OUTDOOR AIR QUALITY AND THERMAL COMFORT IN GREEN-DESIGNED PRIMARY SCHOOLS IN BENIN CITY

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A RESEARCH DISSERTATION SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE (BSc.) DEGREE IN ARCHITECTURE,
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DECLARATION

This is to declare that I, **IKEANUMBA CHIDINDU EVANS** student of the Department of Architecture, University of Benin with MAT.NO: **ENV2103347** conducted the research on this project topic: **OUTDOOR AIR QUALITY AND THERMAL COMFORT IN GREEN-DESIGNED PRIMARY SCHOOLS IN BENIN CITY**, under the supervision of ARC. (MRS) G.E.O IFADA and that all the information provided in this report was taken from the proper factual sources of information. All academic material used in this work and its sources has been duly acknowledged.

_____ _____

Signature Date

CERTIFICATION

This is to certify that this study titled **OUTDOOR AIR QUALITY AND THERMAL COMFORT IN GREEN-DESIGNED PRIMARY SCHOOLS IN BENIN CITY** was carried out by EKHATOR EGHOSA, with Matric Number **ENV2103347** under my supervision and meets the regulation governing the award of the Bachelor degree in Architecture of the University of Benin, Benin City, Edo State, Nigeria. We certify that it has not been submitted for the Bachelor's degree in this or any other university and is approved for its contribution to knowledge and literary presentation.

ARC. (MRS) G.E.O. IFADA	**DR. (ARC.) OKAFOR IWU**
Project Supervisor	**Head of Department**
Date	**Date**

DEDICATION

This project is dedicated to the Almighty God, the author and finisher of our faith who has been with me since the beginning of my life on earth. Also, I dedicate this project with great love and affection to my parents, Teachers, friends, and loved ones.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to God Almighty who has done wonders for me thus far; I would also like to thank my father, mother and my siblings for their love and support. I am also grateful to my colleagues who were always willing to share their knowledge and expertise.

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ABSTRACT

Urban markets in Benin City function as vital economic spaces and cultural landmarks that reflect community identity, traditional practices and social interaction. Recent modernization efforts across Nigerian cities have focused heavily on physical redevelopment, often neglecting the cultural significance and spatial dynamics that shape these markets. This study examines the relationship between urban market revitalization and cultural sustainability in selected markets in Benin City—Oba Market, Uselu Market, Ekosodin Market, Orgie-Ode Market. Using a mixed-methods approach, data were collected from 100 respondents through questionnaires, interviews, field observations and photographs.

Findings indicate major infrastructural and organizational challenges, including inadequate drainage, sanitation, security and spatial planning, which affect market efficiency and user experience. Despite these issues, traders and users maintain strong cultural attachment to the markets, underscoring their historical and symbolic importance. The study concludes that revitalization strategies must integrate cultural preservation with infrastructural improvement to ensure sustainable and socially inclusive market renewal. Recommendations emphasize participatory planning, heritage-sensitive design and improved governance frameworks.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Globally, outdoor air quality and thermal comfort have become critical environmental health concerns in educational environments, particularly in primary schools, where children are physiologically more vulnerable to environmental stressors. According to the World Health Organisation, exposure to ambient air pollution is responsible for millions of premature deaths annually, with children being among the most affected population groups due to their developing respiratory systems and higher inhalation rates relative to body weight (WHO, 2018). Studies conducted in Europe, Asia, and North America have demonstrated that poor outdoor air quality around schools significantly influences indoor air conditions, especially in naturally ventilated buildings, which are common in warm climates (Rivas *et al*., 2017). At the same time, outdoor thermal discomfort from rising ambient temperatures and urban heat stress has been shown to adversely affect children's physical well-being, concentration, and learning performance (Mishra & Ramgopal, 2015; Teli *et al*., 2017). Recent global research has increasingly linked climate change to worsening outdoor thermal environments in urban areas, with schools identified as critical micro-environments requiring special attention. The Intergovernmental Panel on Climate Change has highlighted that increasing surface temperatures, prolonged heatwaves, and changing wind patterns are intensifying thermal stress in cities, particularly in tropical and subtropical regions (IPCC, 2021). These climatic shifts directly affect outdoor spaces within school premises, such as playgrounds, courtyards, and assembly areas, where pupils spend significant periods during the school day. Consequently, green building design strategies, including vegetation, shading devices, permeable surfaces, and passive cooling, are being promoted globally as adaptive solutions to improve outdoor microclimates and reduce pollutant concentrations (Santamouris, 2016).

At the continental level, Africa faces a disproportionate burden of outdoor air pollution and thermal stress due to rapid urbanisation, weak environmental regulation, and limited climate-responsive infrastructure. The World Bank has reported that urban air pollution levels in many African cities exceed international guidelines, largely driven by traffic emissions, biomass burning, and the use of fossil-fuel generators (World Bank, 2019). In parallel, African cities are experiencing accelerated warming rates relative to global averages, exacerbating outdoor thermal

discomfort, especially in public institutions such as schools (Rohat *et al*., 2019). Empirical studies conducted in African school environments have revealed elevated outdoor particulate matter concentrations and extreme thermal conditions, often exceeding comfort thresholds for children (Egondi *et al*., 2017). However, despite the growing promotion of green building concepts across the continent, there remains limited research evaluating their effectiveness in improving outdoor environmental quality in school settings.

Within Nigeria, outdoor air quality has emerged as a major public health issue, with several cities ranking among those with the highest particulate matter concentrations globally. According to the WHO (2022), Nigeria consistently records $PM_{2.5}$ levels far above the recommended annual mean limit of 5 $\mu g/m^3$, exposing urban populations to significant health risks. Studies in Nigerian cities such as Lagos, Port Harcourt, and Ibadan have documented high outdoor pollutant levels around schools, largely attributed to vehicular traffic, open waste burning, and generator emissions (Amegah & Agyei-Mensah, 2017; Obanya *et al*., 2018). In addition, Nigeria's tropical climate, characterised by high temperatures and humidity, creates challenging outdoor thermal conditions that directly influence comfort levels in school environments, particularly where mechanical cooling is absent or unreliable (Oluwafemi & Adebamowo, 2018). Research focusing on thermal comfort in Nigerian schools indicates that outdoor climatic conditions strongly dictate indoor comfort due to extensive reliance on natural ventilation (Adekunle & Nikolopoulou, 2019). This makes outdoor thermal comfort a critical determinant of overall environmental quality in school buildings. Despite this, most Nigerian studies have concentrated on indoor air quality and thermal comfort, with limited attention given to outdoor environments and even fewer studies examining the role of green design strategies in mitigating outdoor environmental stressors.

At the local scale of Benin City, Edo State, these challenges are particularly pronounced. Benin City has experienced rapid urban growth over the past two decades, accompanied by increased vehicular activity, land-use changes, and loss of vegetative cover. Studies on urban climate in Benin City have identified a clear urban heat island effect, with built-up areas recording significantly higher temperatures than surrounding rural zones (Ayoade & Adeyemi, 2014; Efe & Eyefia, 2019). This urban warming contributes to heightened outdoor thermal discomfort, especially in open spaces such as school playgrounds and courtyards. Furthermore, ambient air quality studies conducted in Benin City have reported elevated concentrations of particulate

matter and gaseous pollutants linked to traffic congestion and generator usage, posing potential health risks to school-age children (Eghomwanre *et al*., 2022). Although green building concepts are gradually being introduced in some educational facilities within Benin City, often through landscaping, shading, and natural ventilation strategies, there is a lack of empirical evidence assessing how these design interventions influence outdoor air quality and thermal comfort in primary schools. This gap limits the ability of architects, planners, and policymakers to develop climate-responsive and health-protective school environments.

Outdoor air quality and thermal comfort are integral components of environmental quality in primary school settings, as children's exposure to environmental stressors extends beyond classroom interiors to outdoor school spaces. Outdoor air pollutants such as particulate matter and nitrogen oxides can infiltrate classrooms, particularly in naturally ventilated buildings, thereby affecting indoor air quality and student health (Rivas *et al*., 2017). Similarly, outdoor thermal conditions influence children's comfort, behaviour, and physical activity levels during outdoor school activities. Green building strategies have been shown to moderate outdoor temperatures and improve air quality by enhancing shading, evapotranspiration, and pollutant dispersion (Santamouris *et al*., 2018). However, most existing studies evaluating these benefits have been conducted in temperate climates, leaving tropical African contexts under-represented in the literature. Despite increasing global and national attention to sustainable school design, there remains a significant gap in research addressing the combined assessment of outdoor air quality and outdoor thermal comfort in green-designed primary schools within Nigerian cities, particularly Benin City. Existing Nigerian studies largely focus on indoor environmental quality or general urban air pollution, with minimal emphasis on outdoor school environments and the effectiveness of green design strategies in mitigating environmental stressors. Furthermore, there is limited locally generated data linking outdoor environmental conditions in schools to children's comfort and health outcomes, which constrains evidence-based decision-making.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Despite increasing global interest in sustainable design and environmental quality, there remains insufficient empirical understanding of how outdoor air quality and thermal comfort conditions manifest in green-designed primary schools in Benin City, Edo State, Nigeria. This knowledge gap is rooted in several interrelated limitations in existing research, environmental monitoring

infrastructure, and policy frameworks, all of which constrain how educational environments are conceptualised, planned, and regulated in rapidly urbanising tropical cities.

The current body of empirical research on environmental conditions in Nigerian schools and in Benin City specifically has largely focused on indoor air quality and indoor thermal comfort rather than on outdoor environmental dynamics. Studies on schools in Lagos, Port Harcourt, and Ibadan have documented elevated indoor pollutant concentrations and uncomfortable indoor thermal conditions attributable to urban pollution and climatic factors (Amegah & Agyei-Mensah, 2017; Obanya *et al*., 2018; Adekunle & Nikolopoulou, 2019). While these insights are important, they often treat outdoor conditions primarily as inputs to indoor environments rather than as environmental exposures in their own right. This focus overlooks the fact that children spend substantial time outdoors during play, assembly, break times, queueing for transportation, and non-classroom activities, making *outdoor air quality* and *thermal comfort* equally critical determinants of overall environmental health and well-being in school settings. Also, most environmental monitoring in Benin City and across Nigeria remains sparse, irregular, and spatially limited, especially outside central business districts or high-traffic corridors. Ambient air quality monitoring stations are few, and existing data often lack the granularity necessary to characterise pollutant distributions within neighbourhoods or specific micro-environments such as primary school grounds. The few studies that have assessed ambient pollutants in Benin City suggest that respirable particulate matter ($PM_{2.5}$ and PM_{10}) and gaseous contaminants vary substantially with traffic density, generator use, and urban land-use patterns, but they do not provide school-specific measurements that could link exposures to building design or school location characteristics (Eghomwanre *et al*., 2022). Without localised outdoor pollutant measurements, including peak values, diurnal patterns, and seasonal fluctuations, researchers and designers lack a clear empirical basis for understanding the air quality challenges that children face in outdoor primary school environments.

From research, the climatic characteristics of Benin City are a humid tropical environment with high temperatures, elevated humidity, and marked wet and dry seasons, creating complex thermal stress patterns that are poorly documented at the micro-scale. Thermal comfort studies in Nigerian buildings have focused primarily on indoor spaces, where natural ventilation and building orientation influence indoor heat loads (Oluwafemi & Adebamowo, 2018). However, outdoor thermal conditions are shaped by a combination of macro-scale climatic drivers (e.g.,

solar radiation, synoptic winds) and micro-scale urban factors (e.g., shading, vegetation cover, surface materials, and urban heat island effects). Research conducted in Benin City has identified the existence of urban warming and surface temperature variability across land uses (Efe & Eyefia, 2019), but these studies do not extend to school micro-environments nor examine how green design elements such as tree shading, green buffers, and permeable surfaces influence thermal comfort at the human scale.

Furthermore, the specific context of *green-designed primary schools* in Benin City introduces additional complexity that is not captured in current datasets. Green design strategies are intended to moderate environmental conditions, for example, through increased vegetation cover that can filter pollutants and shade outdoor areas, or through materials and forms that reduce heat absorption. Yet the actual performance of such strategies in the tropical urban context of Benin City is not well documented. International literature has shown that vegetation and urban green infrastructure can improve outdoor thermal comfort and reduce local pollutant concentrations in temperate and subtropical cities (Santamouris, 2016; Bowler *et al*., 2010), but these findings cannot be assumed to apply uniformly to the specific climatic, socio-economic, and urban fabric of Benin City. Context-specific data are needed to understand whether similar benefits accrue in local schools, and if so, under what design configurations and environmental conditions.

