate Conversion
Crop Lands	181.42	0.00	0.00	57.73	0.00	0.00	0.00
Marshy Lands	0.00	790.90	0.00	6.61	0.00	0.00	0.00
Water Bodies	0.00	0.00	646.01	0.00	0.00	0.00	0.00
Built-Up Areas	0.00	0.00	0.00	3545.76	0.00	0.00	1.78
Plantations	0.00	0.00	0.00	0.00	8.85	0.00	0.00
Forests	0.00	0.00	0.00	0.00	0.00	3.87	0.00

Source: Author' data analysis (2021)

Table 4.4: Transition Matrix Rate of Porto-Novo from 2010 to 2020

LULC Classes	Crop Lands	Marshy Lands	Water Body	Built-Up Areas	Plantations	Forests	Land Rate Conversion
Crop Lands	121.63	10.21	0.19	49.39	0.00	0.00	4.79
Marshy Lands	0.00	768.49	0.00	22.41	0.00	0.00	1.31
Water Bodies	0.00	0.00	646.01	0.00	0.00	0.00	0.03
Built-Up Areas	0.00	0.00	0.00	3610.10	0.00	0.00	1.96
Plantations	6.12	0.00	0.00	0.00	2.73	0.00	0.00
Forests	0.00	0.00	0.00	0.50	0.00	3.38	0.00

Source: Author' data analysis (2021)

Table 4. 5: Transition Matrix Rate of Parakou from 2000 to 2010

LULC Classes	Crop Lands	Forests	City Bushes	Built-Up Areas	Bare Lands	Marshy Lands	Plantations	Water Bodies	Land Rate Conversion
Crop Lands	792.08	0.00	213.32	748.04	0.00	0.00	13.78	0.00	24.07
Forests	37.82	436.22	0.00	11.93	0.00	0.00	0.00	0.00	0.00
City Bushes	213.32	0.00	60.68	218.53	0.50	0.00	60.01	0.00	77.85
Built-Up Areas	0.00	0.00	0.00	3532.26	0.00	0.00	0.00	0.00	21.95
Bare Lands	0.00	0.00	0.00	7.90	8.91	0.00	0.00	0.00	5.36
Marshy Lands	0.00	0.00	0.00	5.88	0.00	160.70	0.00	0.00	0.00
Plantations	0.00	0.00	0.00	1.34	0.00	0.00	139.52	0.00	34.59
Water Bodies	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author' data analysis (2021)

Table 4.6: Transition Matrix Rate of Parakou from 2010 to 2020

LULC Classes	Crop Lands	Forests	City Bushes	Built-Up Areas	Bare Lands	Marshy Lands	Plantations	Water Bodies	Land Rate Conversion
Crop Lands	564.32	0.00	0.00	478.90	0.00	0.00	0.00	0.00	33.58
Forests	47.91	298.04	0.00	90.27	0.00	0.00	0.00	0.00	0.81
City Bushes	213.49	0.00	49.08	11.43	0.00	0.00	0.00	0.00	0.00
Built-Up Breas	0.00	0.00	0.00	4525.89	0.00	0.00	0.00	0.00	12.75
Bare Lands	0.00	0.00	0.00	0.00	9.41	0.00	0.00	0.00	0.00
Marshy Lands	10.86	2.44	0.00	9.59	0.00	137.81	0.00	0.00	0.00
Plantations	13.11	0.00	0.00	71.46	0.00	0.00	128.74	0.00	0.00
Water Bodies	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author' data analysis (2021)

Table 4.7: Annual Probability Matrices of Porto-Novo

LULC Classes	Crop Lands	Marshy Lands	Water Body	Built-Up Areas	Plantations	Forests
2000 to 2010						
Crop Lands	0.76	0.00	0.00	0.24	0.00	0.00
Marshy Lands	0.00	0.99	0.00	0.01	0.00	0.00
Water Body	0.00	0.00	1.00	0.00	0.00	0.00
Built-Up Areas	0.00	0.00	0.00	1.00	0.00	0.00
Plantations	0.00	0.00	0.00	0.00	1.00	0.00
Forests	0.00	0.00	0.00	0.00	0.00	1.00
2010 to 2020						
Crop Lands	0.67	0.06	0.00	0.27	0.00	0.00
Marshy Lands	0.00	0.97	0.00	0.03	0.00	0.00
Water Body	0.00	0.00	1.00	0.00	0.00	0.00
Built-Up Areas	0.00	0.00	0.00	1.00	0.00	0.00
Plantations	0.69	0.00	0.00	0.00	0.31	0.00
Forests	0.00	0.00	0.00	0.13	0.00	0.87

Source: Author' data analysis (2021)

Table 4.8: Annual Probability Matrices of Parakou

LULC Classes	Crop Lands	Forests	City Bushes	Built-Up Areas	Eroded Lands	Marshy Lands	Plantations
2000 to 2010							
Crop Lands	0.45	0.00	0.12	0.42	0.00	0.00	0.01
Forests	0.08	0.90	0.00	0.02	0.00	0.00	0.00
City Bushes	0.39	0.00	0.11	0.40	0.00	0.00	0.11
Built-Up Areas	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Bare Lands	0.00	0.00	0.00	0.47	0.53	0.00	0.00
Marshy Lands	0.00	0.00	0.00	0.04	0.00	0.96	0.00
Plantations	0.00	0.00	0.00	0.01	0.00	0.00	0.99
2010 to 2020							
Crop Lands	0.54	0.00	0.00	0.46	0.00	0.00	0.00
Forests	0.11	0.68	0.00	0.21	0.00	0.00	0.00
City Bushes	0.78	0.00	0.18	0.04	0.00	0.00	0.00
Built-Up Areas	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Bare Lands	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Marshy Lands	0.07	0.01	0.00	0.06	0.00	0.86	0.00
Plantations	0.06	0.00	0.00	0.34	0.00	0.00	0.60

Source: Author' data analysis (2021)

4.1.2 Pattern and distribution of urban green spaces in the cities

4.1.2.1 *Variation of spatial configuration of urban green spaces in the cities*

Figure 4.5 showed urban spatial pattern of the green spaces in Porto-Novo and Parakou for the year 2022. The green spaces in these cities could be summarized into forest (sacred forest and gallery forest), marshy land, plantation, crop land, city bush, water body, green cemetery, urban garden and trees. Trees could be found as street trees, office tree assemblages or home tree assemblages that can provide area more than 100-metre square. City bush was the unmanaged areas with greenery in city. It can be the old fallow areas, unbuilt lots or any ephemeral bushes in urban area. Urban garden was known as public gardens or places with greenery, green road junctions, private gardens or courtyards with greenery.

The number of the recorded tree assemblages, urban gardens, forests and city bushes was more in Parakou compared to the city of Porto-Novo while crop lands, plantations and cemeteries were more in Porto-Novo than Parakou. No water body was denoted in Parakou as indicated in table 4.9. It was also revealed that the green spaces covered 20.38 per cent in Parakou while 32.33 per cent were occurred in Porto-Novo (Table 4.9).

The test of ANOVA showed no significant difference (p-values = 0.465) in relation to the configuration parameters of green spaces (green spaces perimeter, size area, shape index and edge density) between the cities (Table 4.10). This result revealed that the same strategies or actions for green space development, improvement or conservation basing on these configuration parameters may be adopted to each of the cities.

Furthermore, a significant difference (p-value ≤ 0.000) was found between green space categories within each city as shown in Table 4.10. In this study, water bodies showed the greatest perimeter followed by forests and marshy lands while no significant difference was recorded between city bush, urban plantation, crop land, urban garden, trees and cemetery (Table 4.11). According to the size area and shape index, the difference was showed with water bodies that presented the greatest values. The values of edge density were highest for water bodies and followed by marshy lands and forests. The low edge densities were found for trees, urban gardens and plantations as presented in table 4.11.

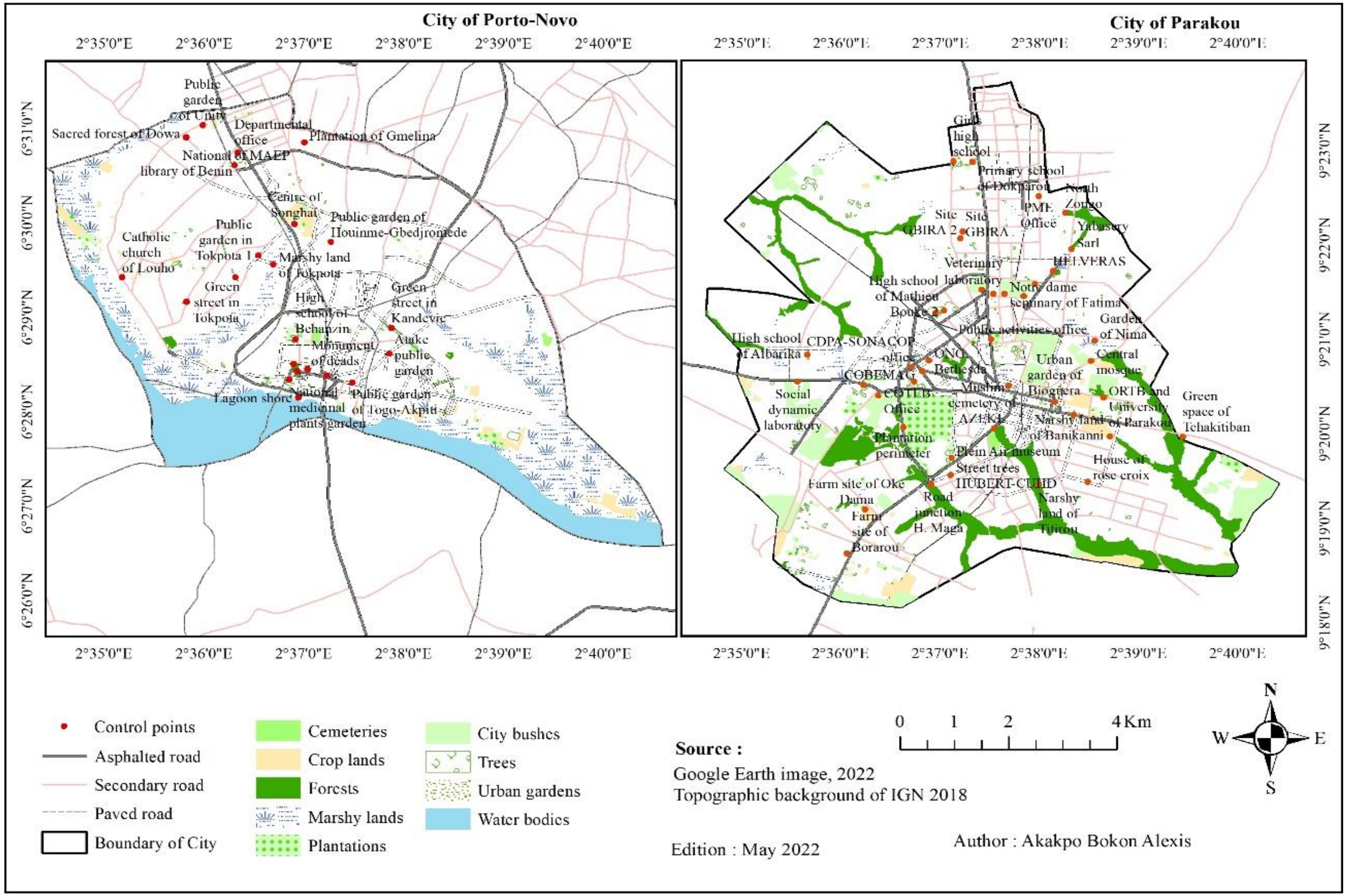

Figure 4.5: Map of Spatial Configuration of Urban Green Spaces in the Study Cities

Table 4.9: Number, Cumulative Area and Cover Proportion of Urban Green Space

Green Space Category	Parakou			Porto-Novo		
	Number	Cumulative Area (Ha)	Cover Percentage	Number	Cumulative Area (Ha)	Cover Percentage
Cemetery	1	6.11	0.09	3	8.65	0.17
City Bush	39	342.75	5.14	31	14.10	0.27
Crop Land	41	105.70	1.59	53	84.07	1.60
Forest	36	540.09	8.11	7	10.51	0.20
Marshy Land	32	136.20	2.04	31	898.54	17.14
Plantation	25	130.38	1.96	31	23.04	0.44
Trees	204	61.74	0.93	86	16.40	0.31
Urban Garden	53	34.39	0.52	33	21.89	0.42
Water Body	0	0	0	2	617.22	11.78
Total	**431**	**1,357.36**	**20.38**	**277**	**1,694.42**	**32.33**

Source: Author' data analysis (2022)

Table 4.10: Summary of ANOVA Model on Green Space Configuration Parameters

Variable	Factor	Df	F-Value
Perimeter (km)	City	1	0.335ns
	Green Spaces Category	8	72.01***
Area (Ha)	City	1	2.306ns
	Green Spaces Category	8	70.77***
Shape Index	City	1	0.534ns
	Green Spaces Category	8	13.27***
Edge Density	City	1	3.777ns
	Green Spaces Category	8	81.95***

Significance codes: ns = no significant, *** = 0.001, ** = 0.01, * = 0.05, Df = Degree of Freedom.

Source: Author' data analysis (2022)

Table 4.11: Mean, Standard Deviation (Std) and Difference Category

Green Space Category	Perimeter (km)	Area (Ha)	Shape Index	Edge Density (m/Ha)
Cemetery	0.86 ± 0.15^{c}	3.69 ± 2.02^{b}	1.20 ± 0.24^{b}	1531.73 ± 148.38^{c}
City Bush	0.80 ± 0.89^{c}	5.10 ± 9.41^{b}	1.21 ± 0.21^{b}	1261.32 ± 1310.99^{c}
Crop Land	053 ± 0.51^{c}	2.02 ± 3.36^{b}	1.14 ± 0.16^{b}	904.77 ± 868.05^{d}
Forest	2.11 ± 2.76^{b}	12.80 ± 24.53^{b}	1.57 ± 0.55^{b}	3198.48 ± 4130.71^{b}
Marshy Land	1.86 ± 1.73^{b}	16.42 ± 30.28^{b}	1.41 ± 0.30^{b}	3325.47 ± 3367.11^{b}
Plantation	0.48 ± 0.63^{c}	2.73 ± 12.90^{b}	1.17 ± 0.22^{b}	804.17 ± 976.25^{d}
Trees	0.23 ± 0.19^{c}	0.27 ± 0.82^{b}	1.30 ± 0.39^{b}	371.70 ± 313.05^{d}
Urban Garden	0.32 ± 0.22^{c}	0.65 ± 1.12^{b}	1.16 ± 0.22^{b}	523.63 ± 368.70^{d}
Water Body	15.14 ± 13.74^{a}	308.61 ± 391.43^{a}	2.49 ± 0.11^{a}	$28,893.21\pm26,218.58^{a}$

Means with the same letter are not significantly different (SNK test)

Source: Author' data analysis (2022)

4.1.2.2 *Spatial pattern and distribution of urban green spaces in the cities*

The spatial pattern of urban green space areas was shown in figure 4.6. An aggregative distribution of green areas was observed in Porto-Novo and Parakou. It was found the similar distribution (aggregative distribution) and spatial pattern of each of the identified green area category in the study urban area.

Moreover, g(r) > one at distance d = 500 metres was obtained on the green areas from the two considered cities confirming that green space individuals were effectively in aggregative pattern of urban green area distribution (Figure 4.7).

