REVITALIZING THE CONCEPT OF URBAN GREEN SPACES:

REPLANNING OF URBAN GREEN SPACES FOR SUSTAINABLE DEVELOPMENT OF ISLAMABAD, PAKISTAN

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A thesis submitted to the National University of Sciences and Technology, Islamabad,

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No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Department of Development Studies in partial fulfillment of the requirements for the degree of Master of Science in Field of Development Studies

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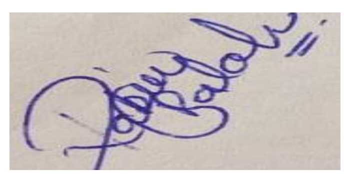

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Rabia Zafar

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GI	Green infrastructure
IQR	Interquartile range
NDBI	Natural different built-up index
NDVI	Natural difference vegetative index
RII	Relative importance index
SCRM	Sustainable climate risk management
UGI	Urban green Infrastructure
UGS	Urban green spaces
UHI	Urban heat island

ABSTRACT

The innovative idea of Urban Green Space (UGS) continues to have a significant impact on urban planning in the twenty-first century. It is still an effective instrument for addressing global sustainable development. UGS are essential to every aspect of a city, and these elements are designed with a particular (regional) social, cultural, economic, topographical, ecological, and geographical aspect in mind. This is particularly true of the urban face of a nation like Pakistan, one of the most urbanised in South Asia. The Land Use Land Cover Changes (LULC) that have caused extreme stress on natural resources and turned green pastures into barren land in Pakistan's capital city of Islamabad are directly linked to this rapid urbanisation, which has occurred in lieu of population growth and the doubling of rural-to-urban migration over the last 20 years. Due to inadequate planning and a lack of Urban Green Infrastructure (UGI) strategies for the capital city, this urban sprawl is ultimately resulting in a decrease in UGS per person. To better understand the current condition of urban green areas, this study will examine the urban heat island effect and ecological urban green indicators in Islamabad's recently urbanised Zone II. The UGI indicators and significant UGI indicators items were assessed using a structured questionnaire with a sample size of 216 households. The data was analysed using the relative importance index (RII) and interquartile range (IQR) approaches. ArcGIS 10.6 was utilised to create UHI and NDBI maps to assess the impact of urbanisation on UHI. The findings showed that the most significant UGS components were green parking lots and permeable pavements, whereas UGI indicators such as decreased carbon emissions had the greatest RII value, at 0.79, and noise quality improvement had the lowest, at 0.72. Additionally, a direct and positive association has been observed between NDBI and UHI, and policies have recommended that UGS be given appropriate attention as part of sustainable spatial planning for Islamabad's sustainable development in order to improve human well-being and lessen the impact of UHI.

Keywords: Climate change, Urbanization, Ecology, Urban Green Spaces, Urban Heat Island, UGS policy, Islamabad/Pakistan.

CHAPTER 1: INTRODUCTION

1.1 Background: UGS and UGI

In recent times the concept of Urban Green Spaces (UGS) holds a powerful influence in the planning and management of the urban areas. To address the ecological, economic and the social complications of Publicly accessible green spaces in cities and other urban regions are becoming more urbanised, UGS are proved as the most protruding tool by the developed countries across the world (Rutt and Gulsrud, 2016). Therefore, UGS stands as a vital tool for all components of a city and these components are planned to view a specific region's biological, physical, economic, and environmental characteristics (Javaid and Waheed, 2021). Because of this, a growing percentage of people live in cities because of urbanisation. (WHO, 2021).

There is a direct correlation between urbanization and population growth (Şenik and Uzun, 2022). According to UNFPA (2016), Currently, over half of the world's population resides in cities. Further, the urban dwellers residing in urban areas is projected to rise, with an estimate of approx. 67% by the year 2050, then currently living around 50% in the urban environment (EEA, 2015). The urban population is prominent in Europe i.e., 75% (Bertram and Redans, 2015). Both natural population increase and migration from rural to urban areas—where moving within an urban region is still a vital means for people to pursue better employment opportunities—have contributed to this urbanisation. Overall, rural-urban migration plays a significant role in the process of structural change (Peri and Sasahara, 2019). According to Adger et al. (2015), Moving from rural to urban areas presents a number of issues, such as worries about the burden on the environment and the social adaptation of the migrants themselves. Because urbanization is fueled by migration and because changes in land use and industrial growth are connected to urban expansion, migration is also held responsible for environmental degradation.

Rapid urbanization and population increase are inextricably linked to Land Use Land Cover Changes (LULC), putting further strain on the world's freshwater supplies. The safe limit of the ground water has been exceeded due to the disproportionate pumping and the increasing population growth has justified it. However, LULC modifications have converted many verdant meadows into barren ground. (Sohail et. al., 2023). Moreover, urban life might raise exposure to some environmental risks and restrict access to nature, noise pollution (WHO, 2021) and air-pollution – an environmental risk to metropolitan populations in times when the concentrations of air pollutants are quickly growing in urban and peri-urban areas of many developing-world megacities (Ahmad and Saqlain, 2018).

Furthermore, as new urban settlements have increasingly reduced access to nature, various ecological issues have arisen, necessitating a rethinking of the urban environment to ensure healthy and sustainable living conditions (Şenik and Uzun, 2022). The concept of large-scale, long-term, visionary planning was revived by sustainable development. Since the word "sustainable development" has been introduced in the planning list by the world commission on environment and development, sustainability has been more institutionalized and has been densely practiced in planning (Campbell, 2016). A connection to nature may become increasingly important as populations grow, and urban areas expand. The most accessible nature inside these urban contexts may thus be urban green areas, such as parks and cemeteries that give essential retreat in the daily life of the urban inhabitants (Shepherd, 2019).