The absence of empirically grounded outdoor environmental data limits the capacity of design professionals, school administrators, and urban policymakers to make evidence-based decisions. Architects and planners working on sustainable school projects in Benin City may incorporate green design principles based on general best practices, yet they frequently lack localized performance metrics against which to evaluate design alternatives or justify particular interventions. Without measured outdoor pollutant levels and thermal comfort indices such as ambient temperature, relative humidity, mean radiant temperature, and human thermal comfort models (e.g., UTCI, PET), design decisions risk being either overly generic or mismatched to the actual environmental challenges faced by users. From a policy and regulatory perspective, the absence of robust outdoor environmental data weakens the formulation of context-responsive standards for school site selection, campus planning, and environmental quality thresholds. Regulatory frameworks that govern educational infrastructure traditionally emphasise indoor building codes, sanitation, and safety, with limited incorporation of outdoor environmental health criteria. In cities like Benin City, where regulatory enforcement faces resource and institutional

constraints, the lack of empirical evidence further reduces the priority given to outdoor air quality and thermal comfort in public infrastructure planning. Moreover, the empirical gap has direct implications for pupils' health, comfort, and educational outcomes. Outdoor air pollution exposure has been linked to increased incidence of respiratory symptoms, absenteeism, and impaired cognitive performance in children (HEI, 2019), while thermal stress has been shown to reduce attention, increase fatigue, and negatively influence mood and behaviour (Teli *et al*., 2017). The inability to characterise these exposures in the specific contexts where children learn and play in Benin City means that stakeholders cannot reliably estimate environmental risk, nor tailor interventions that might mitigate adverse outcomes. For example, decisions about planting shade trees versus installing shade structures, or prioritising air quality buffering versus cooling interventions, require localised evidence on pollutant dynamics and thermal sensation patterns, evidence that is not yet available.

In summary, the lack of context-specific data on pollutant levels and thermal stress in school outdoor environments in Benin City significantly constrains the capacity to design, retrofit, and regulate school buildings in ways that protect children's health and enhance learning outcomes. It leaves practitioners reliant on generalised global standards that may not reflect local environmental realities, and it leaves policymakers without a sound empirical foundation for environmental quality thresholds that matter for pupils' safety and performance. Bridging this empirical gap is essential for advancing green school design in Nigeria, achieving healthier built environments, and aligning educational infrastructure with broader climate adaptation and sustainable development objectives.

1.3 RESEARCH QUESTIONS

This study seeks to answer the following questions:

1. How does outdoor air quality vary around green-designed primary schools in Benin City?
2. What are the prevailing outdoor thermal comfort conditions in these primary school environments?
3. How do green design strategies influence outdoor air quality and thermal comfort compared to conventional primary school designs?
4. What implications do these conditions have for pupils' comfort and well-being in Benin City?

1.4 RESEARCH AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to assess outdoor air quality and thermal comfort conditions in green-designed primary schools in Benin City, Edo State, Nigeria, and to address objectives specifically:

1. To assess outdoor thermal comfort conditions in primary school playgrounds, courtyards, and other open spaces by examining parameters such as air temperature, humidity, wind speed, and solar radiation, and by evaluating thermal comfort indices relevant to pupils' physiological responses.

2. To evaluate the effectiveness of green building design features, including trees, vegetation cover, shading devices, and permeable surfaces, in moderating outdoor air quality and thermal comfort, and to compare conditions between green-designed schools and conventional schools within the city.

3. To compare green-designed primary schools with conventional primary schools in Benin City to identify design and construction practices that most effectively improve outdoor environmental quality and positively influence children's psychological and cognitive experiences.

4. To provide evidence-based recommendations for sustainable primary school design and construction that integrate environmental, architectural, and psychological considerations, supporting healthier, resilient, and child-friendly educational spaces in urban tropical contexts.

1.5 SIGNIFICANCE OF THE STUDY

The findings of this study will make a significant contribution to the growing body of knowledge on sustainable school design in tropical urban contexts, particularly by providing empirical evidence on the effectiveness of green building strategies in improving outdoor air quality and thermal comfort within primary school environments. While green design principles are widely promoted as solutions to environmental and climatic challenges, there remains a shortage of context-specific data demonstrating how these strategies perform in real-life school settings in rapidly urbanising tropical cities. By generating locally grounded evidence from Benin City, this study will help bridge the gap between theoretical sustainability concepts and their practical environmental outcomes in educational facilities.

In addition, the study will enhance understanding of how outdoor environmental conditions influence pupils' health, comfort, and learning experiences. Improved outdoor air quality and thermal comfort can encourage greater use of outdoor spaces for learning and recreation, reduce exposure to harmful pollutants, and minimise heat-related discomfort that can affect children's physical and cognitive performance. The findings will therefore provide a scientific basis for integrating outdoor environmental quality considerations into the design and management of primary schools, rather than limiting attention solely to indoor spaces. For architects and urban planners, the results of this research will offer practical insights into the design features and landscape strategies that are most effective in moderating microclimatic conditions in school environments. Primary School administrators will benefit from evidence that can inform maintenance practices, scheduling of outdoor activities, and decisions on retrofitting existing school facilities. Furthermore, policymakers and regulatory authorities can draw on the findings to develop or refine guidelines, standards, and policies that promote environmentally responsive and child-centred school design. Ultimately, the study will support the development of healthier, safer, and more resilient educational environments capable of adapting to increasing urbanisation and climate-related challenges. By demonstrating the tangible benefits of green building strategies, the research will contribute to long-term sustainability goals and help ensure that primary school environments in tropical cities support both environmental quality and educational performance.

1.6 SCOPE OF THE STUDY

The study is geographically focused on Benin City, Edo State, which provides a representative context of a rapidly urbanising tropical city with unique climatic and environmental challenges. Within this setting, the research specifically targets selected green-designed primary schools to examine how sustainable design strategies influence outdoor environmental conditions. The focus is on primary school premises, including playgrounds, courtyards, and surrounding open spaces, where children spend a significant portion of their day engaged in play, learning, and social activities. By concentrating on these outdoor areas, the study aims to capture the real-world interactions between the built environment, microclimatic conditions, and children's comfort and wellbeing. This geographical and spatial focus allows for a detailed, context-specific assessment of how green building features perform in improving air quality and thermal comfort,

providing insights that are directly relevant to the planning, design, and management of educational spaces in Benin City and similar tropical urban contexts.

1.7 STUDY AREA

Benin City is the capital of Edo State, located in southern Nigeria within a humid tropical climatic zone characterised by high temperatures, high relative humidity, and seasonal rainfall. The city's rapid urbanisation has altered its microclimatic conditions, resulting in increased surface temperatures and variable air quality across different neighbourhoods (Efe & Eyefia, 2019). These characteristics make Benin City an appropriate case study for investigating outdoor environmental quality in primary school environments.

1.8 RESEARCH JUSTIFICATION

Given the vulnerability of pupils to air pollution and thermal stress, understanding outdoor environmental conditions in primary schools is essential for safeguarding health and improving educational outcomes. This study is justified by the need to generate local empirical data that can inform climate-responsive school design, urban planning, and environmental policy in Benin City and similar Nigerian cities.

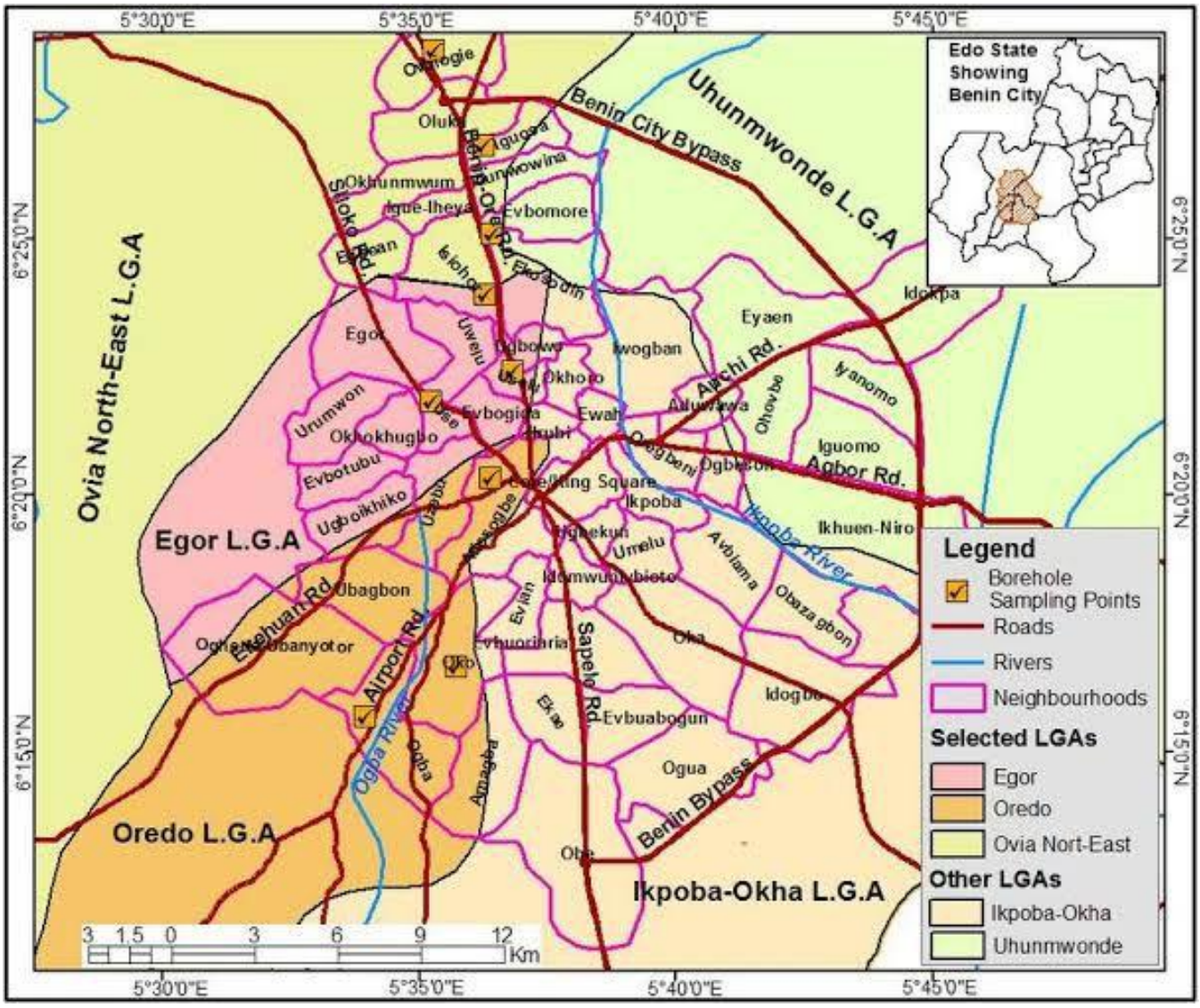


Figure 1.1: Map of Benin City, Edo State.
Source: Researcher's source

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 THEORETICAL FRAMEWORK

This study is theoretically grounded in three complementary perspectives: Human Thermal Comfort Theory, Environmental Stress Theory, and Biophilic Design Theory. Together, these theories provide a robust interdisciplinary foundation for understanding how building design and construction decisions influence outdoor environmental conditions and how these conditions, in turn, affect pupils' physiological comfort, psychological well-being, and learning experiences in primary school environments.

Human Thermal Comfort Theory provides the primary basis for analysing outdoor thermal conditions within primary school premises. Originally developed by Fanger (1970), the theory explains thermal comfort as a function of the interaction between environmental variables such as air temperature, relative humidity, wind speed, and mean radiant temperature and human physiological characteristics, including metabolism and clothing insulation. Although Fanger's model was initially designed for indoor environments, subsequent studies have adapted thermal comfort theory for outdoor contexts, recognising the dynamic nature of outdoor microclimates and human behavioural adaptation (Nikolopoulou & Steemers, 2016). Contemporary outdoor thermal comfort research emphasises indices such as the Physiological Equivalent Temperature (PET) and Universal Thermal Climate Index (UTCI), which integrate climatic variables with human responses to assess perceived comfort in open spaces (Matzarakis *et al*., 2018). In the context of primary schools in tropical cities, this theory is particularly relevant, as pupils are more sensitive to thermal extremes due to their developing thermoregulatory systems and higher activity levels during outdoor play (Teli *et al*., 2017). Human Thermal Comfort Theory, therefore, underpins this study's assessment of outdoor thermal conditions in playgrounds, courtyards, and other primary school open spaces.

Environmental Stress Theory complements thermal comfort analysis by explaining the broader psychological and cognitive implications of adverse environmental conditions. According to Evans and Cohen (1987), environmental stressors such as excessive heat, noise, and air pollution can overwhelm individuals' adaptive capacity, leading to physiological strain, emotional discomfort, reduced concentration, and impaired performance. Later studies have demonstrated

that prolonged exposure to thermal stress and poor air quality negatively affects pupils' attention span, memory, and academic performance, particularly in primary school environments where cognitive demands are high (Lan *et al*., 2017; Wargocki & Wyon, 2017). In outdoor primary school settings, high temperatures and polluted air can discourage physical activity, increase fatigue, and reduce pupils' willingness to engage in learning and social interaction. Environmental Stress Theory, therefore, provides a critical lens for understanding how outdoor air quality and thermal discomfort function as stressors that undermine pupils' comfort, well-being, and learning experiences in primary schools.

Biophilic Design Theory offers a positive, design-oriented perspective that explains how built environments can actively promote wellbeing through integration with nature. Rooted in the concept of biophilia, the innate human tendency to seek connections with natural systems, this theory argues that exposure to natural elements such as vegetation, water, natural light, and airflow enhances psychological well-being, cognitive functioning, and emotional regulation (Kellert & Calabrese, 2015; Kellert, 2018). Empirical research has shown that green spaces in and around primary schools are associated with improved attention, reduced stress, and better academic outcomes among pupils (Dadvand *et al*., 2015; Chawla *et al*., 2018). In architectural and urban design contexts, biophilic principles support the use of trees, green courtyards, shading devices, and permeable landscapes to moderate microclimates, improve air quality, and create restorative outdoor environments. Within this study, biophilic Design Theory justifies the examination of green building features as design strategies that not only enhance outdoor environmental quality but also support pupils' psychological and cognitive development.