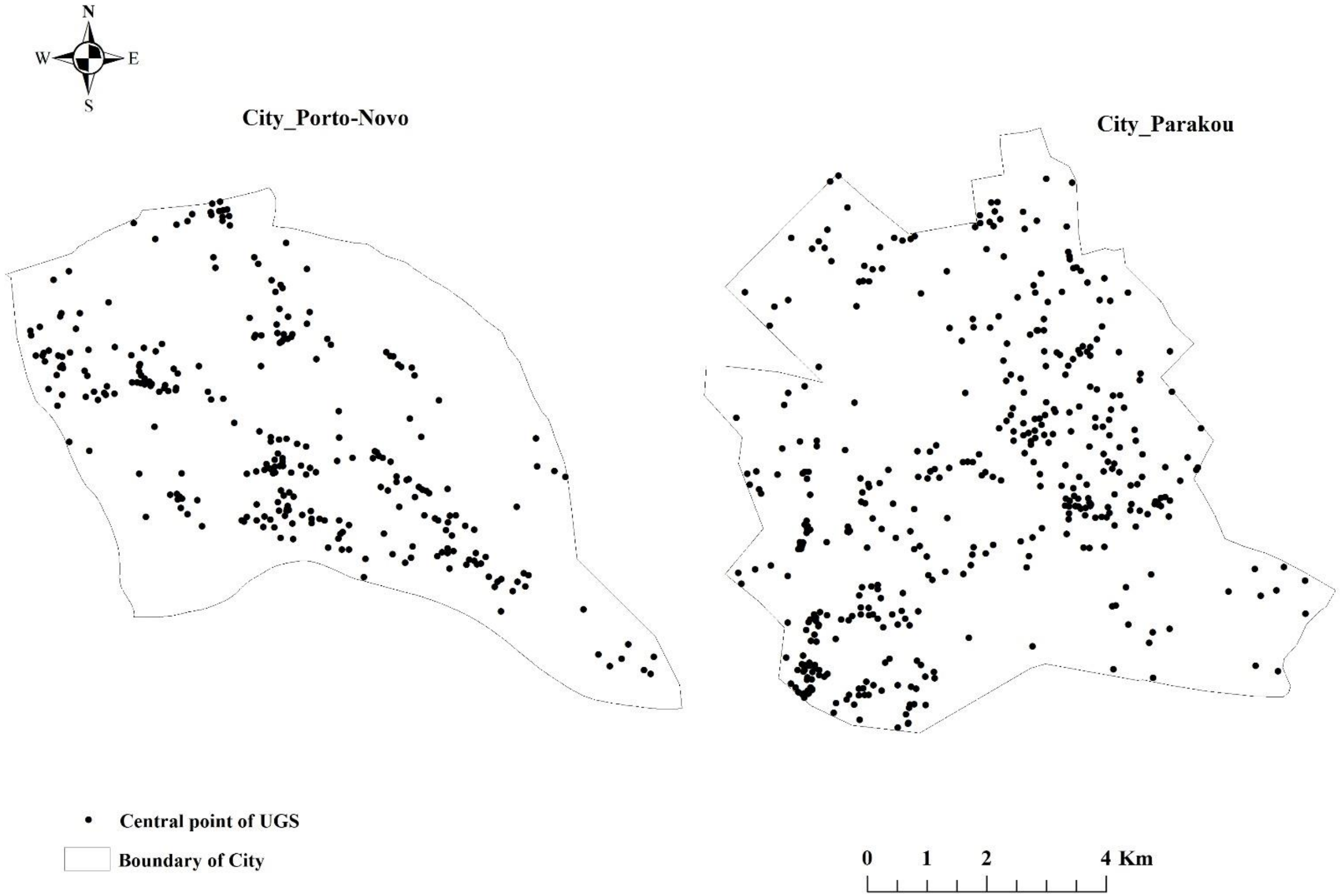

Figure 4.6: Map of Spatial Pattern of Urban Green Spaces in the Study Cities

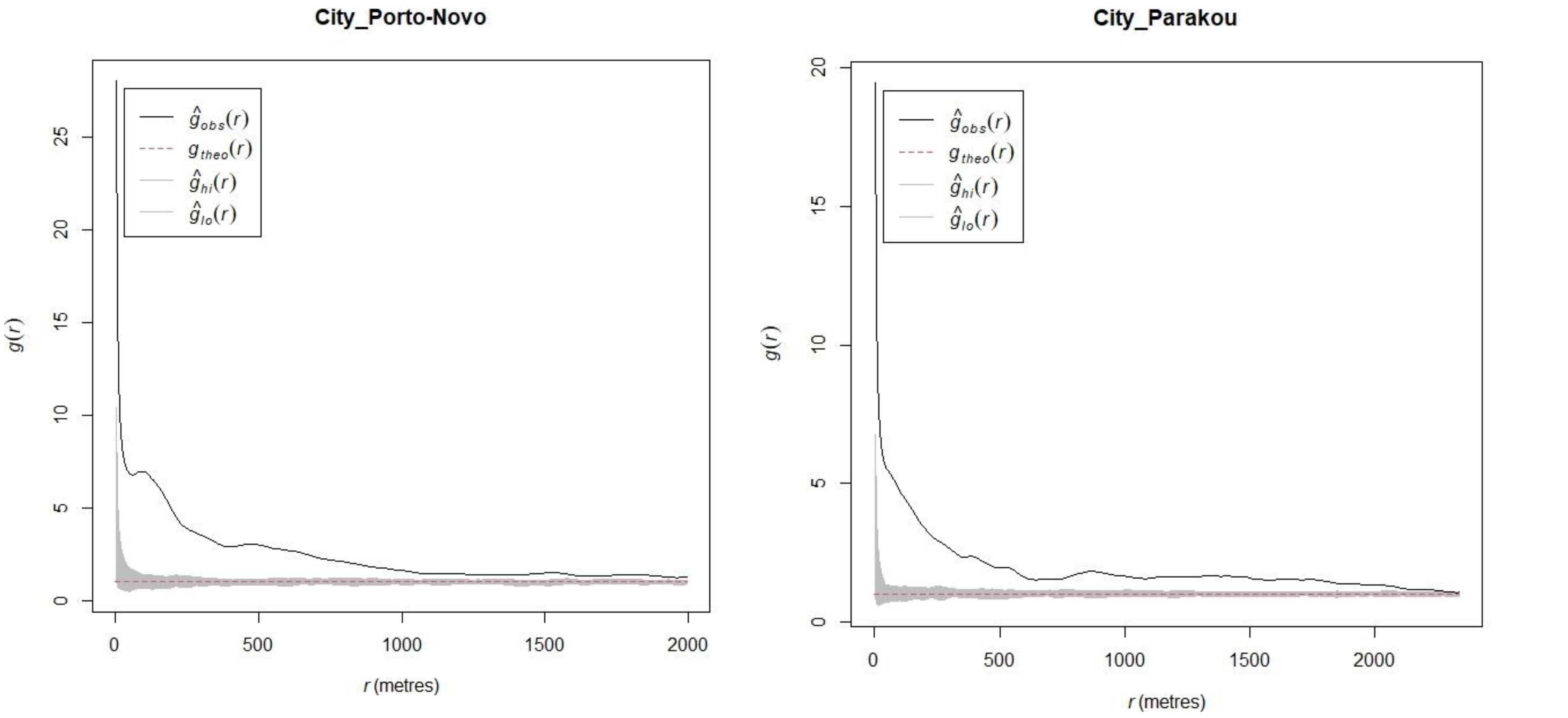

Figure 4.7: Graphs Showing the Spatial Distribution of Urban Green Spaces in the Study Cities

4.1.3 Evaluation of seasonal variation in vegetation and its correlation with air temperature in cities

4.1.3.1 *Changes in urban vegetation index (NDVI) and air temperature (AT) from 2000 to 2020*

The test of Mann-Kendall showed no significant linear trend in annual NDVI data (combined cities : p-values = 0.2; Porto-Novo: p-value = 0.98 and Parakou: p-value = 0.98). Likewise, no significant linear trend was found in the annual AT for data from the combined cities and the city of Parakou (respectively, p-values = 0.49 and p-values = 0.74). However, a significant linear trend was moderatly found in the annual AT data for the city of Porto-Novo (p-values = 0.023). Therefore, an upward trend can be attribute to the annual AT data of Porto-Novo (Figure 4.8). A decrease tendency of NDVI was also noted from 2000 to 2011 (0.21 to 0.19) and an increase from 2011 up to 2020 (0.19 to 0.23) (Figure 4.9). Along this, the mean of NDVI varied from year to year in the cities.

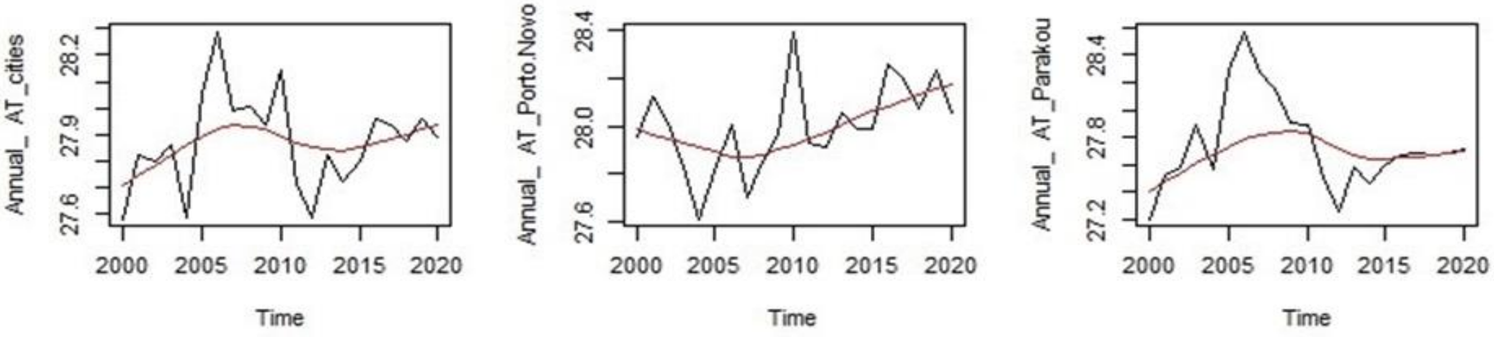

Figure 4.8: Trend of Annual Land Air Temperature (AT) from the Years 2000 to 2020

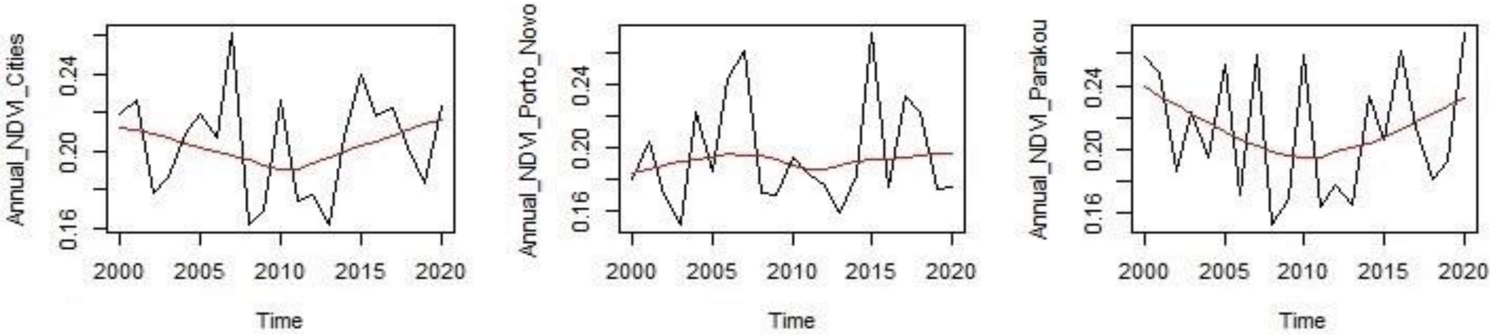

Figure 4.9: Trend of Annual Normalized Difference Vegetation Index (NDVI) from the Years 2000 to 2020

4.1.3.2 *Seasonal variation of vegetation index (NDVI) in the cities*

The assessed vegetation index (NDVI) according to the annual quarters (sensibly season variation) from 2000 to 2020 showed significant difference (p-value < 0.001) for the combined cities as well as for each city (Table 4.12). The mean NDVI for the period January to March was significantly low for the combined cities and Porto-Novo. In opposite, the period from April to June had the lowest mean NDVI value (Table 4.13). Regarding the periods of July to September and October to December, no statistically different was found as indicated in table 4.13. However, the situation of Parakou was different from Porto-Novo. Therefore, although the period of January to March still kept the low mean NDVI value, no significant difference was found for the remaining periods of the year (Table 4.13).

Table 4.12: Summary of ANOVA Model on Vegetation Index (NDVI)

City	Df	Sum sq	Mean sq	F-Value
Both Cities	3	0.701	0.233	19.46^{***}
Porto-Novo	3	0.503	0.167	16.45^{***}
Parakou	3	0.234	0.078	5.76^{***}

Signif. codes: '***'= 0.001; Df = Degree of freedom; sq = square

Sources: Author' data analysis (2022)

Table 4.13: Mean, Standard Deviation (Std) and Difference Structuration of Vegetation Index

Period	Both Cities		Porto-Novo		Parakou	
	Mean	Std	Mean	Std	Mean	Std
Jan. to March	0.147^{a}	0.051	0.137^{a}	0.054	0.162^{a}	0.043
April to June	0.255^{b}	0.133	0.260^{b}	0.119	0.145^{a}	0.146
July to Sept.	0.202^{c}	0.151	0.200^{c}	0.139	0.213^{b}	0.159
Oct. to Dec.	0.213^{c}	0.077	0.195^{c}	0.063	0.233^{b}	0.085

Means with the same letter are not significantly different (SNK test). Jan. to March = January to March; July to Sept. = July to September; Oct. to Dec. = October to December

Source: Author' data analysis (2022)

4.1.3.3 *Relationship between urban AT and seasonal NDVI in the cities*

Greenery seasonal dynamics is more crucial for monitoring urban environment. The attempt was made to understand the quarterly variability of NDVI using Landsat data to get more accurate information about the vegetation effects on urban air temperature reduction. The figures 4.10 and 4.11 showed the results of a simple linear regression study between yearly land air temperature and NDVI for Porto-Novo and Parakou respectively. Thereby, each point revealed the mean land air temperature (AT) and NDVI value linked to the urban area, the red smooth line showed the result of linear simulation and the function of linear regression was also exhibited at the top. It could be therefore understood from these figures that the result showed a moderate negative correlation between the mean AT and the NDVI values (r = - 0.41). Thus, it can be suggested that a season period with more vegetation cover (NDVI value ≥ + 0.5) induced correspondingly greater rates of evapotranspiration and led to the land surface and atmosphere latent and sensible heat exchange in comparison to the season period with few vegetation covers (NDVI value ≤ zero) at the same areas.

A similar result with strong correlation was obtained for the season periods in each city (Table 4.14). However, the regression analysis showed a strong positive correlation between the mean AT and NDVI values for January to March in Porto-Novo (r = + 0.56, Table 4.14 and Figure 4.12) and April to June in Parakou (r = + 0.76, Table 4.14 and Figure 4.13). These findings indicated that urban vegetation cover may not induce to land air temperature reduction during respectively these periods in Porto-Novo and Parakou.

Table 4.14: Linear Regression and Correlation Coefficients (r) for the Relationship Between AT and NDVI

Periods	Regression Functions	Df	r	r^2 (%)
City of Porto-Novo				
Annual	AT = 29.024 - 5.852×NDVI	248	-0.41	16.81
January to March	AT = 27.715 + 6.846×NDVI	61	0.56	31.36
April to June	AT = 30.308 - 8.288 ×NDVI	58	-0.66	43.56
July to September	AT = 27.036 - 3.457×NDVI	58	-0.61	37,21
October to December	AT = 29.06 - 4.89×NDVI	58	-0.85	72.25
City of Parakou				
Annual	AT = 28.704 - 3.914×NDVI	216	-0.41	16.81
January to March	AT = 31.74 - 23.52 ×NDVI	48	-0.86	73.96
April to June	AT = 26.46 + 7.725×NDVI	48	0.76	57.76
July to September	AT = 26.82 - 2.40×NDVI	48	-0.54	29.16
October to December	AT = 28.707 - 5.493×NDVI	48	-0.64	40.96

Df: Degrees of freedom, r^2 : Coefficient of determination

Source: Author’ data analysis (2022)

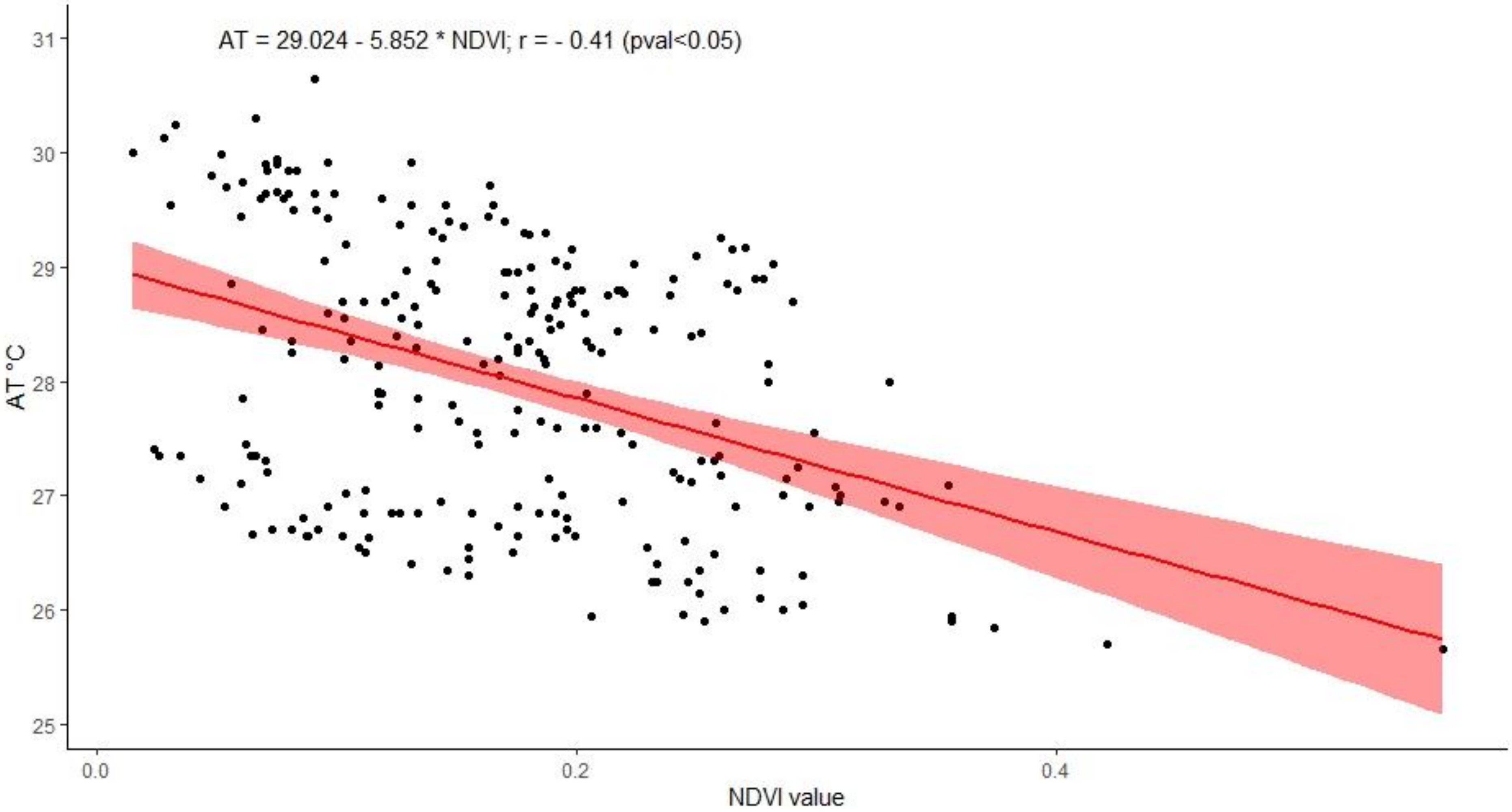

Figure 4.10: Scatter Plot Linear Regression of Mean AT and NDVI for Porto-Novo

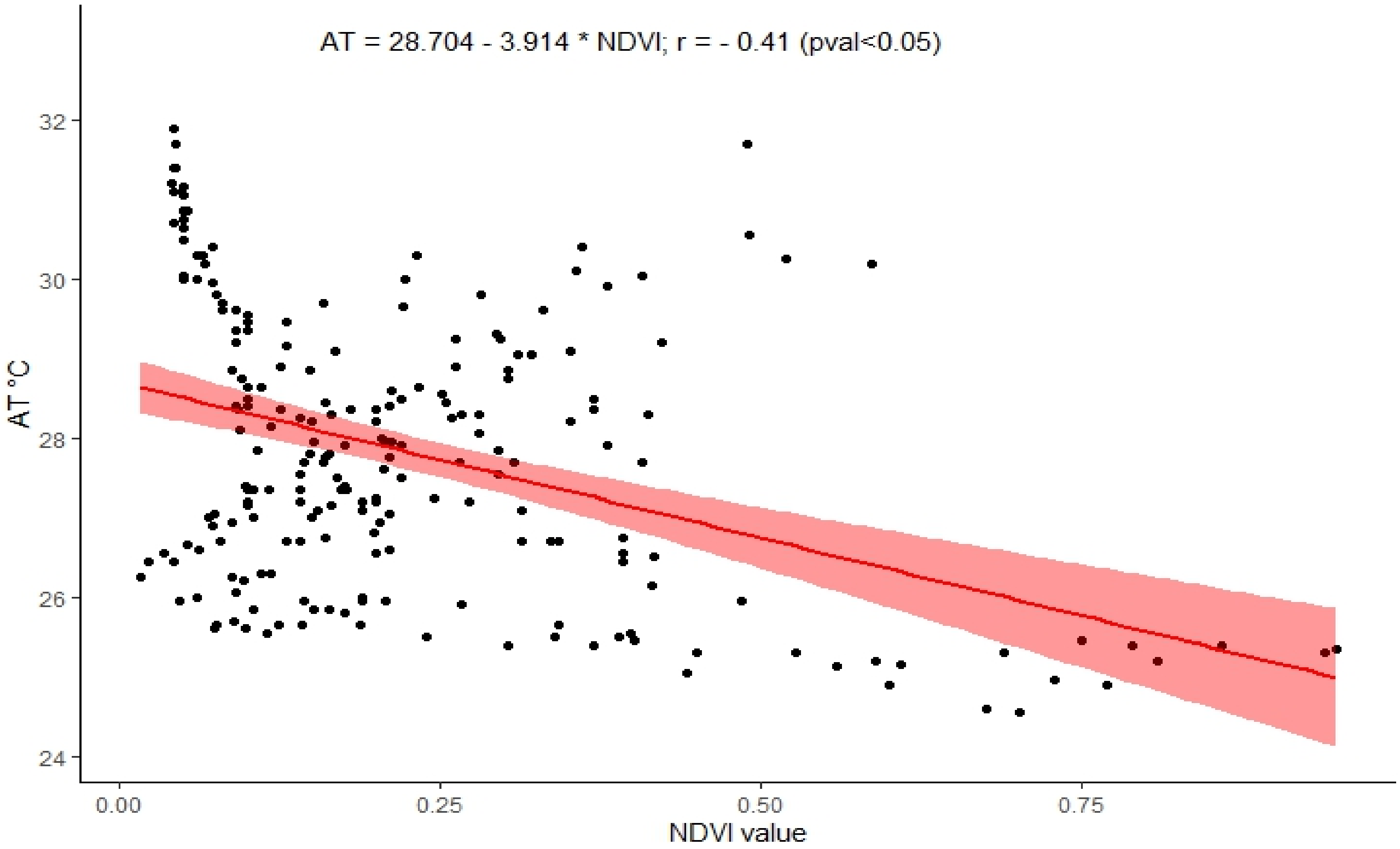

Figure 4.11: Scatter Plot Linear Regression of Mean AT and NDVI for Parakou

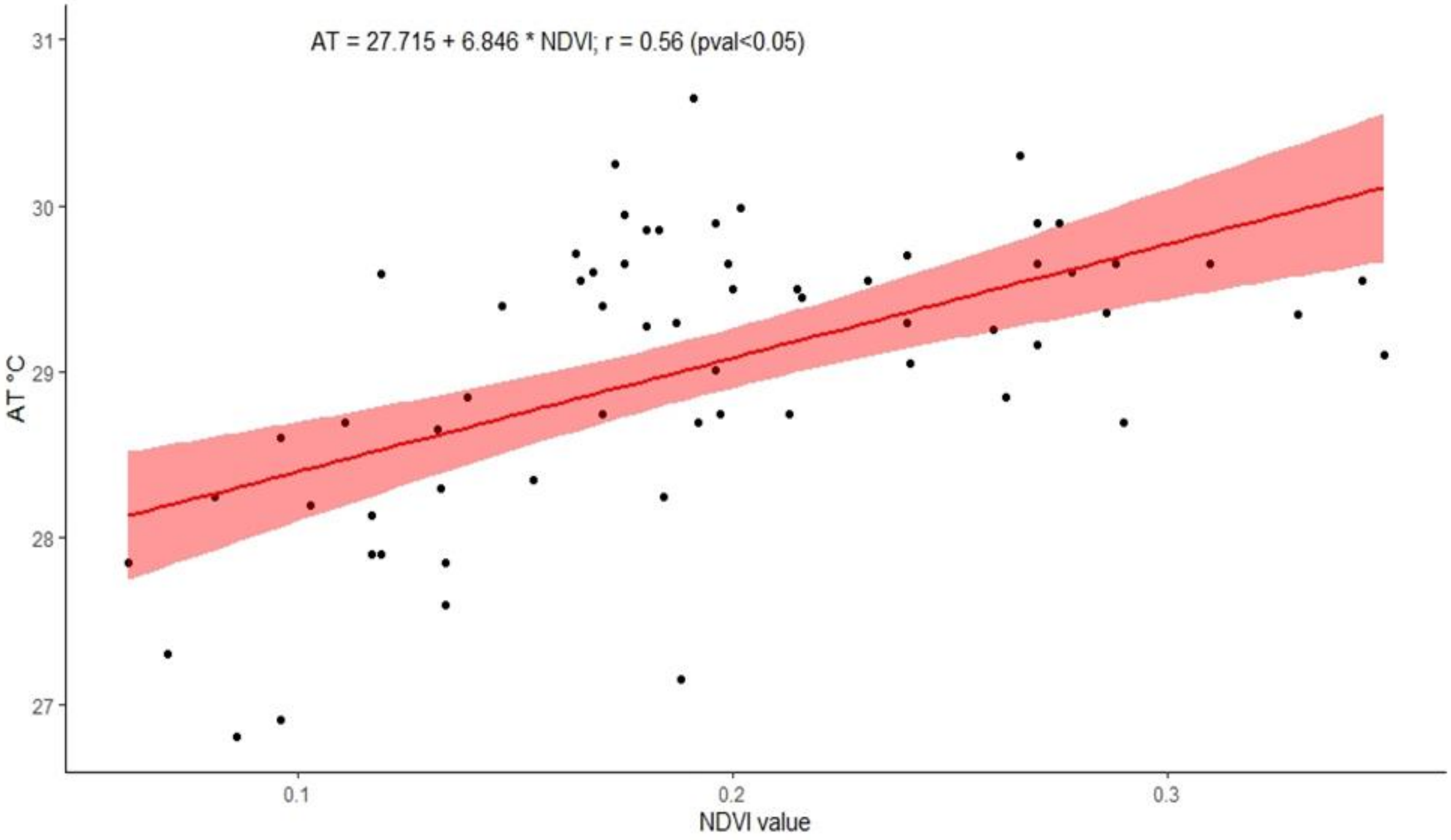

Figure 4.12: Scatter Plot Linear Regression of Mean AT and NDVI for the Period of January to March in Porto-Novo

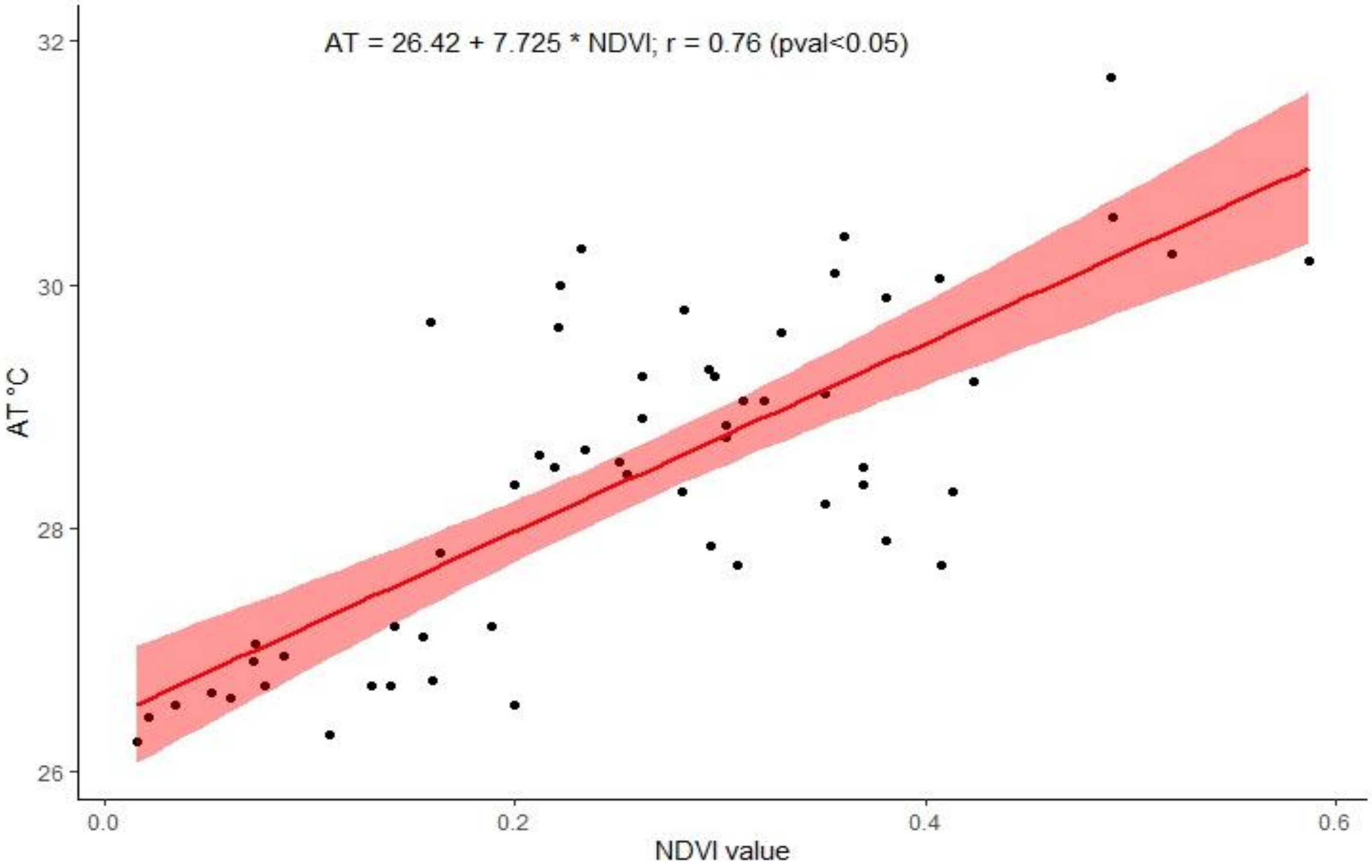

Figure 4.13: Scatter Plot Linear Regression of Mean AT and NDVI for the Period of April to June in Parakou

4.1.4 Stakeholder's perception in urban green spaces development in the cities

4.1.4.1 *Characteristics of sampled respondents in the cities*

The questionnaires were spread equally between the cities of Parakou (N = 400; 50 per cent) and Porto-Novo (N = 400; 50 per cent). About 67.0 per cent of males were surveyed over the two cities with 61.0 per cent in Parakou and 73.0 per cent in Porto-Novo (Table 4.15). The class of age (25 to 44 years) covered more than 50 per cent of the surveyed population for the two cities (Table 4.14). Christian religion was most practiced in these cities (Parakou is 54 per cent and Porto-Novo is 72 per cent). People with married status dominated in Parakou (69 per cent) when single status (57.7 per cent) invaded the city of Porto-Novo. It can be understood that monogamous couples have dominated the surveyed householder in Parakou (79.7 per cent) as well as in Porto-Novo (87.7 per cent). It was noted that most of the surveyed people in Parakou have the level of senior high secondary school (33.3 per cent) while the level of tertiary (43.5 per cent) has been dominated in Porto-Novo.