Collectively, these three theories establish a comprehensive framework linking building design and construction, outdoor environmental performance, and **pupils'** comfort and well-being. Human Thermal Comfort Theory explains how outdoor climatic conditions are perceived physiologically, Environmental Stress Theory clarifies the negative impacts of environmental discomfort and pollution, and Biophilic Design Theory highlights how green design interventions can mitigate stressors and enhance positive outcomes. This integrated theoretical foundation strengthens the study's investigation of outdoor air quality and thermal comfort in green-designed primary schools in Benin City and supports the development of evidence-based recommendations for sustainable, child-friendly primary school design in tropical urban

environments.

2.2 CONCEPTUAL FRAMEWORK

The conceptual framework of this study is founded on the dynamic relationship between green building design and construction features**,** outdoor environmental conditions**,** and children's psychological and cognitive responses within primary school environments. It reflects an integrated building environment–human system approach, which recognises that architectural and construction decisions directly influence microclimatic conditions and, consequently, human comfort and wellbeing (Santamouris, 2016). At the first level, the framework identifies green building design and construction features as the primary independent variables. These include the incorporation of trees and vegetation cover, shading devices, building orientation, and permeable surface materials. Previous studies have shown that vegetation and tree canopies reduce surface and air temperatures through shading and evapotranspiration, while permeable surfaces minimise heat storage and enhance microclimatic cooling (Bowler *et al*., 2010; Abhijith *et al*., 2017). Building orientation and shading devices further control solar exposure and airflow, which are critical determinants of outdoor thermal conditions in tropical climates (Nikolopoulou & Steemers, 2016).

These design and construction strategies directly influence outdoor environmental conditions, which form the intermediate variables within the framework. Specifically, green features modify air temperature, relative humidity, wind flow, solar radiation, and the dispersion and concentration of air pollutants. Empirical studies have demonstrated that well-designed green primary school environments can lower ambient temperatures, improve ventilation, and reduce exposure to particulate matter and gaseous pollutants in outdoor spaces (Santamouris *et al*., 2018; Matzarakis *et al*., 2018). In tropical urban contexts such as Benin City, where high temperatures and urban pollution are increasing, these microclimatic modifications are particularly significant. The resulting outdoor environmental conditions determine the levels of outdoor air quality and thermal comfort experienced by pupils in playgrounds, courtyards, and surrounding school spaces. According to Human Thermal Comfort Theory, these environmental parameters interact with children's physiological characteristics to shape comfort perception and thermal stress (Fanger, 1970; Teli *et al*., 2017). When outdoor conditions are unfavourable, they contribute to

heat stress and environmental discomfort, which are recognised stressors within Environmental Stress Theory (Evans & Cohen, 1987). At the outcome level, the framework links improved outdoor environmental quality to children's psychological and cognitive responses. Research in environmental psychology indicates that reduced thermal stress and improved air quality are associated with enhanced attention, lower fatigue, reduced stress, and improved learning engagement among children (Lan *et al*., 2017; Wargocki & Wyon, 2017). Furthermore, Biophilic Design Theory suggests that exposure to natural elements such as greenery and shaded outdoor spaces promotes emotional well-being and cognitive restoration, reinforcing positive learning experiences in school environments (Kellert, 2018; Dadvand *et al*., 2015).

Finally, the framework connects these outcomes to design and policy implications, emphasising the importance of evidence-based research in guiding sustainable primary school design and construction practices. By demonstrating how green building features influence outdoor environmental quality and pupils' wellbeing, the framework supports informed decision-making by architects, planners, school administrators, and policymakers in Benin City and similar tropical urban contexts. The conceptual framework diagram visually illustrates the causal pathway of the study. Green building design and construction features form the input layer, influencing outdoor environmental conditions such as temperature, airflow, and pollutant levels. These conditions, in turn, shape pupils' thermal comfort, psychological well-being, and learning experiences. The directional arrows emphasise the sequential and interrelated nature of these components, reinforcing the study's multidisciplinary focus on architecture, environment, and child psychology.

2.3 LITERATURE REVIEW

Outdoor air quality has been widely recognised as a critical determinant of environmental health in school settings, particularly for primary school pupils who are physiologically more vulnerable to air pollution due to their developing respiratory systems and higher inhalation rates relative to body weight. According to the World Health Organisation, exposure to ambient air pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), and carbon monoxide (CO) is strongly associated with respiratory diseases, reduced lung development, and impaired cognitive performance in pupils (WHO, 2018). In primary school environments, outdoor air quality is especially important because pollutants present in playgrounds and

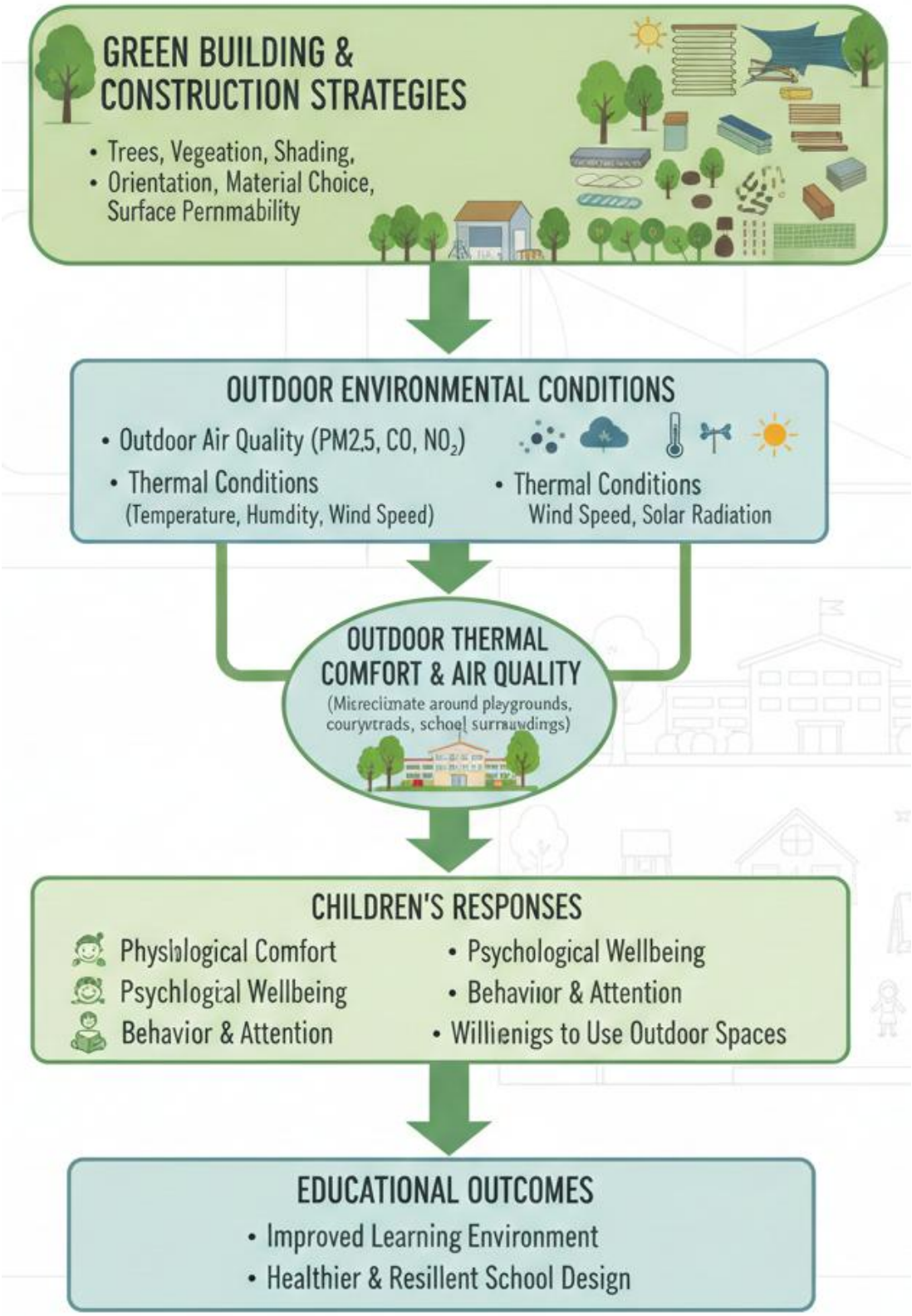


Figure 2.1: Conceptual framework showing construction strategies, environmental conditions, outdoor comfort and outcomes
Source: Researcher's source

courtyards can infiltrate indoor spaces, particularly in naturally ventilated buildings common in tropical regions (Rivas *et al*., 2017). Studies conducted in urban primary school settings across Europe and Asia have shown that outdoor pollutant concentrations near schools are often influenced by proximity to major roads, traffic density, and surrounding land use, leading to pollutant levels that frequently exceed recommended guidelines (Buonanno *et al*., 2018). In developing countries, these challenges are often intensified by weak environmental regulation and limited monitoring infrastructure. In African cities, ambient air pollution has been identified as an emerging environmental health crisis, with urban schoolpupils exposed to elevated particulate matter levels from traffic emissions, open burning, and fossil-fuel generators (Amegah & Agyei-Mensah, 2017).

In Nigeria, studies assessing air quality in urban environments have consistently reported pollutant concentrations above international standards, particularly in rapidly growing cities (Obanya *et al*., 2018). Although some research has examined air quality in and around schools, most Nigerian studies have focused on indoor environments, with limited emphasis on outdoor school spaces where pupils engage in physical activity and social interaction (Adekunle & Nikolopoulou, 2019). This gap underscores the need for focused research on outdoor air quality within school premises, particularly in cities such as Benin City, where urbanisation and traffic growth continue to intensify environmental pressures.

2.3.1 Outdoor Thermal Comfort in Tropical School Environments

1.1.1 Outdoor thermal comfort refers to the state in which individuals experience thermal satisfaction without feeling excessive heat or cold, resulting from the combined effects of air temperature, relative humidity, wind speed, and solar radiation. Unlike indoor environments, outdoor spaces are characterised by dynamic and complex microclimatic interactions, making thermal comfort highly sensitive to environmental design and land-use characteristics (Nikolopoulou & Steemers, 2016). In tropical regions, persistently high temperatures, elevated humidity levels, and intense solar radiation often lead to significant thermal stress, particularly in open spaces with inadequate shading or limited vegetation. For school pupils, outdoor thermal comfort is a critical environmental factor because pupils engage in physical activity, play, and informal learning in outdoor spaces such as playgrounds and courtyards. Children are physiologically more vulnerable to heat

stress due to their developing thermoregulatory systems, higher metabolic rates during activity, and limited ability to adapt behaviourally to extreme heat (Teli *et al*., 2017). Prolonged exposure to thermally uncomfortable outdoor environments has been linked to fatigue, dehydration, irritability, reduced concentration, and decreased participation in outdoor activities, all of which can negatively influence learning performance and overall well-being (Lan *et al*., 2017).

1.1.2 To quantify outdoor thermal comfort, researchers have developed indices that integrate meteorological variables with human physiological responses. The Physiological Equivalent Temperature (PET) and the Universal Thermal Climate Index (UTCI) are among the most widely applied indices in outdoor thermal comfort studies. PET translates outdoor thermal conditions into an equivalent indoor temperature that reflects human thermal perception, while UTCI accounts for dynamic physiological responses to changing environmental conditions (Matzarakis *et al*., 2018). Studies conducted in school courtyards and playgrounds in Mediterranean and Asian cities have shown that shaded areas, vegetation cover, and enhanced airflow significantly reduce PET and UTCI values, leading to improved thermal comfort for pupils (Makaremi *et al*., 2016; Lai *et al*., 2019). However, the majority of existing outdoor thermal comfort studies are situated in temperate or subtropical climates, where thermal stress patterns differ significantly from those in humid tropical environments. Tropical cities experience limited diurnal temperature variation, high moisture content in the air, and reduced evaporative cooling potential, which intensify discomfort even at moderate temperatures (Emmanuel, 2018). As a result, thermal comfort thresholds derived from non-tropical contexts may not accurately reflect school pupils' experiences in cities such as Benin City.

In Nigeria, thermal comfort research has predominantly focused on indoor environments, particularly in residential and office buildings, due to the widespread reliance on natural ventilation systems (Oluwafemi & Adebamowo, 2018). While these studies acknowledge the influence of outdoor climate on indoor comfort, they rarely examine outdoor school environments directly. Despite evidence that Nigerian pupils spend a substantial portion of the school day outdoors, systematic assessment of thermal comfort in primary school playgrounds and courtyards remains limited. In Benin City, urban climate studies have identified increasing

ambient temperatures and urban heat island effects linked to land-use change, reduced vegetation cover, and expanding impervious surfaces (Efe & Eyefia, 2019). However, these studies do not specifically address how such climatic trends affect thermal comfort within primary school environments, revealing a critical research gap addressed by this study's first objective.

2.3.2 Green Building Design Features and Outdoor Environmental Quality

Green building design strategies have gained global recognition as effective approaches for enhancing environmental quality and mitigating the adverse impacts of urbanisation on microclimate and air quality. In outdoor environments, green design features such as trees, vegetation cover, shading devices, building orientation, and permeable surfaces play a significant role in moderating thermal conditions and improving air quality (Santamouris, 2016). These strategies are particularly relevant in primary school environments, where outdoor spaces serve both recreational and educational functions.