The monthly income of most people in Porto-Novo was less than 71.63 USD (63.2 per cent) while the amount between 71.63 USD and 143.25 USD characterized the surveyed people in Parakou (44.0 per cent). Additionally, it was recognized that people were renting more in Parakou (55.7 per cent) than in Porto-Novo (35.2 per cent). Finally, the two cities experienced a high rate of people (Table 4.15) with a stay duration of more than 10 years (67.0 per cent in Parakou and 63.2 per cent in Porto-Novo).

Table 4.15: Profile of the Surveyed Residents

Variables	City of Parakou (N=400)	City of Porto-Novo (N=400)	Both Cities (N=800)
Gender			
Male	244 (61.0 %)	292 (73.0 %)	536 (67.0 %)
Female	156 (39.0 %)	108 (27.0 %)	264 (33.0 %)
Age			
15 to 24	88 (22.0 %)	93 (23.3 %)	181 (22.5 %)
25 to 44	260 (65.0 %)	219 (54.7 %)	479 (59.7 %)
45 to 64	45 (11.3 %)	83 (20.7 %)	128 (16.0 %)
≥ 65	7 (1.7 %)	5 (1.3 %)	12 (1.8 %)
Religion			
Christianism	216 (54.0 %)	288 (72.0 %)	504 (63 %)
Islam	139 (34.7 %)	75 (18.7 %)	214 (26.7 %)
Traditional	45 (11.3 %)	37 (9.3 %)	82 (10.3 %)
Matrimonial			
Single	114 (28.5 %)	191 (57.7 %)	305 (38.1 %)
Married	276 (69.0 %)	182 (45.5 %)	458 (57.2 %)
Divorced	10 (2.5 %)	9 (2.3 %)	19 (2.4 %)
Widower	0 (0.0 %)	18 (4.5 %)	18 (2.3 %)
Polygamy			
Yes	81 (20.3 %)	49 (12.3 %)	130 (16.3 %)
No	319 (79.7 %)	351 (87.7 %)	670 (83.7 %)
Education			
Tertiary	107 (26.7 %)	174 (43.5 %)	281 (35.1 %)
Sr High School	133 (33.3 %)	86 (21.5 %)	219 (27.4 %)
Jr High School	80 (20.0 %)	53 (13.2 %)	133 (16.6 %)
Primary School	34 (8.5 %)	61 (15.2 %)	95 (11.9 %)
Literacy	4 (1.0 %)	5 (1.3 %)	9 (1.1 %)
None	42 (10.5 %)	21 (5.3 %)	63 (7.9 %)
Residence			
Owner	107 (26.8 %)	124 (31.0 %)	231 (28.9 %)
Tenant	223 (55.7 %)	141 (35.2 %)	364 (45.5 %)
Free Accommodated	70 (17.5 %)	135 (33. 8 %)	205 (25.6 %)
Living Duration in Cities (Year)			
< 5	16 (4.0 %)	25 (6.3 %)	41 (5.1 %)
5 to 10	116 (29.0 %)	122 (30.5 %)	238 (29.8 %)
> 10	268 (67.0 %)	253 (63.2 %)	521 (65.1 %)

Jr High School = Junior High School, Sr High School = Senior High School

Source: Author' data analysis (2022)

Table 4.16: Profile of the surveyed residents, 'Continuation'

Variables	City of Parakou (N=400)	City of Porto-Novo (N=400)	Both Cities (N=800)
Main activity			
Agriculture	18 (4.5 %)	17 (4.3 %)	35 (4.4 %)
Own Business	72 (18.0 %)	100 (25.0 %)	172 (21.5 %)
State Job	2 (0.5 %)	82 (20.5 %)	84 (10.5 %)
Private Job	41 (10.3 %)	63 (15.7 %)	104 (13.0 %)
Trade	48 (12.0 %)	116 (29.0 %)	164 (20.5 %)
Student	219 (54.7 %)	4 (1.0 %)	223 (27.8 %)
Pension	0 (0.0 %)	18 (4.5 %)	18 (2.3 %)
Monthly Income (USD)			
< 71.63	102 (25.5 %)	253 (63.2 %)	355 (44.4 %)
71.63 to 143.25	176 (44.0 %)	99 (24.8 %)	275 (34.4 %)
>143.25	122 (30.5 %)	48 (12.0 %)	170 (21.2 %)

Source: Author' data analysis (2022)

4.1.4.2 *Resident's perception towards the location of availability, state of density and diversity of the existing urban greenery between and within the cities*

In the understanding of the perceived location of more greenery entities in each study city, there was a positive perception on the core of the town (85.0 per cent and 77.2 per cent, respectively for the city of Parakou and Porto-Novo) (Table 4.16 and Figure 4.14). A significant dependence was found between this perception and the study cities (Khi-square = 86.67; p-value = 0.000). This dependence should be due to the perceived service areas mostly in Porto-Novo (21.8 per cent vs 4.0 per cent) and extension areas mostly in Parakou (6.5 per cent vs 0.0 per cent). However, there was no significant dependence with city boroughs for this variable in each city (Khi-square = 12.24; p-value = 0.14 and Khi-square = 19.8; p-value = 0.07 respectively for Parakou and Porto-Novo).

Regarding to the perception of the state of the density, diversity, and attraction of urban greenery, residents in any study cities perceived mostly that the urban greenery has an adequate state (Table 4.16). However, a significant dependence was found in relation to the city boroughs within each city (p-value = 0.000). Thus, the perception was mostly inadequate in the 1st city Borough while in the 2nd and 3rd city Boroughs the perception was that the density (Figure 4.15 A) and the diversity (Figure 4.16 A) of the greenery were mostly in an adequate state in Parakou. For urban greenery attraction, the perception was both good and acceptable in the city boroughs (Figure 4.17A) in Parakou.

In Porto-Novo, there was mostly perceived in 1st city Borough that urban greenery density and diversity were in a poor state and its attraction was also weak (Figures 4.15 B, 4.16 B and 4.17 B). Moreover, in 5th city Borough, they perceived greenery density (Figure 4.15 B) and diversity (Figure 4.16 B) in adequate state.

Table 4.17: Proportion of Location, State of Density and Diversity of the Existing Urban Greenery Between Cities

Variables	**Qualification Level**	**Frequency of Respondent's Perception**		**z-Value**	**p-Value**
		Parakou	Porto-Novo		
Location of Urban Greenery	Commercial areas	3 (0.8 %)	3 (0.8 %)	0.00	1.000
	Core of the town	340 (85.0 %)	309 (77.2 %)	2.80	0.007
	Extension areas	26 (6.5 %)	0 (0.0 %)	5.18	0.000
	Service areas	16 (4.0 %)	87 (21.8 %)	-7.49	0.000
	Suburb areas	15 (3.7 %)	1 (0.2 %)	3.54	0.000
Density of Urban Greenery	Excellent	0 (0.0 %)	20 (5.0 %)	-4.53	0.000
	Adequate	195 (48.7 %)	172 (43.0 %)	1.63	0.118
	Inadequate	155 (38.7 %)	155 (38.7 %)	0.00	1.00
	Very poor	50 (12.5 %)	53 (13.3 %)	-0.32	0.833
Diversity of Urban Greenery	Excellent	0 (0.0 %)	27 (6.7 %)	-5.29	0.000
	Adequate	190 (47.5 %)	217 (54.3 %)	-1.91	0.066
	Inadequate	147 (32.7 %)	120 (30.0 %)	2.02	0.051
	Very poor	63 (15.8 %)	36 (9.0 %)	2.90	0.005
Attraction of Urban Greenery	Excellent	0 (0.0 %)	31 (7.7 %)	-5.68	0.000
	Good	100 (25.0 %)	196 (49.0 %)	-7.03	0.000
	Acceptable	222 (55.5 %)	128 (32.0 %)	6.70	0.000
	Weak	78 (19.5 %)	45 (11.3 %)	3.23	0.002

Source: Author' data analysis (2022)

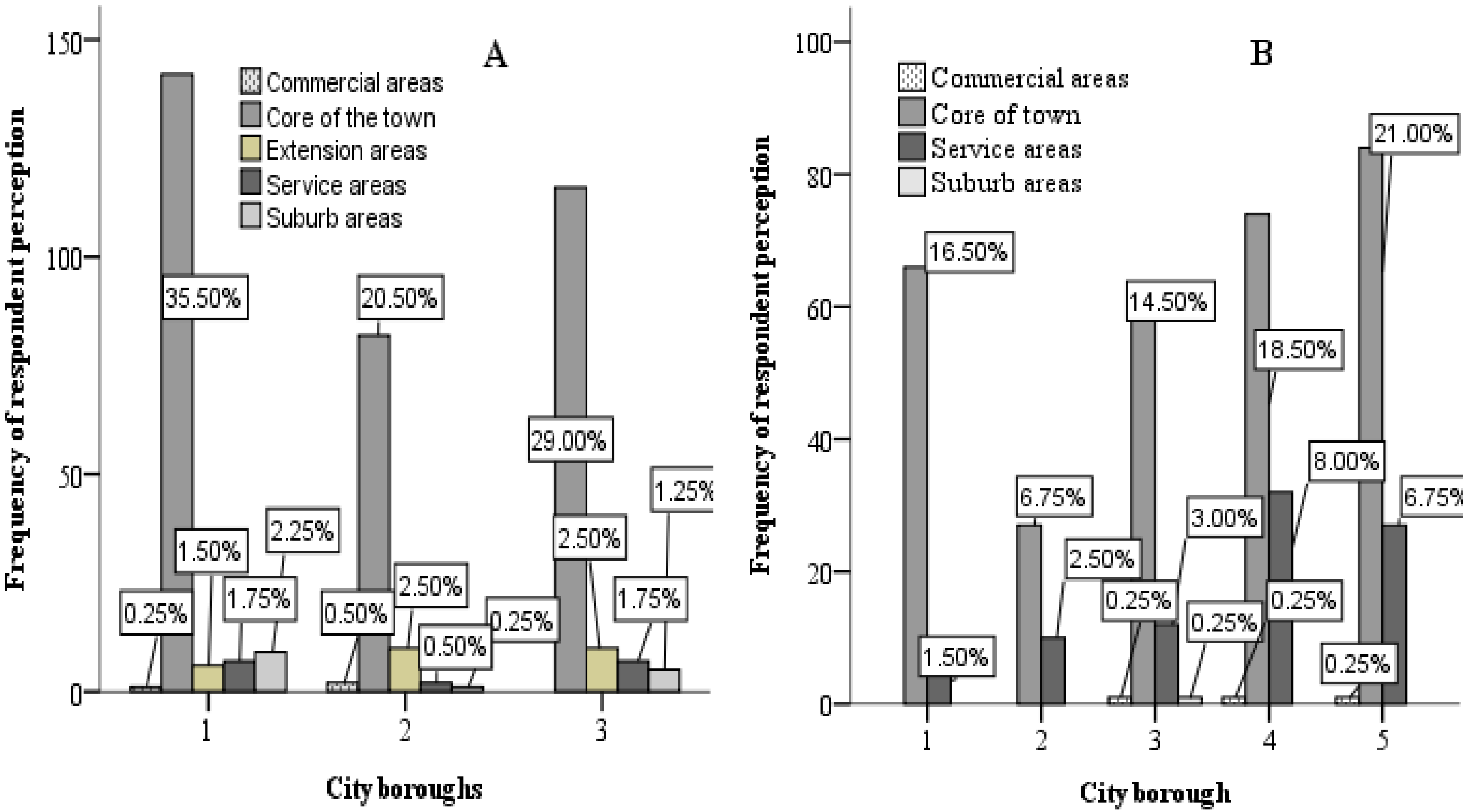

Figure 4.14: Urban Greenery Location; A: Parakou, B: Porto-Novo

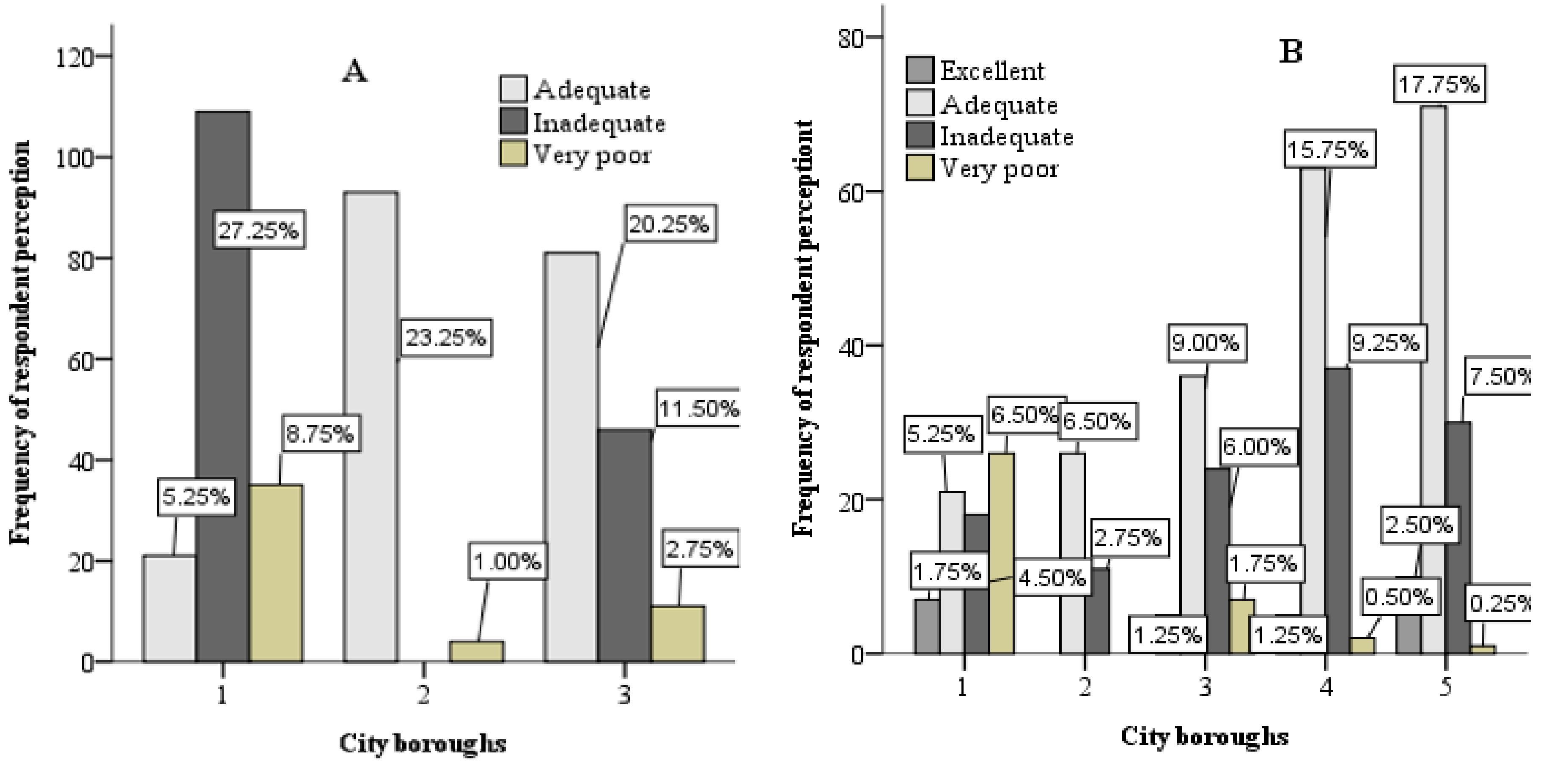

Figure 4.15: Urban Greenery Density State; A: Parakou, B: Porto-Novo

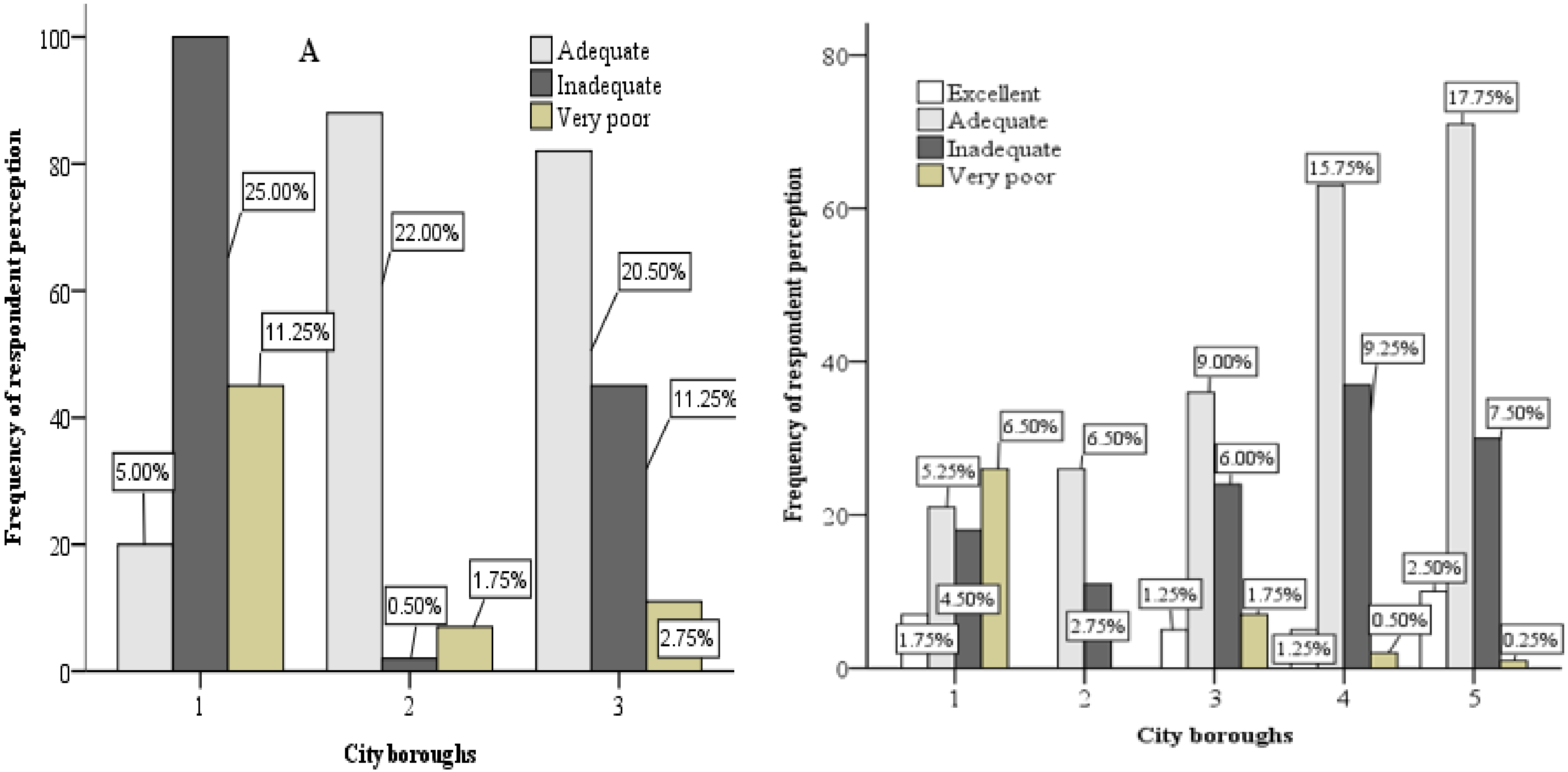

Figure 4.16: Urban Greenery Diversity State; A: Parakou, B: Porto-Novo

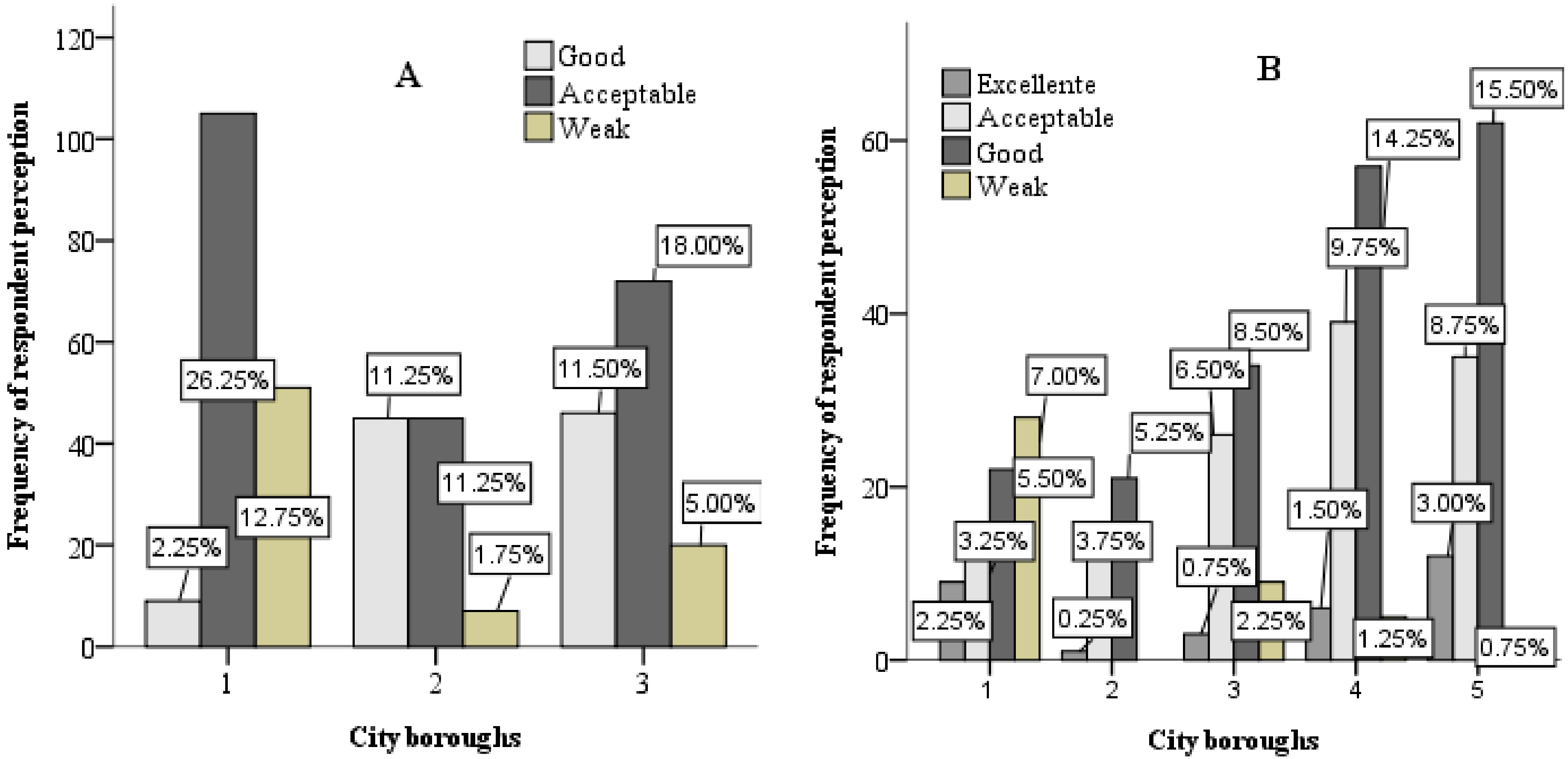

Figure 4.17: Urban Greenery Attractivity State; A: Parakou, B: Porto-Novo

4.1.4.3 *Perception on the main benefits lost and the causes of these losses from urban green spaces in the cities*

The loss of the benefits as air quality and cooling effect was respectively mostly perceived in Parakou and Porto-Novo. The benefits of sound control and biodiversity conservation were not perceived in Parakou. Likewise, the benefits of flooding control and sound control were carelessly perceived in Porto-Novo (Table 4.17, Appendix C). Furthermore, the test Khi-square showed a significant dependence of these losses of benefits between the cities (Khi-square = 348.11; p-value = 0.000) and also between the city borough in Porto-Novo (Khi-square = 13.67; p-value = 0.03 and in Port-Novo (Khi-square = 41.79; p-value = 0.003). In Parakou, the lost air quality benefit was perceived similarly in the city boroughs (Figure 4.18). However, the loss of cooling effect benefit was mostly perceived in the 4^{th} and 5^{th} city boroughs of Porto-Novo (Figure 4.19).

The causes of the losses of greenery benefits were therefore differently perceived in the cities and in the city boroughs of each city. Pearson Khi-square test revealed very high significant dependence between cities (Khi-square = 214.88; p-value = 0.000); between city boroughs of Parakou (Khi-square = 35.12; p-value = 0.000) and somehow inside of Porto-Novo (Khi-square = 30.19; p-value = 0.017). The most cause perceived in both cities was the weakness of urban greenery density (Table 4.18, Appendix D). However, the weakness of greenery diversity was mostly mentioned in Parakou. In Porto-Novo, the lack of greenery management and planning strategies and the weakness of the size of urban greenery space constituted also the important perceived causes of the loss of greenery benefits (Table 4.18).

It could also realize in figure 4.18 that there was a relationship between the loss of air quality and cooling effect benefits and the weakness of greenery density, the lack of greenery management, the weakness of the size of greenery spaces and 2^{nd} city Borough

(Parakou). The loss of beauty or aesthetic and flooding control benefits was associated to the weakness of greenery space diversity and the 1st city Borough (Parakou).

5th city Borough in Porto-Novo could be mostly associated to the weakness of the size of urban greenery spaces and no greenery planning strategy (Figure 4.19). The loss of cooling effect benefit can in turn be mostly give to the greenery density weakness in 4th city Borough of Porto-Novo. Moreover, the loss of beauty or aesthetics, biodiversity sinks and air quality benefits can be in relation to 1st, 2nd and 3rd city Boroughs and greenery management strategies lack and the weakness of greenery spaces diversity (Figure 4.19).

Table 4.18: Resident's Perception on the Loss's Benefits Supplied by Urban Greenery

City	Important Benefits Lost in the Cities					
	Air Quality	Sound Control	Beauty/ Aesthetic	Cooling Effect	Flooding Control	Sink of Biodiversity
Parakou	181 (45.3 %)	0 (0.0 %)	80 (20.0 %)	79 (19.7 %)	60 (15.0 %)	0 (0.0 %)
Porto-Novo	16 (4.0 %)	6 (1.5 %)	62 (15.5 %)	296 (74.0 %)	1 (0.3 %)	19 (4.7 %)
z-Value	13.54	-2.46	1.67	-15.37	7.86	-4.41
p-Value	0.000	0.031	0.115	0.000	0.000	0.000

Source: Author's data analysis (2022)

Table 4.19: Resident's Perception on the Causes the Loss of Given Benefits Supplied by Urban Greenery

City	Causes of Loss of Benefits by Urban Greenery				
	Lack of Greenery Management	No Greenery Planning	Weak Greenery Density	Weak Greenery Space Diversity	Weak Size of Greenery Space
Parakou	15 (3.7 %)	36 (9.0 %)	133 (33.3 %)	206 (51.5 %)	10 (2.5 %)
Porto-Novo	92 (23.0 %)	56 (14.0 %)	180 (45.0 %)	31 (7.7 %)	41 (10.3 %)
z-Value	-8.00	-2.22	-3.40	13.55	-4.49
p-Value	0.000	0.035	0.001	0.000	0.000

Source: Author's data analysis (2022)

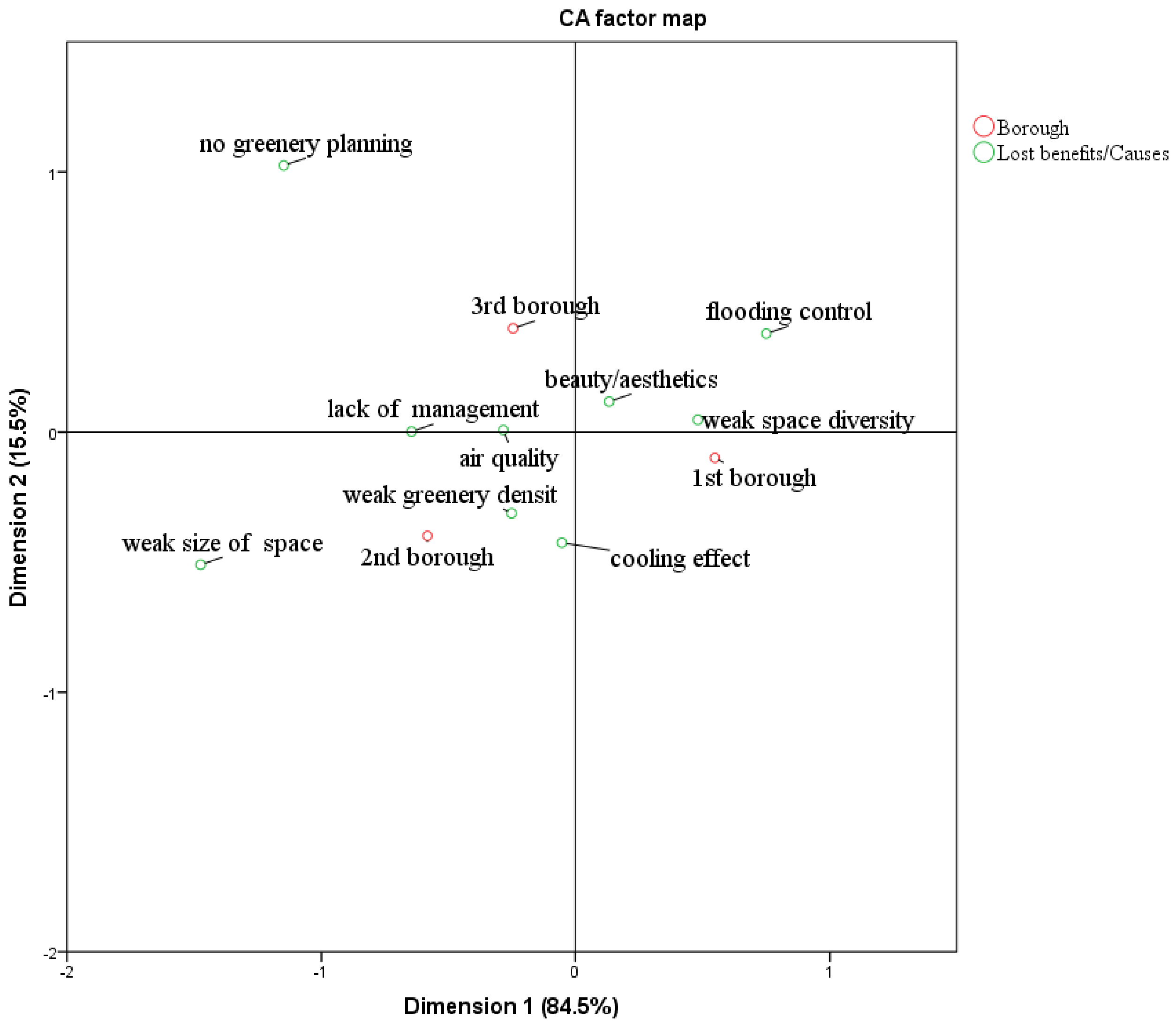

Figure 4.18: Positioning of Greenery Lost Benefits, Causes of Losses and Boroughs of Parakou