Trees and vegetation contribute to outdoor thermal regulation through shading and evapotranspiration, reducing surface and air temperatures while improving thermal comfort in open spaces. Empirical studies have demonstrated that tree-shaded primary school courtyards can experience temperature reductions of up to 4–6°C compared to unshaded areas, significantly lowering thermal stress for pupils (Bowler *et al*., 2010; Santamouris *et al*., 2018). Shading devices, including canopies, pergolas, and building overhangs, further reduce direct solar radiation and improve outdoor usability during hot periods (Nikolopoulou & Steemers, 2016). In addition to thermal regulation, green building features influence outdoor air quality by modifying airflow patterns and reducing pollutant concentrations. Vegetation acts as a natural filter, trapping particulate matter and absorbing gaseous pollutants, thereby improving air quality in micro-environments such as primary school playgrounds (Abhijith *et al*., 2017). Permeable surfaces reduce heat storage and re-radiation while minimising dust resuspension, which is a common source of particulate pollution in schoolyards (Santamouris, 2016). Despite these documented benefits, the effectiveness of green building features varies according to climatic conditions, urban density, vegetation type, and spatial configuration. In tropical urban environments, poorly planned vegetation can restrict airflow and trap pollutants if not carefully integrated into design (Abhijith *et al*., 2017). This highlights the importance of context-specific evaluation of green design performance rather than reliance on generalised assumptions. In

Nigeria, the adoption of green building principles remains relatively limited, and empirical assessments of their performance are scarce. Existing studies largely focus on residential and commercial buildings, with minimal attention given to educational facilities (Adewunmi *et al*., 2019). Furthermore, comparative studies between green-designed and conventional primary schools are rare, particularly with respect to outdoor microclimatic performance. This gap directly informs the second and third objectives of the present study, which seek to evaluate and compare how green building strategies influence outdoor environmental quality in primary schools within Benin City.

2.3.3 Environmental Quality and Pupil's Psychological and Cognitive Experience

The relationship between environmental quality and pupils' psychological and cognitive development has been extensively examined within environmental psychology and educational research. Exposure to adverse environmental conditions, including excessive heat and poor air quality, has been associated with increased stress, reduced attention span, impaired memory, and diminished academic performance among pupils (Lan *et al*., 2017; Wargocki & Wyon, 2017). Thermal discomfort in particular has been shown to negatively affect pupil's mood, motivation, and willingness to engage in learning activities, especially in physically demanding outdoor settings. Conversely, access to thermally comfortable and environmentally supportive outdoor spaces has been linked to positive psychological and cognitive outcomes. Studies have demonstrated that pupils exposed to green school environments exhibit improved attention restoration, reduced stress levels, and enhanced emotional regulation (Dadvand *et al*., 2015; Chawla *et al*., 2018). These benefits are consistent with Biophilic Design Theory, which emphasises the restorative effects of natural elements on human cognition and wellbeing (Kellert, 2018).

In school contexts, outdoor spaces that are comfortable, shaded, and visually green encourage physical activity, social interaction, and experiential learning, all of which contribute to holistic educational development. However, in many urban African and Nigerian schools, outdoor environments are poorly designed, characterised by extensive hard surfaces, limited vegetation, and high exposure to heat and pollution. Such conditions create environmentally stressful settings that discourage outdoor use and undermine the educational potential of primary school open spaces (Amegah & Agyei-Mensah, 2017). This situation reinforces the need for an

integrated approach to sustainable primary school design that considers environmental performance, architectural quality, and pupils' psychological needs simultaneously. By linking outdoor environmental quality to pupils' comfort, wellbeing, and learning experiences, this study aligns with the fourth objective of developing evidence-based recommendations for healthier, resilient, and child-friendly primary school environments in tropical urban contexts such as Benin City.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 INTRODUCTION

Research methodology is essential in ensuring a structured and systematic approach to investigating the thermal comfort and outdoor air quality in primary schools in Benin City. This study adopts a purely qualitative research methodology, focusing on descriptive and interpretative analysis to green-designed primary schools. The research relies on primary and secondary data sources. Primary data is obtained through semi-structured interviews and observations, capturing insights from Pupils, teachers, and school administrators in these primary schools. Secondary data includes academic journals, books, published reports, and case studies, which provide theoretical and contextual grounding for the research (Silverman, 2022). The study's population consists of residents and construction professionals in Benin City, ensuring that expert and public opinions are well represented (Denzin & Lincoln, 2020).

3.2 RESEARCH DESIGN

This study adopts a descriptive and comparative research design. The descriptive approach is used to assess existing outdoor air quality and thermal comfort conditions within selected primary school environments, while the comparative approach enables systematic comparison between green-designed primary schools and conventional primary schools in Benin City. This mixed approach is appropriate because the study seeks to both document current environmental conditions and evaluate the effectiveness of green design strategies in moderating outdoor microclimates and improving pupil comfort and well-being. The research design integrates environmental measurements, building and site assessment, and human-centred evaluation, consistent with the interdisciplinary nature of the study, which links building design, environmental performance, and pupils' psychological experience.

3.3 DATA TYPES AND SOURCES

The study relies on primary data, supported by limited secondary data. Primary data include environmental measurements taken within school premises and direct observation of outdoor space usage. Secondary data include climatic records and relevant planning information for Benin City.

3.3.1 Outdoor Air Quality Measurement

Outdoor air quality is assessed within school playgrounds, courtyards, and surrounding open spaces using portable air quality monitoring devices. Measurements focus on key pollutants commonly associated with urban environments and pupils' health, including:

- Particulate matter ($PM_{2.5}$ and PM_{10})
- Carbon monoxide (CO)
- Nitrogen dioxide (NO_2), where equipment availability permits

Measurements are taken at child-breathing height during school hours to reflect pupils' actual exposure conditions. Multiple readings are recorded at different times of the day to account for temporal variation. This method directly addresses Research Question I, which examines how outdoor air quality varies around green-designed primary schools in Benin City.

3.3.2 Outdoor Thermal Comfort Assessment

Outdoor thermal comfort is assessed by measuring key microclimatic parameters, including air temperature, relative humidity, wind speed, and solar radiation, using handheld weather instruments. Measurements are conducted in different outdoor zones within each primary school, such as open playgrounds, shaded courtyards, and vegetated areas. Thermal comfort indices, including the Physiological Equivalent Temperature (PET) or simplified thermal stress indicators, are used to interpret the measured data in relation to pupils' physiological comfort. This assessment responds directly to Research Question II**,** which investigates prevailing outdoor thermal comfort conditions in primary school environments.

3.3.3 Building and Site Design Assessment

A structured observational checklist is used to document green building and site design features present in each primary school. These features include:

- Tree density and vegetation coverage
- Presence and type of shading devices
- Surface materials (permeable or impervious)
- Building orientation and spacing

This assessment enables comparison between green-designed and conventional primary schools,

addressing Research Question III on the influence of green design strategies on outdoor air quality and thermal comfort.

3.3.4 Observation of Pupil Use of Outdoor Spaces

Non-intrusive observations are conducted to assess how pupils use outdoor spaces under different environmental conditions. Observations focus on duration of outdoor stay, activity intensity, and preference for shaded or vegetated areas. These observations provide contextual insight into the implications of environmental conditions for pupil comfort and well-being, supporting Research Question IV**.**

3.4 RESEARCH POPULATION

The population of the study comprises all primary schools in Benin City, Edo State**.** This includes both public and private primary schools with varying building typologies, site layouts, and levels of green design integration. Pupils, teachers, and school administrators form part of the human environment considered in the study, although direct physiological testing of pupils is excluded for ethical reasons.

3.5 RESEARCH SAMPLE SELECTION AND SAMPLING TECHNIQUE

A purposive sampling technique is adopted to select representative case-study schools. The sample consists of:

- Selected green-designed primary schools, identified based on the presence of vegetation, shaded outdoor spaces, permeable surfaces, and climate-responsive site planning
- Selected conventional primary schools, characterised by limited greenery, extensive hard surfaces, and minimal shading.

Schools are selected to ensure variation in location within Benin City, proximity to roads, and urban density, allowing for meaningful comparison of outdoor environmental conditions.

3.6 METHOD OF DATA ANALYSIS

Quantitative data collected from air quality and thermal measurements are analysed using descriptive statistics, including mean values, ranges, and comparative analysis between primary school types. Graphs and tables are used to illustrate spatial and temporal variations in

environmental conditions. Comparative analysis is conducted to identify statistically and practically significant differences between green-designed and conventional primary schools. Observational data are analysed thematically to support the interpretation of quantitative findings and to link environmental conditions with behavioural responses.

Research Question	Data Required	Method of Data Collection	Method of Data Analysis
RQ I: How does outdoor air quality vary around green-designed primary schools in Benin City?	Levels of outdoor air pollutants ($PM_{2.5}$, PM_{10}, CO, NO_2), location characteristics	On-site air quality measurements using portable air quality monitors at play grounds, courtyards, and school surroundings	Descriptive statistics (mean, range), comparison between green-designed and conventional schools using tables and charts
RQ II: What are the prevailing outdoor thermal comfort conditions in primary school environments in Benin City?	Air temperature, relative humidity, wind speed, solar exposure	Field measurements using handheld weather instruments at different outdoor zones and times of day	Calculation and interpretation of thermal comfort indicators (e.g., PET), descriptive and comparative analysis
RQ III: How do green building design features influence outdoor air quality and thermal comfort in primary school environments?	Presence of trees, vegetation cover, shading devices, surface materials, building orientation	Structured site observation checklist and photographic documentation	Comparative analysis linking design features with measured air quality and thermal comfort data
RQ IV: What are the implications of	Pupil outdoor space usage patterns,	Non-intrusive observation of pupils'	Thematic interpretation supported by

Research Question	Data Required	Method of Data Collection	Method of Data Analysis
outdoor environmental quality for children's comfort and wellbeing in school environments?	preference for shaded/green areas	activities and spatial behavior	environmental data trends and descriptive analysis

Table 4.1: Mapping of research questions to data collection and analysis methods

1.1.3

3.7 ETHICAL CONSIDERATIONS

Ethical considerations are observed throughout the study. Permission is obtained from primary school authorities before conducting measurements. No personal data is collected from pupils, and no invasive or harmful procedures are involved. Observations are conducted in a non-disruptive manner, ensuring the safety and privacy of all participants.

3.8 LIMITATIONS OF THE METHODOLOGY

The study is limited by the availability of monitoring equipment and the duration of field measurements, which may not capture long-term seasonal variations. However, by collecting data during active school periods and comparing multiple school types, the methodology provides reliable insight into typical outdoor environmental conditions experienced by pupils in Benin City.

Data Collection Instruments

The study will employ both visual and survey-based data collection instruments to obtain comprehensive and reliable data. The instruments include Photo voice and a structured survey questionnaire. Photo voice will be used to visually document green building design features and outdoor environmental conditions within selected school environments in Benin City, Edo State. Photographs of buildings, courtyards, playgrounds, vegetation, shading elements, and surrounding spaces will be captured using digital devices and organised using online or paper-based formats for analysis.

A self-administered survey questionnaire will also be developed to obtain perceptual data from

teachers and school administrators regarding outdoor thermal comfort, air quality, and pupils' responses to the outdoor environment. The questionnaire will be administered either online using platforms such as Google Forms or in paper-based format, depending on internet accessibility. Prior to full deployment, the questionnaire will be pilot-tested to ensure clarity, validity, and reliability.

CHAPTER FOUR

4.0 ANALYSIS, FINDINGS AND DISCUSSION

4.1 INTRODUCTION TO DATA PRESENTATION AND ANALYSIS

This chapter presents, analyzes, and discusses the data collected from a field survey conducted among pupils across the selected Primary schools in Benin City. A total of 100 questionnaires were administered, supplemented with direct observations and informal qualitative interviews. Following this, the chapter is structured into thematic sections capturing socio-demographic characteristics, current physical conditions, cultural elements, user perceptions, challenges facing the air quality and thermal comfort in line with the green-designed areas of Primary schools in Benin City. The goal is to connect data with the study objectives and provide evidence-based insights necessary for proposing a revitalization model. Ultimately, the analysis provides a foundation for the conclusions and recommendations presented in the final chapter.

4.2 DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

This section takes a closer look at the people who took part in the survey, exploring details like the name of the school, the location and the approximate year in which the school was established. Understanding who these respondents are helps us make better sense of their responses. After all, the way people view green-designed areas & their perception can vary widely depending on their background. By considering these differences, we gain a richer and more meaningful understanding of how the outdoor air quality and thermal comfort within the primary school relate to the green-designed areas and overall urban sustainability. The survey attracted a diverse group of participants, representing a wide range of schools and green designed features.

A. Gender

Out of 103 respondents, 57.3% were female, 41.7% were male, and a small fraction preferred not to disclose their gender. This reflects the gendered nature of market participation in Benin City, where women traditionally dominate trading activities. The data supports the need for gender-inclusive revitalization strategies that prioritize female traders' safety, access, and empowerment. Respondents were distributed across age groups as follows: 32% were aged 18–25, 15.5% were

4.3 INTERPRETATION OF OPINION-BASED SURVEY RESPONSES

This section offers a comprehensive interpretation of the 20 opinion-based questions, organized according to the study's research questions and objectives.