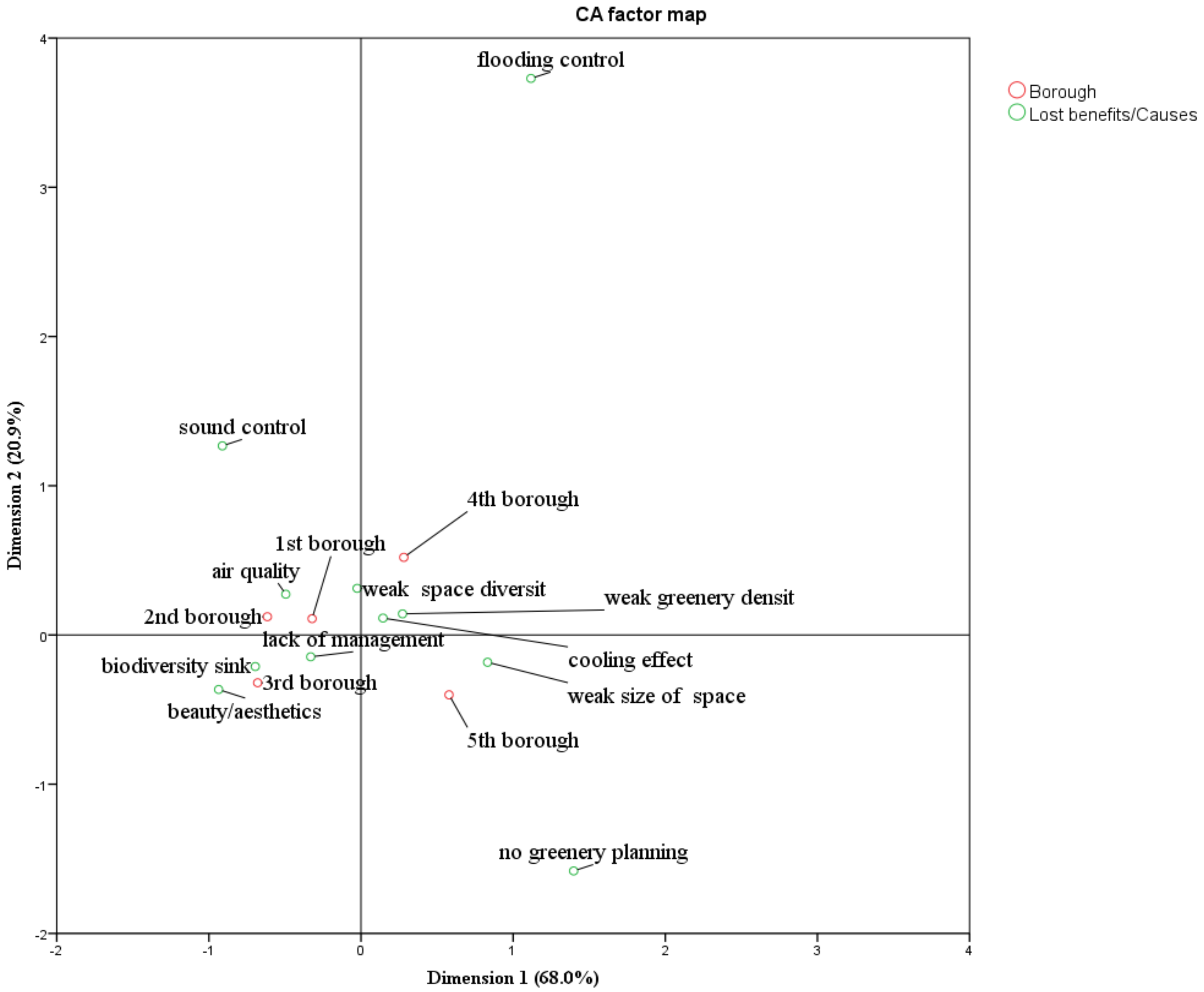

Figure 4.19: Positioning of Greenery Lost Benefits, Causes of Losses and Boroughs of Porto-Novo

4.1.4.4 *Resident's participation for urban greenery development in the cities*

Globally, the degree of public involvement in urban greenery development was significantly dependent on the cities (Khi-square = 12.74; p-value = 0.002). At least 93.0 per cent residents in Parakou and 86.5 per cent in Porto-Novo could perceive the low level of public involvement. No significance was found for city boroughs in the cities (Parakou: Khi-square = 0.88; p-value = 0.644; Porto-Novo: Khi-square = 2.25; p-value = 0.688).

Only institutional cooperation can positively determine local community willingness to involve in greenery development in both Parakou and Porto-Novo (Table 4.19). Otherwise, the residents of Parakou and Porto-Novo can increase their willingness to participate in urban greenery development when the institutions in charge of urban management or planning work more with them. Beside the institutional cooperation, the level of education is the factor that can lead residents in Parakou to perform their willingness to get involved in urban greenery development. Thus, most people attain Senior high school, better they manifest feeling to be involved in urban green space development.

However, the Stay Duration, House Greenery and Knowledge on general impact of urban greenery can also significantly determine community involvement in Porto-Novo (Table 4.19). Furthermore, new residents (< five years of stay) in the city of Porto-Novo can mostly manifest their willingness to urban greenery improvement. The previous house greening is a factor that can actively excite people to contribute to greenery development in Porto-Novo. Finally, having some insights on the benefits supplied by greenery in urban area was known to strengthen people's motivation for the development of urban greenery in Porto-Novo.

Table 4.20: Results of Binary Logistic Regression (Entry Method) Model Showing Factors Affecting Local Community's Involvement in Urban Greenery Development

Variables	Variable Modality	Parakou City				Porto-Novo City			
		B	S.E.	Sig.	Exp(B)	B	S.E.	Sig.	Exp(B)
City Boroughs	1st Borough			.479				.941	
	2nd Borough	.383	.323	.235	1.467	.153	.525	.771	1.165
	3rd Borough	.113	.273	.679	1.120	-.062	.434	.887	.940
	4th Borough					.248	.410	.545	1.281
	5th Borough					.091	.417	.827	1.096
Sex		-.199	.245	.416	.820	-.252	.308	.414	.777
Age		.014	.022	.521	1.014	.016	.024	.498	1.017
Religion	Christianism			.981				.747	
	Islam	-.042	.284	.882	.959	.280	.372	.452	1.324
	Traditional	-.061	.375	.871	.941	.140	.497	.778	1.150
Marital Status	Divorced			.666				.539	
	Married	-.066	.710	.926	.936	1.243	1.000	.214	3.466
	Single	-.471	.817	.565	.625	1.404	1.052	.182	4.072
	Widower					.705	1.174	.549	2.023
Polygamy		-.009	.372	.980	.991	-.094	.475	.843	.910
Educ. Level	Jr High School			.140				.999	
	Literacy	-.253	1.073	.814	.777	.235	1.138	.836	1.265
	None	-.557	.450	.216	.573	-.023	.679	.973	.977
	Primary School	-.624	.445	.160	.536	-.160	.482	.740	.852
	Sr High School	-.860	.323	**.008**	.423	.011	.499	.982	1.011
	Tertiary	-.369	.405	.362	.691	-.010	.551	.986	.991
Residence	Free Accom.			.857				.754	
	Owner	-.055	.433	.899	.946	.392	.533	.462	1.480
	Rental	.126	.338	.709	1.134	.065	.346	.851	1.067

For city of Parakou: -2 Log likelihood function = 519.099; X2 = 34.418; df. = 14; Constant = -0.307; Cox and Snell R square = 0.082; Nagelkerke R square = 0.110
For city of Porto-Novo: -2 Log likelihood function = 413.847; X2 = 127.640; df. = 14; Constant = -5.719; Cox and Snell R square = 0.273; Nagelkerke R square = 0.368.
Educ. Level = Educational Level; Jr High School = Junior High School; Sr High School = Senior high school and Free Accom. = Free Accommodation

Source: Author's data analysis (2022)

Table 4.21: Results of Binary Logistic Regression (Entry Method) Model Showing Factors Affecting Local Community's Involvement in Urban Greenery Development, 'Continuation'

Variables	**Variable Modality**	**Parakou City**				**Porto-Novo City**			
		B	S.E.	Sig.	Exp(B)	B	S.E.	Sig.	Exp(B)
Monthly Income (USD)	< 71.63			.622				.505	
	>143.25	-.453	.511	.376	.636	-.593	.899	.510	.553
	71.63 to 143.25	-.162	.337	.631	.850	.272	.382	.477	1.312
Main Activity	Agriculture			.635				.613	
	Own business	-.026	.403	.948	.974	-.013	.985	.989	.987
	Pension	-.352	.864	.684	.703	-1.02	1.445	.479	.359
	Private job	-.170	.464	.714	.844	-.116	1.007	.908	.890
	Public job	-.337	.559	.547	.714	.263	1.123	.815	1.301
	Student	.685	.640	.285	1.983	.891	1.081	.410	2.438
	Trade	-.553	.436	.205	.575	.180	.925	.846	1.197
Stay Duration	<5 years			.947				**.004**	
	>10 years	.058	.594	.923	1.059	-.842	.546	.123	.431
	5 to 10 years	.094	.286	.743	1.098	.149	.544	.784	1.161
House Greenery		.304	.225	.175	1.356	1.050	.273	**.000**	2.859
Inst. Collab		.989	.231	**.000**	2.689	2.303	.287	**.000**	10.007
Knowledge of Impact		-.063	.260	.808	.939	2.461	.812	**.002**	11.722

For city of Parakou: -2 Log likelihood function = 519.099; X2 = 34.418; df. = 14; Constant = -0.307; Cox and Snell R square = 0.082; Nagelkerke R square = 0.110
For city of Porto-Novo: -2 Log likelihood function = 413.847; X2 = 127.640; df. = 14; Constant = -5.719; Cox and Snell R square = 0.273; Nagelkerke R square = 0.368. Inst. Collab = Institutional Collaboration

Source: Author's data analysis (2022)

4.2 Discussion of Results

4.2.1 Land use and land cover dynamic of the cities

Eight land use and cover classes were found, where the built-up areas were considered as the urbanized areas while forests, plantations, marshy lands, crop lands, city bushes, water bodies can be considered as urban green spaces. Similar conclusion was made by Osseni *et al.* (2023) on the municipality of Sèmè-Podji in southern Benin (West Africa).

The findings revealed a tremendous change in terrain, with built-up areas exerting tremendous stress on non-built-up areas. The findings revealed the dramatic land cover change and the built-up areas exerted incredible pressure on natural areas. This was consistent with the findings of Gashu and Egziabher (2018), who assessed the spatiotemporal tendency of urban land use, land cover, and greenery changes in the Ethiopian cities of Bahir Dar and Hawassa (East Africa). The current case study revealed how great the effect of urbanisation could impact the urban green space consistency in Porto-Novo and Parakou, making accent of climate variation.

The crop lands and marshy lands were in total regression from 2000 to 2020 in Porto-Novo. In Parakou, the covers of crop land, city bush, forest and urban plantation depleted during the 20 years. These findings indicated that, due to urbanisation and population increase, the destruction of green space in the studied cities should not be overlooked (Mandal *et al*., 2019). The known difference in land cover proportion (built-up areas and other classes) between cities could be due to the fact that Porto-Novo is an old and concentred city contrary to Parakou which is a recent and much interesting in terms of the decentralisation in the country.

The speed of urban green space loss was great in Parakou than Porto-Novo. The results showed also that the rates of conversion were weak in the city of Porto-Novo than in

Parakou. This finding could be justified by the fact of the saturation of Porto-Novo because of its urban oldness comparing to Parakou which is a recent and much interesting city in terms of the decentralisation in the Republic of Benin (Ministry of Decentralization, Local Governance, Administration and Territorial Planning (MDGLAAT), 2016; PAG, 2016). Likewise, the important conversion rates were found for the period of 2010 to 2020. Therefore, the exponential growth of urban population from 2013 to 2018 (Figure 3.5) in Porto-Novo and Parakou can support this increasing rate of land conversion (Ministry of Living Environment and Sustainable Development (MCVDD), 2019; Twumasi *et al.*, 2020). These findings implied that policy of urban growth and green spaces conservation planning need to account any urban area to mitigate the environmental degradation in the Republic of Benin.

4.2.2 Pattern and distribution of urban green spaces in the cities

The green areas in these cities could be summarized into forest (sacred forest and gallery forest), marshy land, tree plantation, crop land, city bush, water body, green cemetery, urban garden and city trees. The similar category of urban green spaces (Water bodies, trees, and agriculture land) were found in Thailand (Thaiutsa *et al*., 2008), (Wetlands, crop lands, gardens and cemeteries) in Democratic Republic of the Congo (Sikuzani *et al*., 2018) and (Crop and cultivated areas, gardens and parks) in Italy (Pristeri *et al*., 2021). However, the specific categories of urban greenery spaces found in the study included urban plantations and city bushes could be due to the field particularity. Therefore, the fruit trees (example: Cashew and mangoes) and wood plantations were established in Parakou and can provide some ecosystem services to the urban areas. In Porto-Novo, wood plantations as well as palm plantations occurred urban areas with many ecosystem benefits. According to the city bushes, there were common in the study cities and can disappear anytime because of its unsustainable nature (Twumasi *et al.*, 2020).

The proportions of green spaces were 20.38 per cent in Parakou while 32.33 per cent were occurred in Porto-Novo. These proportions could be compared to Kuang and Dou (2020) findings, which revealed an average of 28.43 per cent of the greenery cover in China's 70 largest cities in 2018. Moreover, the difference of the coverage percentage between the cities should be attributed to the absence of water body category in Parakou and the area of marshy lands in Porto-Novo.

ANOVA test showed no significant difference between cities for the configuration parameters (green area perimeter, size area, shape index and edge density) of green areas. This finding can be supported by the fact that, the target cities were experiencing the similar rhythm of urbanisation despite the difference of climate location (Liu *et al*., 2022). Therefore, according to Hassan *et al*. (2016), urban changes are generally associated with population growth and economical and social development. Indeed, the similar population growth was recorded for both cities (Porto-Novo: 264,320 inhabitants and Parakou: 255,478 inhabitants) (INSAE, 2016). Likewise, the urban areas of the cities are similar and they were occurring the similar economic as well as social development level in the country (PAG, 2016; Plan de Developpement Urbain (PDU), 2020). This implies that the same strategies or actions for green space development, improvement or conservation basing on these configuration parameters may be adopted to each of the cities.

Furthermore, as indicated in table 4.10, a substantial variation (p-value 0.000) was discovered across green space categories throughout each city. Comparable conclusions were found in several previous studies such as Fu *et al*. (2022) where the authors reviewed the optimized urban vegetation area configuration in relation to heat reduction. In this study, water bodies showed the greatest perimeter followed by forests and marshy lands while no significant difference was recorded between city bush, urban plantation, crop land, urban garden, trees and cemetery (Table 4.11). The results can be supported by the fact that forests, marshy lands and water bodies undergo a low fragmentation risks due to the difficulty to build up or to settle in water bodies and marshy lands in the study cities. Regarding to the forests, the majority of them are sacred forests and gallery forests where settlement access is mostly least because of the traditional interdictions (sacred forest) and flooding risks (gallery forest). Moreover, it was suggested that the specific strategies or actions are needed for the development or conservation of each of green space configuration categories. In addition, further studies are important on the current cities to highlight the relationship between green space configuration and climate effects mitigation and adaptation. For this concern, Fu *et al*. (2022) showed that studies were scarce on urban areas in southern hemisphere especially in developing countries where great population growth are experiencing.

The geographical pattern of green spaces in urban areas was found to have an aggregative dispersal throughout both Porto-Novo and Parakou. The similar findings were found by Alam *et al.* (2014) who stated that urban green spaces included urban parks and play grounds were unequal distributed in the Gulberg town (Pakistan). According to Liang *et al*. (2017), the spatial distribution of urban green space is affected by distinct areas of development in the metropolis. (Fangnon, 2021) previously demonstrated an uneven distribution of urban green areas in the municipality of Sèmè-Podji (Republic of Benin), with variable density in city boroughs because of historically significant, socioeconomic, political, recreational, and aesthetic roles. Consequently, the study's findings may be justified by the uneven urbanisation in each studied city. Thus, the city boroughs of Porto-

Novo and Parakou have varying levels of urbanisation and histories (PDU, 2020). Moreover, these findings could imply the useful insights on the distribution of urban ecosystem service supply in the cities (Dobbs *et al*., 2017). Furthermore, the results could support urban decision making and planning for the inclusive green space benefits to the residents.