4.3.1 Research Question One: What is the School's Building and Site Design?

A. Green Design Features

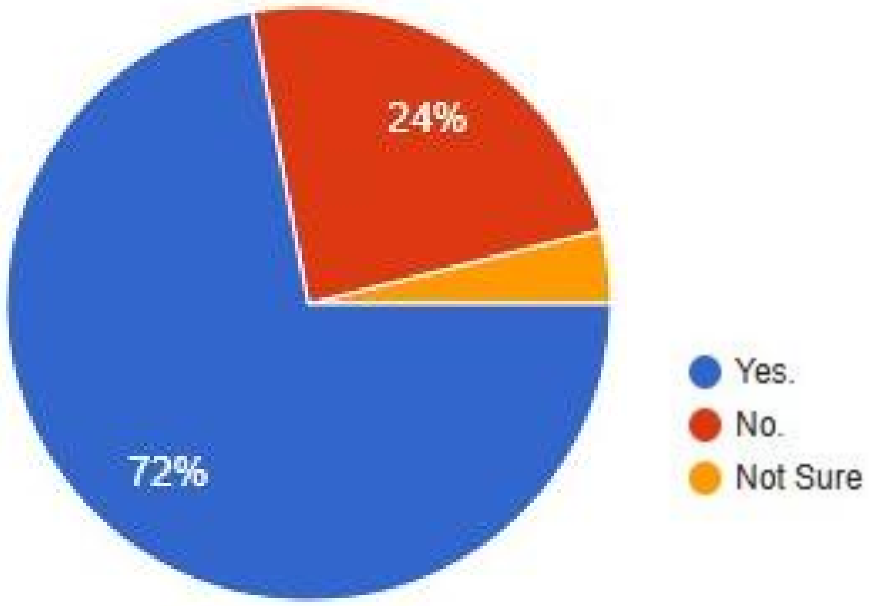
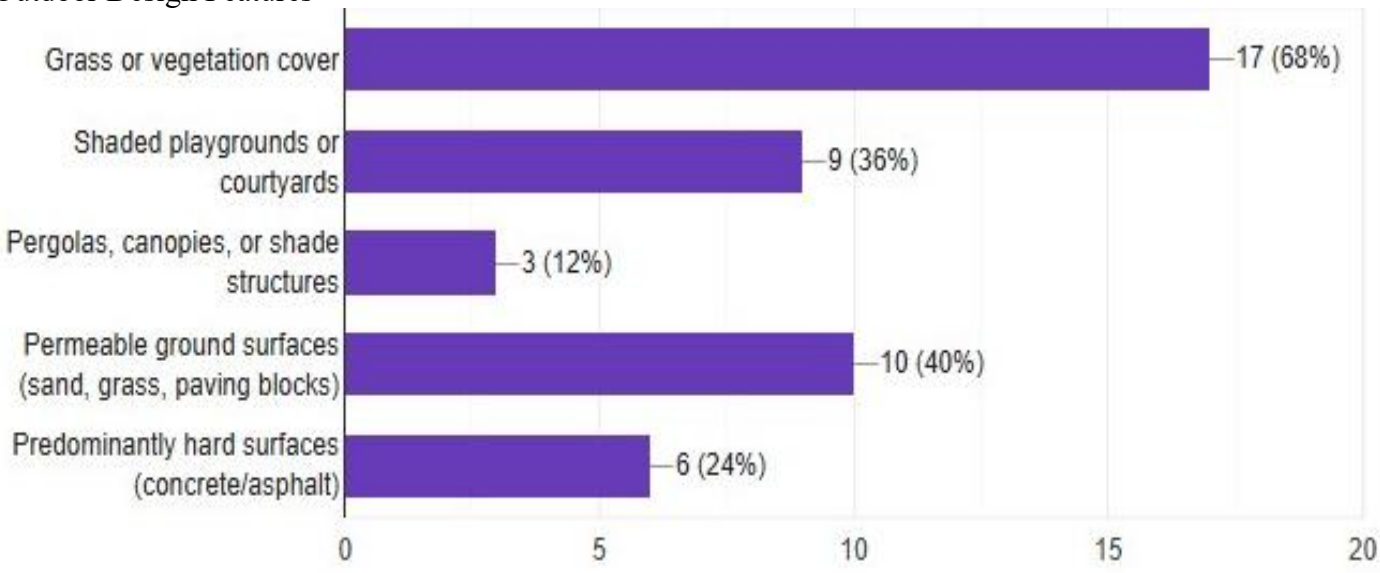


Figure 4.1: Pie Chart showing intentional green design features of primary schools of respondents
Source: Researcher field work, 2026

Majority of respondents confirmed that their schools possess green design elements such as trees, landscaping, and shaded courtyards. Approximately 72% of respondents answered "Yes," while a smaller percentage indicated "No" or "Not sure." This suggests that many of the selected schools have incorporated environmental design strategies intended to improve outdoor environmental quality. The widespread presence of trees and landscaping indicates growing awareness among school administrators and planners about the importance of sustainable and climate-responsive school environments. The significance of this finding lies in the role green design features play in reducing heat accumulation, improving air circulation, filtering airborne pollutants, and creating more comfortable outdoor spaces for pupils. Trees and vegetation can reduce surface temperatures through shading and evapotranspiration, while landscaped areas contribute to improved environmental aesthetics and psychological wellbeing. However, the percentage of respondents who indicated the absence of such features reveals that some schools still lack adequate green infrastructure. This implies unequal access to environmentally

supportive learning spaces across schools in Benin City. Overall, the chart demonstrates that green design features are increasingly recognized as important components of sustainable educational environments.

B. Outdoor Design Features



2 Figure 4.2: **Bar Chart showing Outdoor Design Features present in the primary schools of respondents**
Source: Researcher field work, 2026

Grass or vegetation cover recorded the highest response frequency, followed by shaded playgrounds and permeable ground surfaces. Pergolas and other artificial shade structures recorded the lowest responses. This indicates that natural landscape elements are more common than constructed shading systems within the school environments studied. The dominance of vegetation cover suggests that schools rely more on natural methods of environmental moderation rather than advanced architectural shading devices. The presence of vegetation and shaded playgrounds is highly beneficial because they reduce direct solar exposure and lower outdoor temperatures. Permeable surfaces also help reduce heat retention compared to concrete or asphalt surfaces. The low presence of pergolas and artificial shade structures may be linked to financial limitations, inadequate planning, or lack of awareness regarding their environmental benefits. This suggests that while schools attempt to integrate green features, the implementation may still be incomplete. This findings support the argument that outdoor environmental quality can be improved through strategic site planning and the incorporation of both natural and artificial shading systems.

C. Amount of Greenery

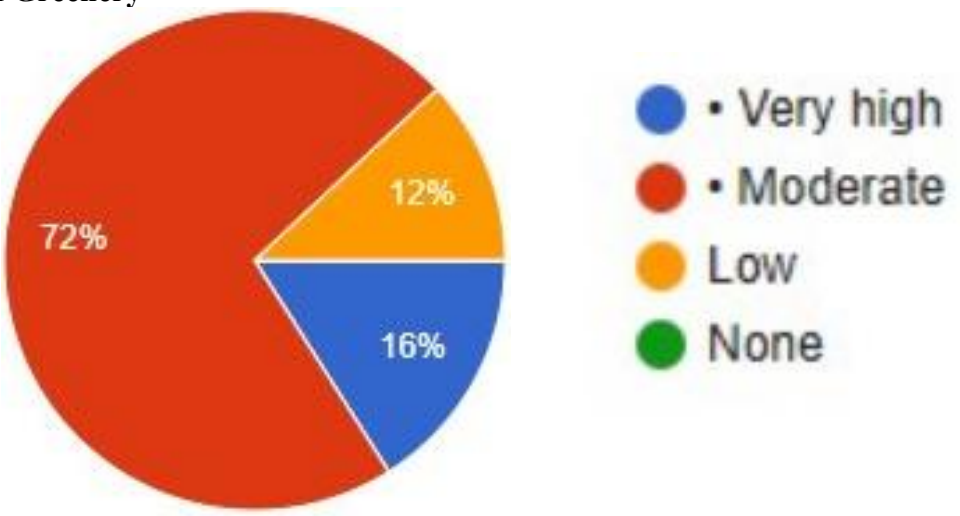


Figure 4.3: Pie Chart showing how respondents describe the amount of greenery in the primary school
Source: Researcher field work, 2026

A large proportion of respondents rated the greenery level in their school environment as "Moderate," while fewer respondents selected "Very high," "Low," or "None." This result suggests that although greenery exists in most schools, the quantity may not yet be sufficient to create optimal outdoor environmental conditions. Moderate greenery can provide some level of cooling and air purification, but it may not fully offset the effects of urban heat and pollution. The limited number of respondents who selected "Very high" indicates that extensive landscaping and dense vegetation are not common features in most schools. This may be due to space constraints, maintenance challenges, or inadequate funding. Greenery is an important environmental factor because plants absorb pollutants, trap dust particles, and reduce heat through shading. Schools with higher levels of greenery are more likely to provide healthier and more comfortable environments for children. The findings imply that increasing vegetation density in school compounds could significantly enhance outdoor thermal comfort and air quality conditions.

Most respondents agreed that outdoor activity areas are directly exposed to sunlight during the day, while only a smaller percentage indicated partial or no exposure. This shows that many playgrounds, assembly grounds, and recreational spaces lack adequate shading protection. Continuous exposure to direct sunlight contributes to increased outdoor temperatures and thermal discomfort among pupils. The implication is that pupils may experience heat stress during outdoor activities, especially within the hot tropical climate of Benin City. Excessive heat

exposure can lead to fatigue, dehydration, reduced concentration, and discomfort. This result also suggests that many school outdoor spaces are not adequately designed to respond to climatic conditions and further reinforces the importance of climate-responsive school planning and the need for additional shaded outdoor space However, Proper orientation of buildings, strategic tree planting, and the installation of shading devices could significantly reduce direct solar exposure.

D. Exposure to Sunlight

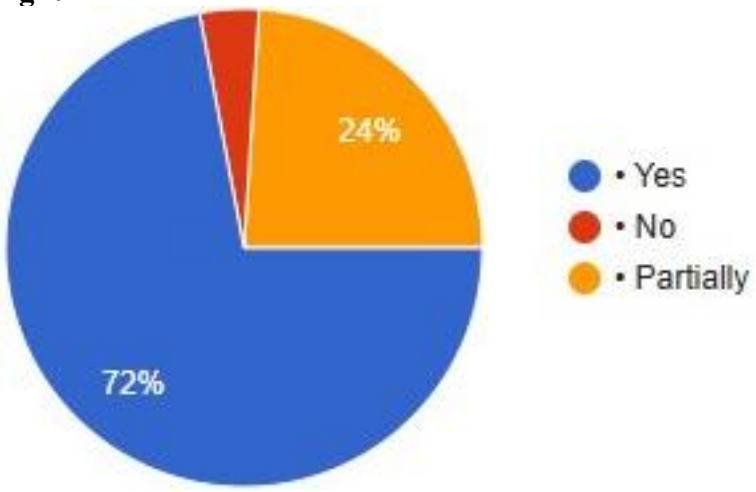
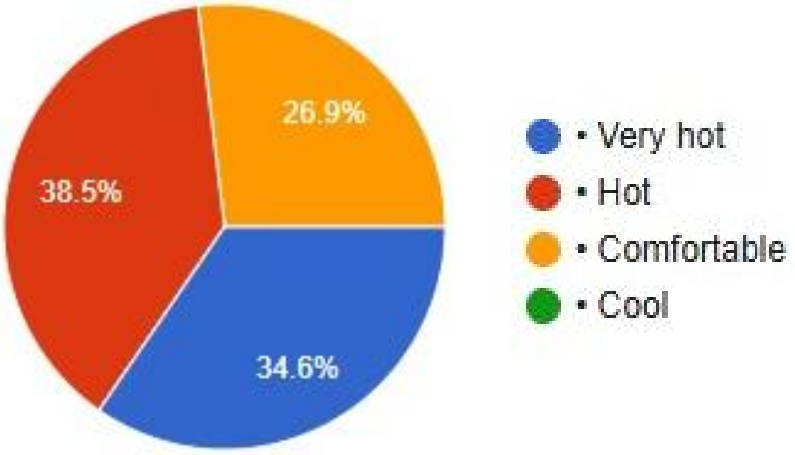


Figure 4.4: Pie Chart showing exposure of outdoor activity areas directly to sunlight
Source: Researcher field work, 2026

4.3.2 Research Question Two: What is the School's Outdoor Thermal Comfort?

A. Temperature conditions



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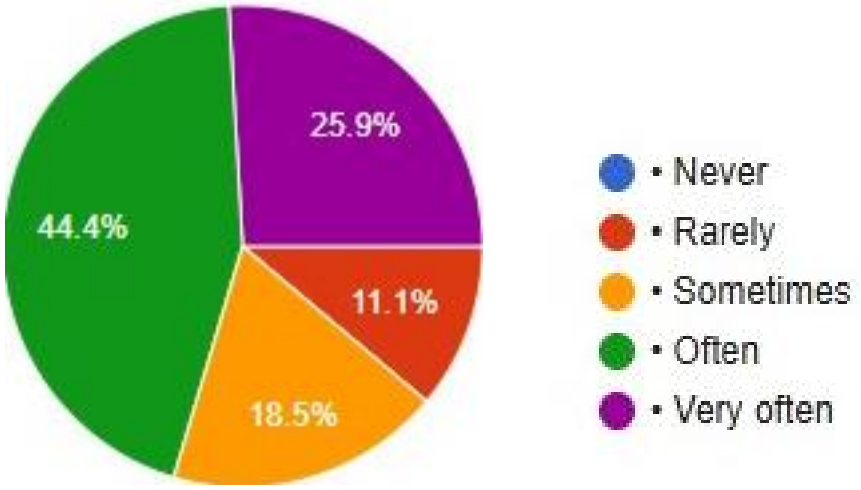
4 Figure 4.5: **Pie Chart showing how respondents description of the outdoor temperature conditions during school hours**

Source: Researcher field work, 2026

Most respondents described the school environment as either "Hot" or "Very hot," while only a few respondents considered the conditions comfortable. This indicates that outdoor thermal

conditions in many primary schools are unfavorable during school hours. The predominance of hot conditions reflects the combined effects of high solar radiation, inadequate shading, urban heat accumulation, and limited vegetation cover. High outdoor temperatures negatively affect children's comfort and wellbeing. Pupils exposed to excessive heat may become physically stressed, less active, and less attentive during learning activities. These are consistent with existing studies on tropical urban environments, which emphasize, that poor thermal conditions in schools can affect academic performance, health, and behaviours. This also highlights the urgent need for environmental interventions such as increased tree planting, reflective materials, shaded walkways, and improved site landscaping to reduce outdoor heat stress.