4.2.3 Evaluation of seasonal variation in vegetation and its correlation with air temperature in the cities

The seasonal dynamics of urban greenery are crucial for monitoring the urban environment. The authors have attempted to understand the quarterly variability of NDVI using Landsat data to get more accurate information about the urban vegetation effects on the reduction of urban land air temperature in Porto-Novo and Parakou. Along this, NDVI varied from year to year in cities. A similar trend was globally observed with a decreasing trend from 2000 to 2011 and an increasing trend from 2011 to 2020. This finding can be explained by the national commitments to vegetate cities with the governmental project "10 million people – 10 million trees" instituted in 2013 (MCVDD, 2019). Therefore, this governmental project would encourage good management and the preservation of the existing urban vegetation in these cities. As well, the main goal of the project was to ensure that each inhabitant plants at least one tree per year with careful monitoring. Moreover, the particular changes among cities could be the response to the vegetation density and the plant species diversity changes in these cities (Kinyanjui, 2011, Zohoun *et al*., 2020, Sehoun *et al*., 2021).

The land air temperature (AT) followed similar trend for the combined cities as well as for the cities the individual cities. This result can be attributed to the changes in vegetation index. The AT was globally in decreasing (Figure 4.8) with increasing NDVI (Figure

4.9). Similar findings were reported by Zhao *et al*. (2019) on factors affecting the decreased temperature. Likewise, a recent study in the Horn of Africa has also discovered a negative relationship between air temperature and vegetation cover (Ghebrezgabher *et al*., 2020). However, although there are continuous efforts to improve greenery in Beninese cities, a considerable increase in AT is experienced in the city of Porto-Novo. This finding could be due to the weakness in the management and monitoring of planted trees (MCVDD, 2019). It can be likely due to the density of built- up area (lack of areas for trees plantation), and the introduction of new plant species without consent of local (Osseni *et al*., 2014). The NDVI pattern in this city has since deteriorated as a result presented in figure 4.9.

A significant difference was shown between seasonal variations of vegetation index (NDVI). This finding can be justified by season-wise vegetation statuses in the cities. Therefore, not only urban vegetation state varied according to space but also it varied by climatic period (Malik *et al*., 2020). For combined cities just like the individual studied cities, the period of January to March had a significantly low mean NDVI value. This result is in line with the study Piao *et al*., (2019), who found a low NDVI value for the period of June to July on the city of Nanjing (China). The authors further explained that this difference could be due to the interference of clouds and rain. Another study conducted in India indicated that from January to April, the vegetation showed very low NDVI because during this period very few leaves were available to reflect NDVI signature (Malik *et al*., 2020). The dry season in the south and central parts of Benin spans from January to March and sometimes April to June, during which overall vegetation features are under water stress (Ahokpossi, 2018, Oussou *et al*., 2022). Moreover, a link could be also made between the vegetation index and the vegetation phenology (Su et *al*., 2020). Furthermore, it has also been demonstrated that the seasonal variability is more important to describe the variation in phenological expression of urban vegetation (Li *et al*., 2017, Piao *et al*., 2019). The study of Su *et al*. (2020) went further to establish a relationship between season period and canopy phenology which is an essential determinant of vegetation index importance. Along this, what should be the impacts of both seasonal and NDVI variability on land air temperature in the study areas?

Yearly AT average builds a moderate negative correlation with NDVI in the combined cities as well as in separate cities. Similarly, numerous researchers have demonstrated an inverse relationship between AT and NDVI for different land use types and polygons (Yue *et al*., 2007, Richards *et al*., 2020). Although the cooling benefits of greening urban areas are widely known, the physiology of vegetation due to environmental conditions can impact the benefits (Norton *et al*., 2015). In assessing seasonal variation's relationship between AT and NDVI, a moderately positive correlation was revealed for January to March in Porto-Novo (Figure 4.12) and April to June in Parakou (Figure 4.13). This finding implies that the increase in urban vegetation in these cities during these months could not decrease the AT. This could be due to the fact that the dry season occurs in these months. During this period of dry season, the vegetation that could be experiencing water stress situation which can limit the rate of evapotranspiration and thereby resulting in the occurrence of higher surface temperature (Norton *et al*., 2015; Wollschläger *et al*., 2022). This was confirmed by the studies of Ahokpossi (2018) and Lanmandjèkpogni *et al.* (2018) which reported that Porto-Novo and Parakou usually experience strong dry periods with high water stress from January to March, and April to June correspondingly. Therefore, to ensure a sustainable reduction in urban air temperature, and ecosystem service provision, practising urban greening irrigation should be adopted (Norton *et al*., 2015).

4.2.4 Stakeholder's perception in urban green spaces development in the cities

The findings of this study gave evidence of the perceived location, state of density, and diversity of urban greenery in Parakou and Porto-Novo. It provides insights into the potential relationship between the core of the city and urban greenery entities. In fact, major public offices and people with high-income usually live the core of the city where greenery entities have chances to be more maintained. This statement echoes the conclusion that the centre of urban areas provides the financial resources and maximum skills required to improve urban greenery (Gwedla and Shackleton, 2015; Richards *et al.*, 2017; Venter *et al.*, 2020; Cobbinah *et al.*, 2021). Likewise, the location of urban greenery significantly depended on cities. This dependence could be explained by the fact that the city of Parakou is under construction (Lanmandjèkpogni *et al.*, 2019) while the city of Porto-Novo is under renovation (Tohozin *et al.*, 2014; Boko-haya *et al.*, 2018; Auclair and Garcia, 2019). In addition, no significant dependence on greenery location and city boroughs was found in this study. This can be justified by the fact that the centre of the city stretches through all the city boroughs.

The density, diversity, and attraction of urban greenery depend on cities and city boroughs. The cities are located in different climatic and Phyto district zones that have influence on species diversity and vegetation development in Benin Republic (Adomou, 2005). Thus, the dependence on urban greenery can be due to the geographical location of the cities (Dobbs *et al.*, 2018). In addition, Parakou and Porto-Novo experience different urban management behaviour as to what cities have peculiar status in the country (MDGLAAT, 2016). The observed dependence in resident perception for urban greenery state can be supported by the relative shifts in the existing urban greenery, urban planning, and city's governance paradigm as concluded by Bokhari *et al.* (2018). Also, in Pakistan, a study stated that a significant proportion of residents perceived smoothly the observed changes in the existing greenery in their city (Bokhari *et al*., 2018). Within the cities, the statistical differences can be justified by the relative change in the existing urban vegetation. Therefore, the urban greenery layer in Parakou was irregularly distributed over the city borough and the effort will be needed to regularly improve street trees development in this city (Zohoun *et al*., 2021). The different perceptions of urban greenery density, diversity, and attraction between city boroughs can also be attributed to the difference in the benefits procured from these infrastructures. Indeed, the positive relationship was perceived on the health or the quality of urban green spaces and the benefits they procure (Gwedla and Shackleton, 2019; Rey Gozalo *et al*., 2019).

Moreover, the causes of benefit losses were differently perceived between cities and city's borough. Regarding to cities, the difference can be supported by the fact that the same benefits lost were not perceived. Thus, each city dwellers attributed the possible cause to the phenomenon they were experiencing. Moreover, any urban area undergo tremendous changes, and the main cause of the loss of ecosystem services is the depletion of greenery (Crespin and Simonetti, 2016). Thereby, the weakness of urban greenery density was found as the major cause of the loss of benefits in both cities. Therefore, the association of the lost benefits and the causes of these losses and the city boroughs of each city must be considered, to succeed the projects on the development of urban greenery in these cities

Other important focus in this study was the understanding of residents' attitudes towards involving in urban greenery improvement from diverse perspectives. The results have revealed that local communities' involvement in urban greenery management and development was low. This result corroborated with those of (Mensah *et al*., 2016) that stated that local communities were generally passive towards involvement in urban greenery initiative. Also, the participation of residents constitute a main driving force for successfully implementing spaces (Yu *et al*., 2019). Thus, Mabelis and Maksymiuk (2009) have stated that residents' mostly participate as volunteers and donors which can enhance the development of urban greenery. The study also showed a significant difference of residents' perception for public participation in urban greenery development between the city of Parakou and Porto-Novo. According to Yu *et al*. (2019), there was the correlation between the existing urban greeneries and the scale of people's involvement in the case of activities leading to greenery development. Thus, because of general unequal vegetation type in the cities, residents must have different perceptions. Moreover, a similar study in Bahir Dar and Hawassa (Ethiopia) has arrived at the same conclusion (Gashu *et al*., 2019). Then, the present findings can be supported by the functioning system of urban greenery planning and management that should be specific to each city (Vaňo *et al.,* 2021). In this context, binary logistic regression has been done to examine factors determining resident willingness in greenery improvement in each city.

The result showed that institutional cooperation has positive and significant influence on resident willingness to invest in urban greenery improvement of the cities. This result was similar to the conclusions that the effective improvement of institutional capacities, the collaboration between institutions and local communities have higher impacts on urban development, in general, and urban greenery in particular (Gashu *et al*., 2019; Cobbinah *et al*., 2021). Also, the institutional cooperation and collaboration was seen as an effective climate adaptation principle in South Saharan regions (Singh *et al.,* 2021). Thus, as institutional reforms are more topical in the Republic of Benin, the acquaintance with local population may be more fruitful for suitable development of these cities.

The result also showed that the level of education (senior high school) was significant for people implication in urban green space development in Parakou. This can be due to the impacts of the environmental courses and teachings developed in the secondary school and colleges. Thereby, in Parakou the campaigns of awareness for urban green space development must target people with senior high school or students in colleges or high school. In Porto-Novo, the variables such as Stay Duration (stay less than 5 years), House Greenery and Knowledge of the Impact of urban greenery were additionally significant for local population involvement (Table 4.19). The peculiarity in socioeconomical aspects in this city can justify people actions for greenery development. Porto-Novo is undergoing thorough city restructuring which should support the fact that having knowledge of general effect urban vegetation can enhance the motivation to contribute to vegetation maintenance. Also, living in a greening house means to be able to know the impact of greenery. Therefore, for improved willingness of residents to contribute to urban greenery planning and management in Porto-Novo, these aspects have also to be considered in Porto-Novo. People reside less than 5 years in Porto-Novo are more favourable to contribute to urban greening improvement. The result can find the obviousness in the interest to increase climate adaptation actions so that the stay be peaceable in the new place.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

In this study, urban land use and cover dynamics were assessed from 2000 to 2020 on the cities of Porto-Novo and Parakou in Benin (West Africa). Six land use and cover classes were found in each of both cities included forests (gallery and sacred), plantations (wood and fruit), marshy lands, crop lands (annual and perennial), city bushes, and built-up areas whereas an additional bare land class was found in Parakou and water body class in Porto-Novo. During the considered study period, a great decreasing changes were occurred in the range of forests, plantations, marshy lands, crop lands, city bushes classes when built-up areas were in increasing. The dramatic land cover change was found in these cities and the built-up areas exert incredible pressure on non-built-up areas except water body class. All the lost proportions were converted into built-up areas where the crop lands were the most threatened in the cities with evidence of about 24 per cent and 46 per cent respectively converted into built-up areas in Porto-Novo and Parakou. An average of 40 per cent of city bushes were also in threat in Parakou from 2000 to 2020. Generally, the conversion rate was weak in Porto-Novo than Parakou. This conclusion was supported by the fact that Porto-Novo is old and more saturated city than Parakou which is in structuration in terms of the decentralisation in the Republic of Benin. Therewith, the best land use practices should be promoted by city's decision makers to cope and prevent natural devastation in these cities.

The green spaces in these study cities could be summarized into forests (sacred forest and gallery forest), marshy lands, plantations, crop lands, city bushes, water bodies, green cemeteries, urban gardens and tree assemblages. No significant difference was shown on these urban green spaces' configuration between cities. However, a statistical difference

(P-value ≤ 0.000) was denoted between green space categories in each studied city's landscape. These findings revealed that the strategies or actions for green space development, improvement or conservation based on their configuration should not depend on city (even in different changing climate). On the other hand, specific strategies or actions are needed for the development, improvement or conservation of each green space configuration category. In each city, the urban green spaces showed an aggregative distribution that would be due to irregular urbanisation in the cities. This finding could reveal useful insights on the distribution of the urban expected ecosystem services supplied in the cities (Dobbs *et al*., 2017). Urban decision makers and planners should be aware and strengthened for the inclusive green space benefits to the urban residents.

This study also assessed urban greening trends and their seasonal variations' impact on AT mitigation in the Republic of Benin (West Africa). The results showed no significant linear trends for annual vegetation index (NDVI) and AT. The NDVI decreased from 2000 to 2011 and increased from 2011 to 2020 in both cities which probably due to the governmental efforts to afforest cities over the country. The period from January to March showed the lowest mean values (0.147) of NDVI. In addition, a negative relationship was generally found between annual mean AT and NDVI. However, January to March (the dry season period) in Porto-Novo (r = 0.56) and April to June (the dry season period) in Parakou (r = 0.76) revealed a positively inverse correlation. Thus, the wise management of urban greenery through irrigation practices will ensure a sustainable reduction in urban AT in these cities. This study advises further research into the physiological effects of urban greenery plant species on heat attenuation and the periodic irrigation possibility of the urban vegetation in the analysed cities, particularly during the dry seasons.

This work has also investigated the perception of urban residents on the improvement of urban green spaces contrasting ecological conditions such as the city of Parakou and the city of Porto-Novo in the Republic of Benin. Globally, it was recorded a significant dependence of cities and city boroughs about urban green space location and density and diversity of greenery areas. Further, greenery benefits lost, and the causes of benefit lost were not similar in the cities and city boroughs. The main benefits lost from urban greenery were air quality (45.25 per cent) for Parakou and cooling effect (74 per cent) for Porto-Novo. Additionally, local public involvement was perceived to be low (> 85 per cent) and institutional cooperation with local communities, educational level and knowledge on the main impacts of urban greenery must be improved to foster higher involvement of people in urban green space development. Thus, as institutional reforms are topical in the country, its acquaintance with local communities may be fruitful for suitable development of green spaces in these cities (Akakpo *et al.*, 2023). This study is significant for adding to the literature and for research to come. It will also serve as a guide for policymakers, urban planners and managers, cityscape architects, and programmes promoting sustainable development in the Republic of Benin.

5.2. Recommendations

The next recommendations have been drawn up in regard to the results of this research and are arranged accordingly performance improvement, policy improvement and further researches.

This study found generally that the urban green spaces (UGS) are increasingly converted into the built-up areas. Especially, it showed the conversion rate per category of UGS in each city. These findings will be helpful for Urban planning Service at the municipality of each city, Beninese Environmental Agency and Land Use Planning Department of the

Ministry of Living Environment and Sustainable Development, to prioritize the UGS conservation strategy and the sustainable land use planning to adopt.

The urban residents must be committed for the implication of UGS in the nature-based solution cities. Therefore, they must get involved in the actions and activities in relation to UGS development, protection and restoration. Also, the study found that there is a seasonal influence in the cooling effect role of vegetation. Thus, during the dry seasons, urban population must adopt additional heat mitigation strategies in order to be more resilient to the heat waves. For both national and municipal governments, smart urban management of water availability such as greenery irrigation should be helpful in ensuring the sustainable urban surface temperature mitigation.

Public participation was perceived as low (>85 per cent) and institutional cooperation with local communities, the level of education and knowledge on the main impacts of greening needs to be improved to foster the involvement of people in development, urban greening. Thus, Non-governmental organisations (NGOs), national and international institutions, working or expected working in UGS development in these cities must know the dispositions such as increase confidence to cooperate with the key stakeholders. The campaigns must be considered to increase knowledge improvement on the main impacts of UGS. Finally, strategies and actions must target people with high education level (up to senior high school).

Over the period of the study, it was found a drastic decreasing of the relative natural areas (tree plantation, marshy land, forest grove) in favour of the built-up spaces. This is effectively due to the evident rapid growth of the population in the urban areas. Given that nature-based solutions can economically and gracefully improve cities' sustainability, resilience, and living conditions (forests mop up contaminants, inhibit noise, and chilly the air; marshy lands reduce flood risk and buffer storms; urban gardens facilitate exercise, spiritual nourishment, and community interaction), this study calls on town municipality decision makers to effectively enforce urban land use policies in restricting sprawl. The government through Ministry of Living Environment and Sustainable Development must have to issue ministerial orders to effectively prevent the allotment of marshy lands and the existing forests for residency and enhance urban parks creation in the major cities for climate change effect purposes. Thus, the campaigns should emphasize the strategy to enhance effective urban area protection over the Benin country.

Scientific information on urban green space (UGS), especially the spatial patterns and distribution are crucial for policies to promote a comprehensive, efficient and fair ecosystem service in cities. This because, the UGS ecosystem services sharing by people can be decayed by distance, type and size of UGS. The findings of his study could improve future vision for the update of urban planning to climate change effects. Especially since it has been observed the aggregative distribution for all categories of UGS in the studied cities, policy should envisage regular UGS implementation in order to procure fair urban ecosystem services to residents. Given that the size of the UGS is one of the factors that increases their ability to optimize adaptation to the effects of climate change, research policy should consider studies at national level to assess the minimum size of the area, different categories of UGS, in order to strengthen the implementation of urban planning.

Assessing the perception of stakeholders and their involvement in improving UGS is an important study for policy guideline and design especially Fund projects of urban sustainability (Goal 9), Climate Action (Goal 13), Urban afforestation and Environment protection (Goal 15). The results of the study provided important information on strengthening the commitment of residents to the improvement and development of urban green spaces through operational institutional cooperation.

i. Further studies are important on the current cities to highlight the relationship between green space configuration and climate effects mitigation and adaptation.
ii. It is suggested further studies on environmental and socio-economic factors influencing the aggregative distribution of each found green space categories.
iii. It is also advised that studies be conducted into the impact of urban green spaces on plant conservation.
iv. Further research on the relationship between urban green space categories, the state of their distribution, and the consistency of the provided ecosystem services is also advised.
v. It is also suggested the studies to explore the possibility to optimize the effect of different types of urban plant essences on urban microclimate.

Finally, future studies are suggested to examine urban greenery physiological characteristics, and vegetation planting arrangement in terms of irrigation, evapotranspiration and shading during dry seasons.

5.3. Contribution to Knowledge

The study integrated remote sensing methods, physical measurements, questionnaire administration, interviews and participative observation to assess urban environmental sustainability in the cities. Consequently, the research findings could prove valuable for policy development, decision making and urban planning and managing capacity. The study will be valuable for the general public as it helps enhance and expand their understanding of the connections between urbanisation, the development of green spaces, and the adaptation and mitigation of climate change effects.

Some main knowledges have been added to urban green space sustainability in the study areas through:

i. The green spaces in these cities could be summarized into forests (sacred forest and gallery forest), marshy lands, plantations, crop lands, city bushes, water bodies, green cemeteries, urban gardens and tree assemblages.
ii. The aggregative pattern of each category of urban green space of each study cities.
iii. Specific strategies or actions must be needed for the development or conservation of each of green space configuration categories.
iv. The knowledge of the periods in the year when urban vegetation should not contribute to heat attenuation if no adequate management action in terms of greenery irrigation is carried out or promoted.
v. How dramatic is urban land cover change in only 20 years period and the built-up areas exerted incredible pressure on non-built-up areas.
vi. Urban green space consistency in the study cities is greatly impacted by urbanisation.
vii. How institutional cooperation with local communities must be improved in order to foster the involvement of people in urban greenery development. As a result, the findings are applicable to a literature database for future studies and urban development projects.

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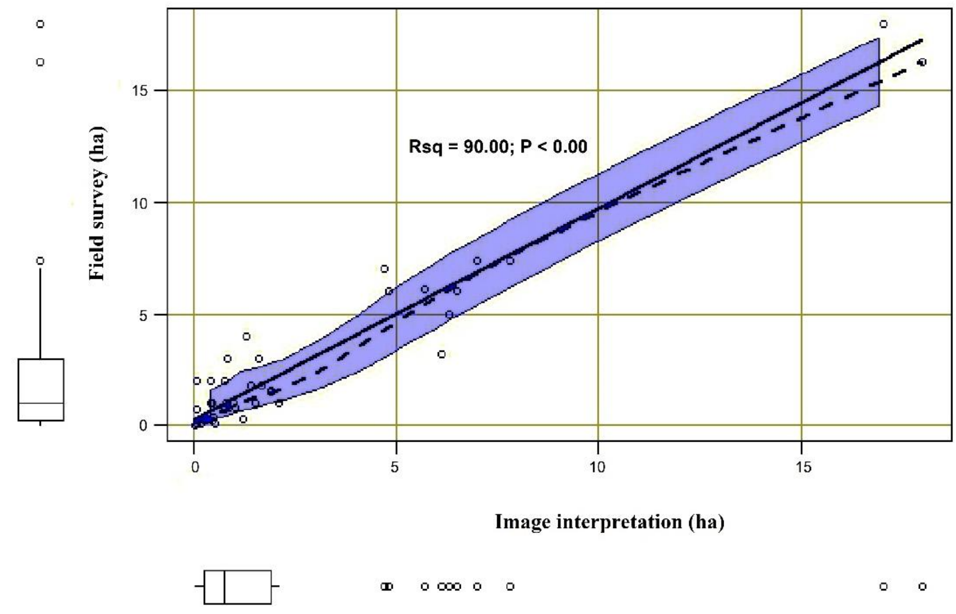
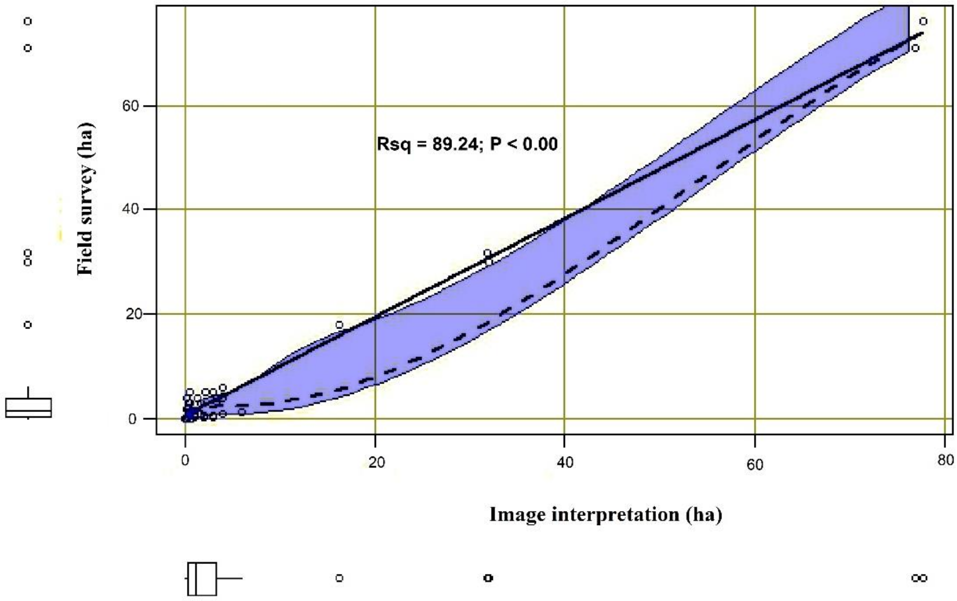
APPENDICES

Appendix A: Comparison Between Image Interpretation and Field Survey Data



Comparison of the green space area (ha) obtained by visual interpretation of Google Earth images and field survey measurement. The dots represent the matched-pair comparison between values from visual interpretation of images and field survey on the same UGS category in Parakou. Solid lines indicate the linear regression, dashed lines show the local lowess-type regression curve and the bleu band show the full regression curve



Comparison of the green space area (hectare) obtained by visual interpretation of google earth images and field survey measurement. The dots represent the matched-pair comparison between values from visual interpretation of images and field survey on the same UGS category in Porto-Novo. Solid lines indicate the linear regression, dashed lines show the local lowess-type regression curve and the bleu band show the full regression curve

Appendix B: Stakeholder Questionnaire

In order to promote sustainability in our settlements at these moments of harmful effects of climate change, this interview is set to appreciate efficacity of green spaces in the cities of Porto-Novo and Parakou.

Interviewer: ………………………………………...…………………………….

Date: Day………………...Month………………...Year…………………

City: ……………….………………and…………. **City borough name…**…………..……

Language of survey: ……………………………………….................................

I. Description of interviewee

1	Name of interviewee if possible	(Mast be typed here)
2	Age	(Mast be typed here)
3	Gender	1= male 0= female
4	Ethnic	(Mast be typed here)
5	Religion	1= Christianism 2= Islam 3= traditionalist 4= Other (to specify)
6	Matrimonial	1= Single 2= Married 3= Widow 4= Divorced
7	Polygamy	1= Yes 0= No
8	School education level	1= Primary 2= Secondary and first cycle 3= Secondary and second cycle 4= University 5= Literacy in local tongue 9= Never at school
9	Residence acquisition	1= Rent 2= Free lodge 3= Owner 4= other (to specify)
10	Main activity	1= Trade 2= Agriculture 3= Transformation of agro-food 4= Handcraft 5= Public officer 6= Private officer 7= Student 8= Retired 9= Other (to specify)
11	Level of monthly income	1= Less than 40 000 FCFA 2= Between 40 000 and 80 000FCFA 3= More than 80 000 FCFA
12	**How many years do you spend in the city**	1= less than 02 years 2= between 02 and 05 years 3= more than 05 years

II. Characteristics of Green infrastructure

13	Type of green infrastructure exist in your location	1= Street trees 2= Public gardens 3= Private garden 4= Urban park 5= Community or Sacred forests 6= Urban cropland 7= Improved verges 8= House trees 9= Green roof 10= Other to be cited
14	Main green infrastructures in your location	(Mast be typed here)
15	How would you have rated key aspects of green infrastructures in your location	1= Poor 2= Inadequate 3= Adequate 4= excellent
16	Vegetation diversity of green infrastructures in your location	1= Poor 2= Inadequate 3= Adequate 4= excellent
17	Management of green infrastructures in your location	1= Poor 2= Inadequate 3= Adequate 4= excellent
18	Attractivity of green infrastructures in your location	1= Poor 2= Inadequate 3= Adequate 4= excellent
19	Greenery in your house	1= Yes 0= No; If yes, which one
20	Worry about improving housing green infrastructures	1= Yes 0= No
21	Public participation in green infrastructure development and planning	1= Yes 0= No If yes, 1= Maintenance and protection, 2= Financial support, 3= Technical support, 4= Local referendum
22	Location of dominated green infrastructures	1= Centre of the city 2= Business areas of the city 3= Suburbs 4= New expansion areas 6= Public offices 7= Private offices

III. Knowledge on green infrastructure importance in the town

23	**General awareness on the impacts of Greenery in town?**	1= Yes 2= No
24	Currently loss of benefits of green infrastructures	1= Yes 0= No
25	More important benefits lost in the city in your opinion?	1=Beauty and aesthetic 2=Heat control 3=Flood control 4=Biodiversity sink 6=Air quality 7= Sound control 8= Other (to specify)
26	Main causes of the given loss of benefit?	1= Weak density green infrastructure 2= Size of green space 3= Weak diversity of green infrastructures 4= Unplanning of green infrastructure 5= Lack of management or green infrastructure
27	Possibility of restoring some benefits	1= Yes 2= No 3= Maybe
28	King of green infrastructures mostly interesting in urban environmental control	1= Street trees 2= Public gardens 3= Private garden 4= Urban park 5= Urban cropland 6= Improved verges 7= House trees 8= Green roof 8= Other (to specify)
29	Will you contribute to the development of green infrastructures in your locality?	1= Yes 0= No
30	If No, Give the principal reasons.	
31	Which kind of contribution	1= Financial by subscription 2= Manpower volunteer 3= Information awareness 4= Self tree plantation 5= Self home garden management 6= Security and protection of public green infrastructures 7= Other (to specify)

IV- Knowledge and practice of green infrastructures management and planning

32	Is there any program of urban greening development?	1= Yes 2= No 3= I don't know
33	If yes, specify	(Mast be typed here)
34	Are there planning spaces for greening in your location?	1= Yes 2= No 3= I don't know
35	Do you have knowledge on institution in charge of green infrastructure management?	1= Yes 2= No If Yes, Specify them (By typing here)
36	What are the two main institutions that close questions on greening in the city?	1= NGOs (to specify) 2= Town hall 3= University 4= Environmental office 5= Heath office 6= Other (to specify)
37	Is there good cooperative between institutions?	1= Yes 2= No
38	If Yes, Specify their relationship or collaboration	(By typing here)
39	What are the attributions of each in greening planning and development	1= Installation of new greening in the city 2= Maintenance and protection of green infrastructures 3= Financial support, 4= Technical support 5= Communication, awareness and education
40	Cooperation attitude of institution with local communities	1= Yes 2= No
41	Is there any community association for greening planning and development	1= Yes 2= No
42	Level of involvement of the community association in the management of the green spaces	1= High 2= Medium 3= Low
43	Specify the stages of community involvement in green management	(By typing here)
44	Main challenges for green space planning and management	1= Lack of fund 2= Lack of understanding 3= Default of communication 4= Lack of new technology 5= Other (to specify)
45	Main strategies taken to face these challenges	(By typing here)

Appendix C: Distribution of Resident's Perception on the Loss's Benefits Between the Boroughs of the Cities

City	**Borough**	**Important Benefits Lost in the Cities**					
		Air Quality	Sound Control	Beauty/ Aesthetic	Cooling Effect	Flooding Control	Sink of Biodiversity
Porto-Novo	1	3 (0.7%)	2 (0.5%)	15 (3.7%)	51 (12.7%)	0 (0.0%)	1 (0.2%)
	2	3 (0.7%)	1 (0.2%)	10 (2.5%)	23 (5.7%)	0 (0.0%)	0 (0.0%)
	3	3 (0.7%)	1 (0.2%)	18 (4.5%)	48 (12.0%)	0 (0.0%)	2 (0.5%)
	4	4 (1.0%)	2 (0.5%)	8 (2.0%)	89 (22.2%)	1 (0.2%)	3 (0.7%)
	5	3 (0.7%)	0 (0.0%)	11 (2.7%)	85 (21.2%)	0 (0.0%)	13 (3.2%)
Parakou	1	63 (15.7%)	0 (0.0%)	35 (8.7%)	33 (8.2%)	34 (8.5%)	0 (0.0%)
	2	51 (12.7%)	0 (0.0%)	17 (4.2%)	23 (5.7%)	6 (1.5%)	0 (0.0%)
	3	67 (16.7%)	0 (0.0%)	28 (7.0%)	23 (5.7%)	20 (5.5%)	0 (0.0%)

Appendix D: Distribution of Resident's Perception on the Causes of the Given Loss of Benefits Between the Boroughs of the Cities

City	Borough	Causes of the given loss of benefits supplied by urban greenery				
		Lack of Greenery Management	No Greenery Planning	Weak Greenery Density	Weak Greenery Space Diversity	Weak Size of Greenery Space
Porto-Novo	1	17 (4.2%)	12 (3.0%)	29 (7.2%)	8 (2.0%)	6 (1.5%)
	2	11 (2.7%)	4 (1.0%)	16 (4.0%)	4 (1.0%)	2 (0.5%)
	3	28 (7.0%)	14 (3.5%)	24 (6.0%)	3 (0.7%)	3 (0.7%)
	4	19 (4.7%)	13 (3.2%)	55 (13.7%)	8 (2.0%)	12 (3.0%)
	5	17 (4.2%)	13 (3.2%)	56 (14.0%)	8 (2.0%)	18 (4.5%)
Parakou	1	4 (1.0%)	4 (1.0%)	49 (12.2%)	107 (26.7%)	1 (0.2%)
	2	5 (1.2%)	11 (2.7%)	41 (10.2%)	35 (8.7%)	5 (1.2%)
	3	6 (1.5%)	21 (5.2%)	43 (10.75%)	64 (16.0%)	4 (1.0%)