B. Hot Weather



5 Figure 4.6: **Pie Chart showing how often respondents complain about outdoor heat during hot weather**
Source: Researcher field work, 2026

Majority of respondents indicated that outdoor activities are sometimes reduced or rescheduled because of excessive heat. This demonstrates the practical impact of thermal discomfort on school operations. Heat conditions are severe enough to disrupt outdoor activities such as sports, assemblies, and recreational programs. The reduction of outdoor activities can negatively affect pupils' physical development, social interaction, and overall educational experience. Outdoor play is essential for children's health, creativity, and cognitive growth. The findings indicate that school environments lacking thermal protection may restrict opportunities for outdoor engagement. This emphasizes the importance of designing school compounds that remain thermally comfortable throughout the day. The chart further supports the argument that climate-responsive design strategies are necessary for sustainable educational environments.

C. Outdoor Activities

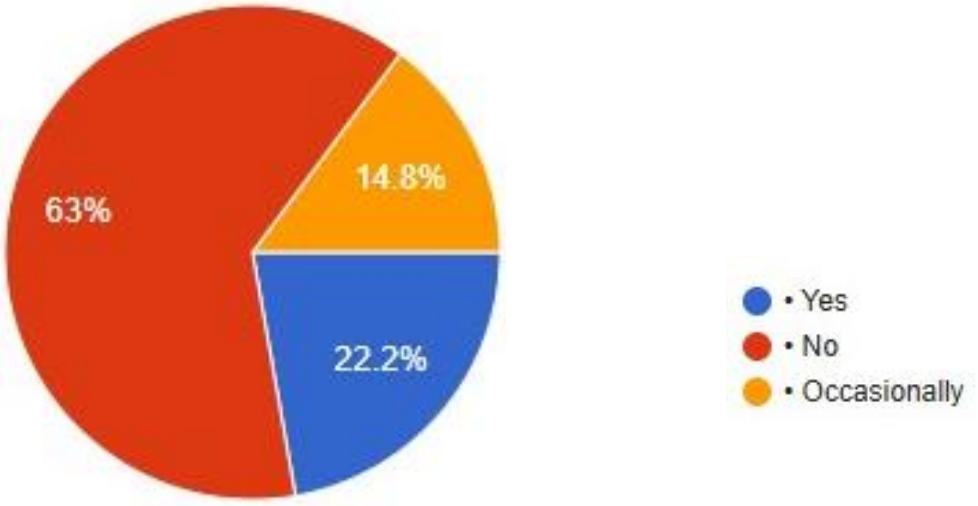


Figure 4.7: Pie Chart showing reduction or reschedule of outdoor activities due to heat
Source: Researcher field work, 2026

D. Outdoor Areas

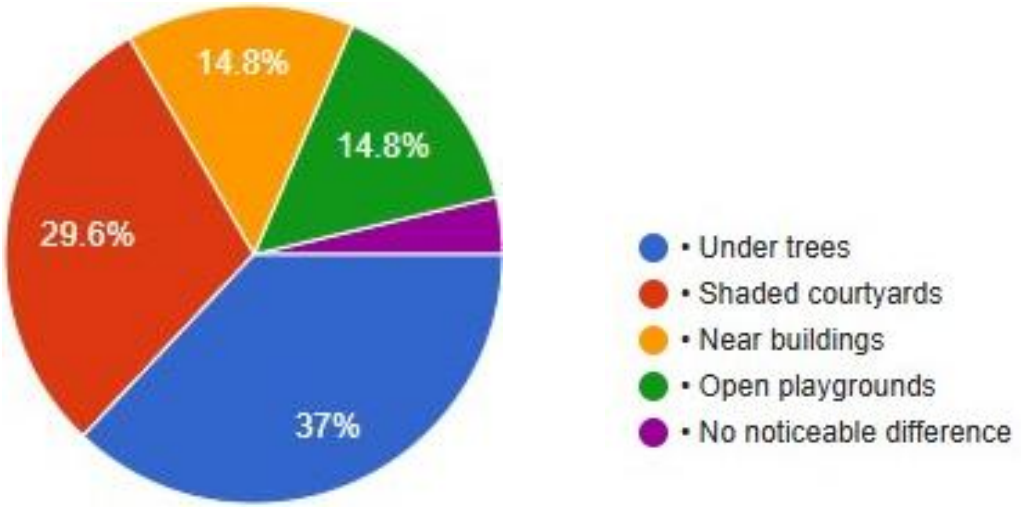


Figure 4.8: Pie Chart showing outdoor areas that are more comfortable for pupils
Source: Researcher field work, 2026

Areas under trees and shaded courtyards were identified as the most comfortable outdoor spaces for pupils, while open playgrounds received lower responses. This clearly demonstrates the environmental value of natural shading elements in school environments. Trees and shaded spaces create cooler microclimates by reducing direct solar radiation and improving air movement. The preference for shaded spaces suggests that pupils naturally seek environments that provide thermal relief and comfort. This aligns with environmental psychology theories which state that people gravitate toward spaces that promote physical and psychological wellbeing. The lower preference for open playgrounds indicates that unshaded spaces may be too

hot and uncomfortable for prolonged use. This result confirms that green design features significantly improve outdoor comfort conditions and should be prioritized in school planning and landscape design.

4.3.5 Research Question Three: What is the School's Outdoor Air Quality?

A. Outdoor Air Quality

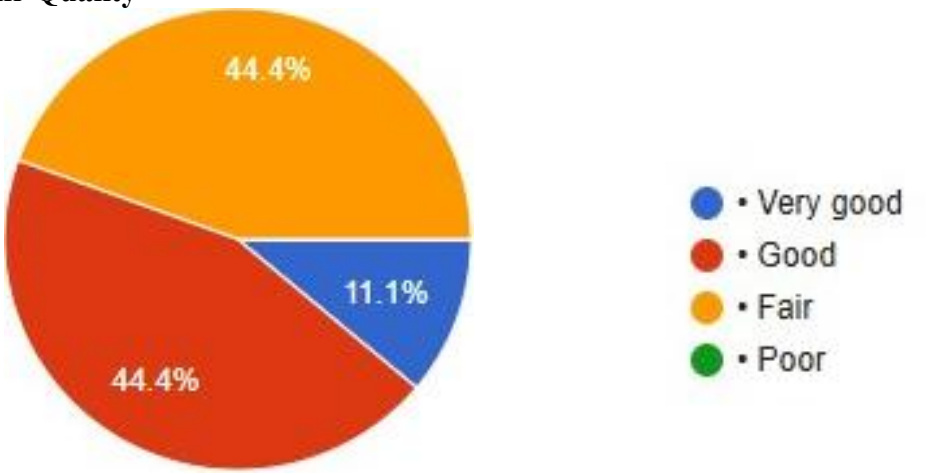


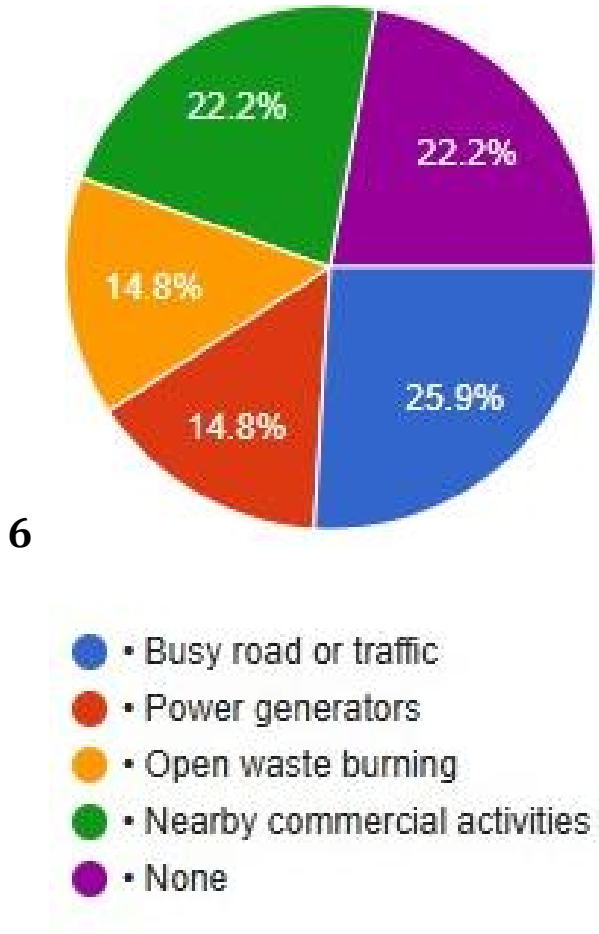
Figure 4.9: Pie Chart showing the rating of the general outdoor air quality around school
Source: Researcher field work, 2026

Many respondents rated the air quality as "Fair" or "Good," while fewer respondents considered it "Very good" or "Poor." This suggests that although outdoor air conditions are relatively acceptable in some schools, there are still concerns regarding environmental pollution and air cleanliness. The moderate air quality ratings may be influenced by nearby traffic, generator use, dust, and commercial activities commonly found within urban environments. Benin City's rapid urbanization may contribute to increasing pollutant concentrations around school environments. The presence of green features may help improve air quality by filtering pollutants and trapping airborne particles. However, the findings indicate that these measures may not completely eliminate environmental pollution. This also demonstrates the need for stronger environmental management practices around schools, particularly through traffic control, reduction of open waste burning, and increased vegetation cover.

The chart reveals that busy roads, traffic congestion, generators, and nearby commercial activities are major sources of pollution around the schools. This highlights the environmental challenges facing urban primary schools in Benin City. Vehicular emissions and generator fumes contribute significantly to poor air quality and expose pupils to harmful pollutants. The

implication is that schools located near busy roads may experience higher levels of dust, smoke,

B. Air Pollution



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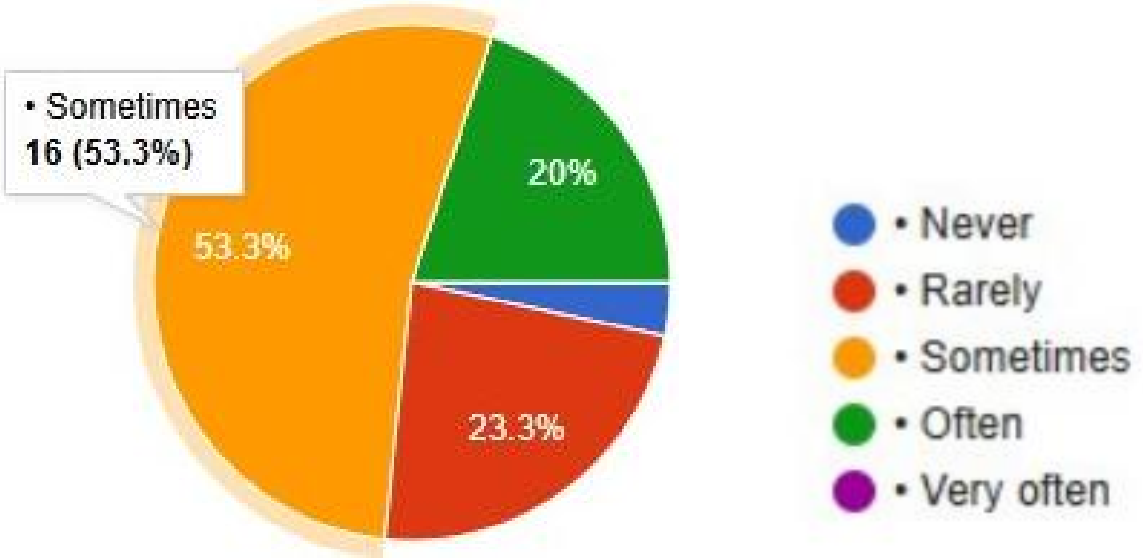
7 Figure 4.10: **Pie Chart showing noticeable sources of air pollution near the school**
Source: Researcher field work, 2026

and gaseous pollutants. Long-term exposure to polluted air can negatively affect children's respiratory health and cognitive performance. The finding also reflects broader urban environmental problems associated with rapid urbanization, inadequate power supply, and mixed land-use patterns. This also emphasizes the importance of proper school site selection and the integration of vegetation barriers that can help reduce pollutant exposure.

C. Observation



8 Figure 4.11: **Pie Chart showing how often respondents observe dust, smoke or unpleasant odors within the school**
Source: Researcher field work, 2026

When asked how often dust, smoke or unpleasant odors are observed within the school, many respondents agreed "Sometimes" and "Often". This confirms that outdoor air pollution is a recurring environmental issue in the schools studied. Dust and smoke may originate from nearby roads, construction activities, waste burning, or generator use. The presence of unpleasant odours suggests poor environmental sanitation and inadequate control of pollution sources. Such conditions can negatively affect pupils' health, comfort, and concentration. Exposure to polluted outdoor air has been associated with respiratory illnesses, allergies, and reduced academic performance. This finding demonstrates the need for environmental monitoring and pollution control strategies within and around school environments.

4.3.5 Research Question Four: How are the Pupils' Comfort and Well-being?

A. Comfort

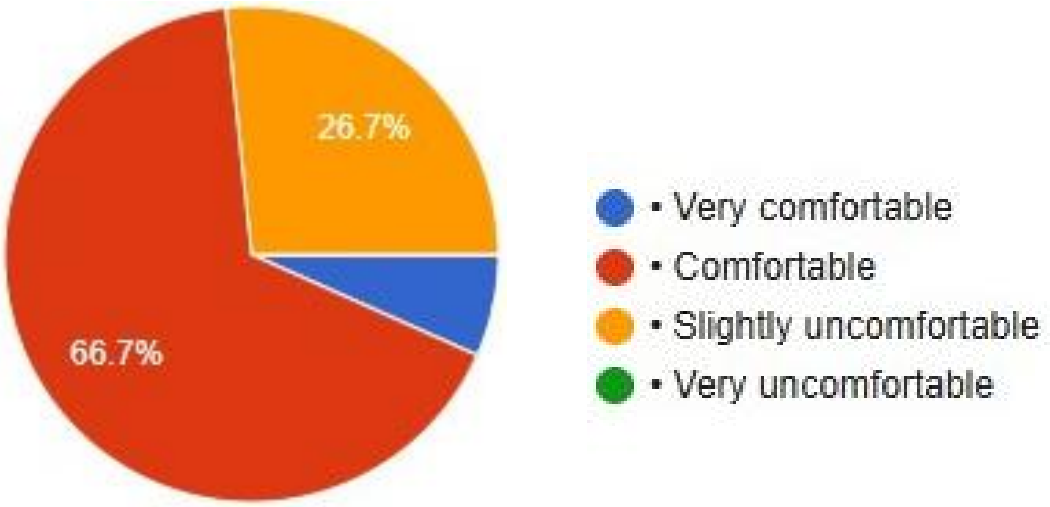


Figure 4.12: **Pie Chart showing how comfortable respondents appear during outdoor activities**
Source: Researcher field work, 2026

Most respondents described pupils as "Comfortable" during outdoor activities, while fewer respondents considered them "Very comfortable" or "Very uncomfortable." This suggests that although thermal discomfort exists, pupils may still adapt to environmental conditions to some extent. However, the relatively lower percentage of "Very comfortable" responses indicates that the outdoor environment is not fully optimized for comfort. The findings may reflect the influence of existing green features that provide partial environmental moderation. Comfort during outdoor activities is important because it influences children's willingness to participate in physical exercise, recreation, and social interaction. This also implies that improving environmental conditions through additional shading and landscaping could significantly

enhance pupils' outdoor experiences.

B. Heat or Discomfort

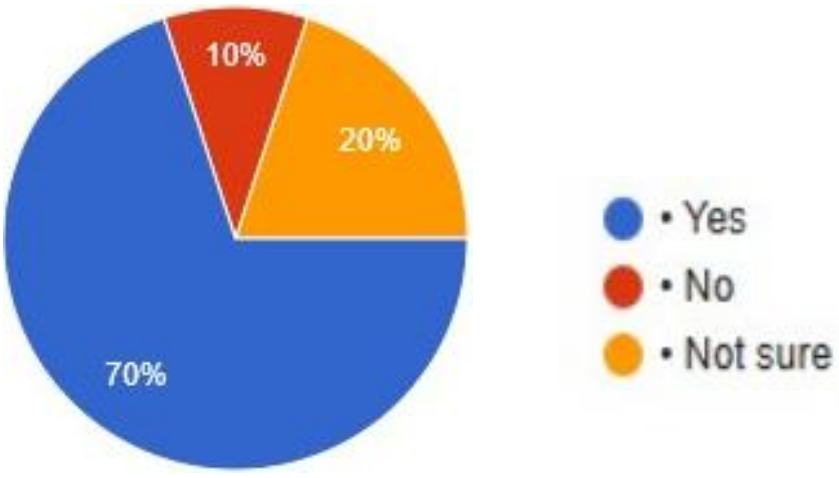


Figure 4.13: Pie Chart showing pupils tend to avoid outdoor areas due to heat or discomfort
Source: Researcher field work, 2026

A large percentage of respondents agreed that pupils avoid certain outdoor areas because of heat or discomfort. This indicates that thermal discomfort directly influences how outdoor spaces are used within school environments. Pupils naturally avoid excessively hot or exposed spaces and prefer cooler, shaded areas. The implication is that some outdoor spaces may become underutilized due to poor environmental design. The result also demonstrates the importance of environmental comfort in shaping children's spatial behavior and movement patterns. This finding also suggests that school designers should prioritize the creation of thermally comfortable spaces that encourage active outdoor use.

C. Outdoor Spaces

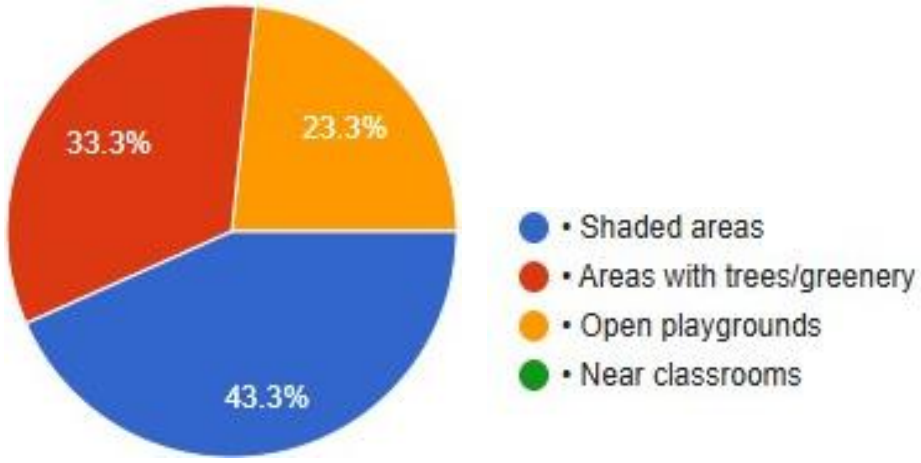


Figure 4.14: Pie Chart showing the outdoor spaces pupils prefer most
Source: Researcher field work, 2026

Shaded areas and spaces with trees or greenery are the most preferred outdoor environments among pupils. This finding reinforces the idea that natural elements strongly influence comfort and environmental satisfaction. Green spaces provide cooling effects, visual relief, and psychological comfort. The preference for shaded and vegetated areas indicates that pupils associate these spaces with safety, relaxation, and enjoyment. The result supports previous studies emphasizing the importance of biophilic and nature-based design strategies in educational environments. This chart demonstrates that integrating greenery into school environments can improve both environmental quality and user satisfaction.

D. Environmental Comfort

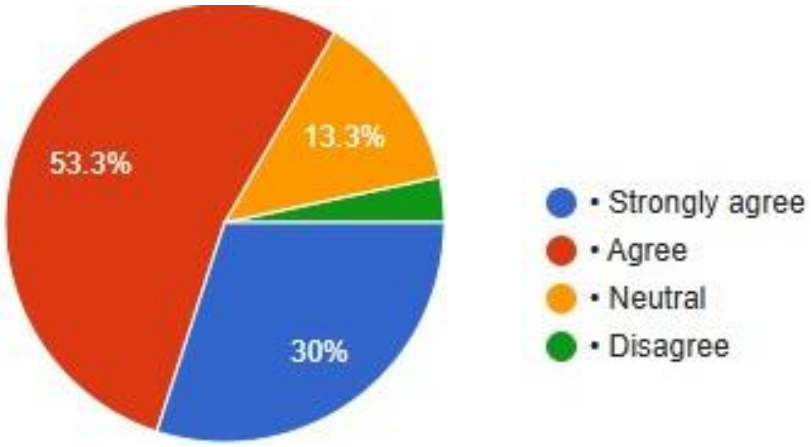


Figure 4.15: Pie Chart showing that the outdoor environmental comfort affects pupils behavior and attention
Source: Researcher field work, 2026

When asked that outdoor environmental comfort affects pupils' behavior and attention, most respondents responded either "Strongly agree" or "Agree". This finding demonstrates the strong relationship between environmental conditions and children's cognitive and behavioral performance. Comfortable outdoor environments can improve concentration, reduce stress, encourage positive social interaction, and enhance learning experiences. Conversely, excessive heat and pollution can contribute to irritation, fatigue, and reduced attentiveness. This result supports environmental psychology theories and existing research linking environmental quality to academic performance and wellbeing. This chart also highlights the educational importance of designing school environments that promote both physical and psychological comfort.

4.3.5 Research Question Five: What is the Pupils' Perception?

A. Outdoor Environment

Many respondents rated their school outdoor environment as "Better" or "About the same"

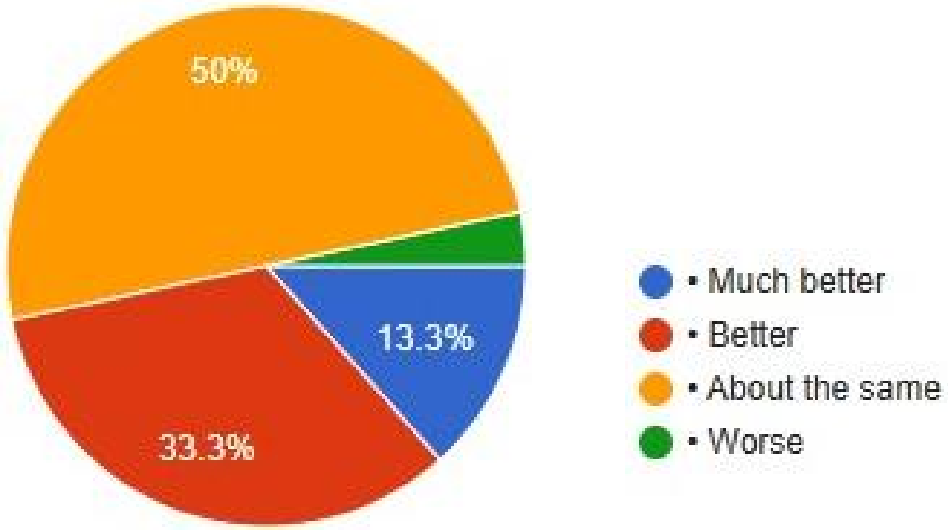


Figure 4.16: Pie Chart showing how respondents rate their school's outdoor environment
Source: Researcher field work, 2026

compared to other schools. This suggests that while some improvements have been achieved, many schools still face similar environmental challenges. The result indicates that environmental quality differences between schools may not be very significant, possibly because urban climatic and pollution conditions affect most schools within the city. However, schools with greener environments may still provide relatively better comfort conditions than schools dominated by hard surfaces and limited vegetation. This chart also suggests the need for broader city-wide implementation of sustainable school design strategies.

B. Comfort Outdoors

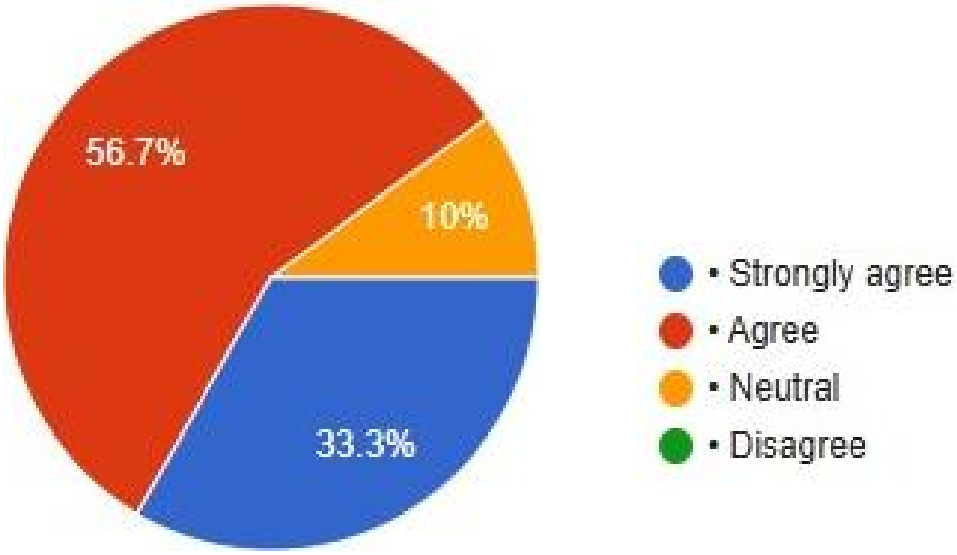


Figure 4.17: Pie Chart showing green elements improves pupil's comfort outdoors
Source: Researcher field work, 2026

Majority of respondents strongly believe that green design elements improve pupils' outdoor comfort. This finding confirms public awareness of the environmental and psychological benefits of green infrastructure in schools. Green design features such as trees, landscaping, shaded courtyards, and permeable surfaces contribute significantly to reducing heat stress and improving environmental quality. The strong positive perception also suggests that sustainable design strategies are socially accepted and valued by users of the school environment. The chart therefore supports the central argument of the study that green-designed school environments can positively influence outdoor air quality, thermal comfort, and pupils' wellbeing.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY OF THE STUDY

This study critically examined outdoor air quality and thermal comfort in green-designed primary schools within Benin City, Edo State, Nigeria, with the aim of understanding how environmental conditions in outdoor school spaces affect pupils' health, comfort, and overall learning experience. The research emerged from the growing global and local concern that children, due to their physiological vulnerability, are significantly affected by poor air quality and thermal stress, especially in school environments where they spend a substantial portion of their day both indoors and outdoors. The study also established that while much attention has traditionally been placed on indoor environmental quality, outdoor spaces such as playgrounds, courtyards, and assembly areas are equally important. These spaces serve as active zones for physical activity, social interaction, and informal learning, making them critical to pupils' wellbeing. However, in rapidly urbanising cities like Benin City, these outdoor environments are increasingly exposed to environmental stressors such as vehicular emissions, generator fumes, dust, and rising temperatures associated with urban heat island effects. Through a comprehensive review of global, continental, national, and local literature, the study identified a significant research gap, particularly in the Nigerian context, where limited empirical data exists on outdoor environmental conditions in school settings. While green building strategies have been widely promoted as solutions for improving environmental quality, their actual effectiveness in tropical school environments remains underexplored. This gap formed the foundation for the study's core investigation.

The research adopted a descriptive and comparative design, combining quantitative environmental measurements with qualitative observations. Selected green-designed and conventional primary schools in Benin City were studied using purposive sampling to ensure meaningful comparison. Data collection involved measuring key outdoor air pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide, and nitrogen dioxide, alongside microclimatic parameters including temperature, humidity, wind speed, and solar radiation. In addition, observational assessments and structured questionnaires were used to understand how pupils interact with outdoor spaces and how environmental conditions influence their comfort

and behavior. Findings from the study highlight that outdoor environmental conditions in primary schools are highly variable and strongly influenced by site characteristics, proximity to pollution sources, and the presence or absence of green design features. Green-designed schools generally demonstrated improved environmental performance, with vegetation, shading elements, and permeable surfaces contributing to reduced temperatures, better airflow, and lower pollutant concentrations. These features created more comfortable and usable outdoor spaces for pupils. Conversely, conventional school environments characterised by extensive hard surfaces, minimal vegetation, and direct exposure to sunlight were found to experience higher thermal stress and greater exposure to pollutants. Such conditions negatively affect pupils' comfort, often leading to reduced outdoor activity, fatigue, and decreased engagement in learning-related activities.

The study also established a strong link between outdoor environmental quality and pupils' psychological and cognitive experiences. Comfortable and well-designed outdoor environments were associated with increased physical activity, improved mood, and better attention levels, while harsh environmental conditions contributed to discomfort, stress, and reduced participation.

Overall, the research demonstrates that outdoor air quality and thermal comfort are essential components of environmental quality in primary schools and should be given equal consideration as indoor conditions in both design and policy frameworks.

5.2 CONCLUSION

The study concludes that outdoor environmental quality in primary school settings is a critical yet often overlooked determinant of pupils' health, comfort, and educational outcomes in tropical urban environments such as Benin City. The findings reinforce the understanding that children are not only passive occupants of indoor classrooms but active users of outdoor spaces, making their exposure to environmental conditions in these areas highly significant.

A key conclusion drawn from the research is that green building design strategies have a measurable and positive impact on improving outdoor air quality and thermal comfort in school environments. Elements such as trees, vegetation cover, shading devices, and permeable surfaces play a vital role in moderating microclimatic conditions by reducing heat exposure, enhancing airflow, and filtering pollutants. These interventions transform outdoor spaces from

environmentally stressful zones into supportive and restorative environments that promote pupils' wellbeing. However, the study also highlights that the effectiveness of green design is highly context-dependent. Simply introducing vegetation or shading elements without proper planning can limit airflow or create unintended environmental challenges. Therefore, successful implementation requires a holistic and climate-responsive approach that considers local environmental conditions, spatial configuration, and urban context. Another important conclusion is the inadequacy of existing environmental monitoring and regulatory frameworks in addressing outdoor environmental quality in schools. The lack of localized data and school-specific environmental assessments limits the ability of architects, planners, and policymakers to make informed decisions. As a result, many school environments are designed based on generalized standards that may not reflect the realities of tropical urban climates. Furthermore, the study underscores the direct relationship between environmental quality and pupils' psychological and cognitive performance. Exposure to high temperatures and polluted air contributes to fatigue, reduced concentration, and decreased motivation, while access to comfortable and green outdoor environments enhances learning experiences, emotional wellbeing, and social interaction. This reinforces the need to view environmental design not just as a physical or aesthetic concern, but as a fundamental component of educational quality.

In conclusion, improving outdoor air quality and thermal comfort in primary schools is not optional but essential. It is a critical step toward creating healthier, more inclusive, and more effective learning environments in rapidly urbanising cities. The integration of green design principles into school planning and construction offers a practical and sustainable pathway to achieving this goal, but it must be supported by empirical research, policy commitment, and interdisciplinary collaboration.

5.3 RECOMMENDATIONS

Based on the findings and conclusions of this study, it is recommended that a more integrated and evidence-based approach be adopted in the design, planning, and management of primary school environments in Benin City and similar tropical urban contexts. There is a clear need for architects, planners, and developers to prioritise outdoor environmental quality as a fundamental design consideration rather than an afterthought. School layouts should be intentionally designed to incorporate adequate vegetation, strategically placed trees, and well-designed shading

structures that provide protection from direct solar radiation while maintaining proper airflow. In addition, landscape design should go beyond aesthetic considerations and function as a critical environmental control system. The selection of plant species, density of vegetation, and spatial arrangement should be carefully planned to maximise cooling effects, enhance air filtration, and avoid obstructing natural ventilation. Permeable surfaces should be encouraged to reduce heat retention and improve ground-level thermal conditions, particularly in playgrounds and courtyards where pupils spend significant time.

There is also a strong need for policymakers and regulatory authorities to develop and enforce guidelines that specifically address outdoor environmental quality in school environments. Existing building codes and educational infrastructure standards should be expanded to include requirements for air quality buffering, thermal comfort provision, and green infrastructure integration. School siting decisions should consider proximity to major pollution sources such as busy roads and industrial activities, ensuring that new schools are located in healthier environments. Furthermore, investment in environmental monitoring infrastructure is essential. Government agencies and research institutions should collaborate to establish localized air quality and microclimatic monitoring systems within urban areas, including school environments. This will provide the data necessary for informed decision-making and enable continuous assessment of environmental conditions.

School administrators also have a role to play in improving outdoor environmental quality. Regular maintenance of green areas, proper management of waste, and control of on-site pollution sources such as generators can significantly enhance air quality. In addition, scheduling of outdoor activities should consider periods of lower heat intensity to reduce pupils' exposure to thermal stress. From an academic and research perspective, further studies are encouraged to expand on this work by exploring seasonal variations, long-term environmental trends, and the integration of advanced thermal comfort models. Future research should also investigate the economic feasibility and long-term benefits of green design interventions in school environments to support wider adoption.

Finally, there is a need for increased awareness and education among stakeholders, including school owners, parents, and the wider community, about the importance of outdoor

environmental quality. Understanding that a well-designed outdoor environment contributes directly to children's health, comfort, and academic performance will drive demand for better school infrastructure and encourage the adoption of sustainable practices. In essence, creating environmentally responsive primary schools requires a shift in mindset—from viewing outdoor spaces as leftover areas to recognising them as essential components of the learning environment. By embracing this approach, it is possible to design school environments that are not only functional and sustainable but also supportive of the holistic development of pupils in Benin City and beyond.

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APPENDIX

SURVEY QUESTIONNAIRE
Topic: Outdoor Air Quality and Thermal Comfort in Primary School Environments in Benin City
By **Ikeanumba Chidindu Evans**
Mat No: **ENV2103347**
Submitted to the Department of Architecture,
Faculty of Environmental Science,
University of Benin Questionnaire

Dear Respondent,

This questionnaire is designed to gather information on outdoor air quality and thermal comfort conditions in selected primary schools in Benin City, as well as your observations, experiences, and opinions regarding how the

school environment affects pupils' comfort, health, and overall wellbeing. The aim of this research is to better understand how outdoor environmental conditions such as temperature, air quality, shading, and vegetation influence pupils' experiences in school environments. It also seeks to evaluate how green design features contribute to improving environmental quality and enhancing learning conditions.

Your responses will help identify key environmental challenges affecting pupils and provide valuable insights that will guide the development of sustainable, climate-responsive, and child-friendly school design strategies in Benin City. All information provided will be treated with strict confidentiality and will be used solely for academic research purposes. No personal identities will be recorded or disclosed.

Your participation is voluntary, and your honest input is highly valuable to the success of this study. Thank you for taking the time to contribute to improving the quality of primary school environments and promoting healthier learning spaces.

Appendix A
SURVEY QUESTIONNAIRE COLLECT DATA FROM RESIDENTS ON THE OUTDOOR AIR QUALITY AND THERMAL COMFORT IN PRIMARY SCHOOL ENVIRONMENTS IN BENIN CITY

Part One: Demographic Information
Please fill or tick (✓) the appropriate response.
(Question Type: Short answer / Multiple choice)

1. **Name of School**
   (Short answer)

2. **Location of School (Area/Neighbourhood in Benin City)**
   (Short answer)

3. **Approximate year the school was established**
   (Short answer)

4. **Does the school have intentional green design features (trees, landscaping, shaded courtyards)?**
   □ Yes
   □ No
   □ Not sure
   31.1

31.2

31.3 Section B: Research Questions

School Building and Site Design
(Question Type: Multiple choice / Checkbox)

5. Which of the following outdoor design features are present in your school? (Checkboxes – select all that apply)
   □ Trees within the school compound
   □ Grass or vegetation cover
   □ Shaded playgrounds or courtyards
   □ Pergolas, canopies, or shade structures
   □ Permeable ground surfaces (sand, grass, paving blocks)
   □ Predominantly hard surfaces (concrete/asphalt)

6. How would you describe the amount of greenery in your school compound?

□ Very high
□ Moderate
□ Low
□ None

7. Are most outdoor activity areas exposed directly to sunlight during the day?
□ Yes
□ No
□ Partially

31.4 Section C: Research Questions

31.5 Outdoor Thermal Comfort

31.6 **(Question Type: Likert scale / Multiple choice)**

8. How would you describe outdoor temperature conditions in your school during school hours?
□ Very hot
□ Hot
□ Comfortable
□ Cool

9. During hot weather, how often do pupils complain about heat while outdoors? (Likert scale)
□ Never
□ Rarely
□ Sometimes
□ Often
□ Very often

10. Are outdoor activities (playtime, assembly, sports) sometimes reduced or rescheduled due to heat? (Multiple choice)
□ Yes
□ No
□ Occasionally

11. Which outdoor areas are usually more comfortable for pupils?
□ Under trees
□ Shaded courtyards
□ Near buildings
□ Open playgrounds
□ No noticeable difference

31.7 Section D: Research Questions

31.8 Outdoor Air Quality

31.9 **(Question Type: Likert scale / Multiple choice)**

12. How would you rate the general outdoor air quality around your school?
□ Very good
□ Good
□ Fair
□ Poor

13. Are there noticeable sources of air pollution near the school? (Checkboxes)
    □ Busy road or traffic
    □ Power generators
    □ Open waste burning
    □ Nearby commercial activities
    □ None

14. How often do you observe dust, smoke, or unpleasant odours within the school compound? (Likert scale)
    □ Never
    □ Rarely
    □ Sometimes
    □ Often
    □ Very often

31.10 Section E: Research Questions

31.11 Pupils' Comfort And Wellbeing

(Question Type: Likert scale / Multiple choice)

15. How comfortable do pupils generally appear during outdoor activities? (Multiple choice)
    □ Very comfortable
    □ Comfortable
    □ Slightly uncomfortable
    □ Very uncomfortable

16. Do pupils tend to avoid certain outdoor areas due to heat or discomfort? (Multiple choice)
    □ Yes
    □ No
    □ Not sure

17. Which outdoor spaces do pupils prefer most? (Checkboxes)
    □ Shaded areas
    □ Areas with trees/greenery
    □ Open playgrounds
    □ Near classrooms

18. In your opinion, does outdoor environmental comfort affect pupils' behaviour and attention? (Multiple choice)
    □ Strongly agree
    □ Agree
    □ Neutral
    □ Disagree

31.12 Section F: Research Questions

31.13 Comparative and Perception-Based Questions

(Question Type: Likert scale)

19. Compared to other schools you know, how would you rate your school's outdoor environment?
    □ Much better
    □ Better
    □ About the same
    □ Worse

20. Do you think green design elements improve pupils' comfort outdoors?
    □ Strongly agree
    □ Agree
    □ Neutral
    □ Disagree

31.14 Section G: Research Questions

Recommendations and Open Feedback

(Question Type: Paragraph)

21. What outdoor environmental improvements would you recommend for primary schools in Benin City? (Paragraph)

22. Any additional comments on outdoor air quality, heat, or pupil comfort in your school? (Paragraph)