According to Taylor & Hochuli (2017) the definition of urban green spaces varies across the disciplines and there can be two major interpretations of urban green spaces the one as a synonym of nature while the other interpretation can be related to the urban vegetation and as discussed by Schuch et al., (2017) — these interpretations are important for assisting the urban planners for the ecological connectivity. Hadavi etal, (2015) and Farahani & Maller, (2018) describe Urban green spaces are defined as open places that are totally or partially covered by a significant amount of vegetation and are owned and accessible by the public inside urban and peri-urban regions. As stated by Nor et al., (2017), the rapid urban expansion has had a significant impact on green space structure. Green spaces help to reduce the negative effects of urbanization and boost the human wellbeing which includes trees canopy, parks, greenways, urban forest gardens and the rest of the green infrastructure (Ambrey 2016; Hordyk et al.,2015; Mavoa et al., 2015) not only this, but green spaces also help to acknowledge to conserve and increase the permeability (Schuch et al., 2017).

When the network of natural and semi-natural areas is planned strategically with other environmental features that is maintained to enhance biodiversity and provide a wide variety of ecosystem services is what the European Commission defines as urban green infrastructure. Furthermore, according to the European Environment Agency (EEA, 2018), green infrastructure in urban areas include parks, trees, small woods, grasslands, as well as private gardens and cemeteries. All of this help to maintain pollinators, biodiversity, carbon sequestration, flood prevention, and protection from extreme heat events.

According to Clemente et al., (2017), urban parks are becoming a more important part of bottom-up integrated initiatives for urban regeneration, because of the economic downturn, they help in meeting the desire for "natural landscape" in peri-urban regions. Similarly, to identify UGI indicators, also known as UGS components, it is necessary to consider the local built-in context, which is still essential for improving urban planning (Rayan et al., 2022), this study also demonstrates that, depending on the geographical situation, every UGS element has a unique feature that contributes to raising the standard of the corresponding UGI indicators in the battle against climatic catastrophes (such as urban floods, droughts, etc.).

1.1.1 Urban Green Spaces elements

Eleven components of urban green infrastructure have been recognized by the US Environmental Protection Agency (EPA, 2024). Green parking, green roofs, urban tree canopy, permeable pavements, rainwater harvesting, rain gardens, planter boxes, bioswales, green streets, sometimes known as green alleyways, and land conservation are some of these components.

Nettle (2016) claims that community gardens are small plots of land created by a few committed gardeners in a neighborhood. One of the many activities held in the community gardens is the preservation and enhancement of the urban environment. Developing ecosystem services like air quality and temperature regulation, mitigating severe events, and controlling water flows through community gardens is a smart way to lessen the negative effects of impermeable surfaces, which are primarily responsible for flooding occurrences and UHI. In urban locations, community gardens can lessen energy dependency and carbon emissions (Dubbeling, 2015).

As the name implies, pocket parks are a type of public area that falls within the larger 'parks' umbrella. In literature, they go by a variety of titles, including neighborhood parks, vest-pocket parks, and mini-parks. In addition to serving as buffer zones from the bustle of the city, pocket parks also promote a variety of social events to occur near the busy metropolis they are intended to buffer (Hamdy & Plaku, 2021). High-density urban neighborhoods, where pocket parks are closely linked to their local communities, are of more concern.

Pocket parks get their closeness from their tiny size and strong ties to the surrounding area. Even though they are small, pocket parks have intricate goals, designs, and programmes (Bruces, 2017).

Green lanes and streets may be used to achieve several social, economic, and environmental goals as part of a sustainable development strategy. When compared to impermeable pavements, green streets can contribute to urban sustainability by raising awareness and facilitating the effective implementation of green streets (Im, 2019).

Permeable pavements absorb, clean, and/or store precipitation where it falls, according to US EPA, (2024). Permeable interlocking pavers, porous asphalt, or pervious concrete can be used to make them. In areas where floods or icing is an issue and land values are high, this method can be very cost-effective. Plans for parking lots may easily incorporate a variety of green infrastructure components. A parking lot can have portions with permeable pavements, and its medians and perimeter can have rain gardens and bioswales added. These features, when incorporated into a parking lot, help lessen the area's heat island effect and enhance walkability.

1.1.2 UGS and UHI

Land surface temperature (LST) measurements can be used to evaluate the UHI effect (Rotem-Mindali et al., 2015). UHI is predicted to become a significant issue in future urban life as it is predicted that the proportion of the global population living in cities will rise from 54% in 2016 to 60% in 2030 (UN, 2016). Regarding China, from 2000 to 2015, most of the cities (25 out of 31) showed a rising trend in UHI, of which 44% were significant, indicating a greatly amplified UHI effect (Ren et al., 2021). UGI effect is also linked with rise in air temperature that has also increased 0.5 to 4.0 ºC during the day, and by 1 to 2 ºC at night in the urban regions, compared to the surrounding rural regions in America (Wuebbles et al., 2017)

1.2 Rationale of the Study: State of UGS and UGI in Islamabad

In South Asia, Pakistan is the most populace and urbanized country, where the urban population grown from 43 million to 75 million from the year 1998 to 2015 (EA Wing, 2016) according to Pakistan Bureau of Statistics (GoP, 2023) the current population of Pakistan reaches 241.49 million and by the year 2025 there are estimates that this urban population will grow drastically (GoP, 2017). Natural resource depletion and rapid deforestation which is close to the urban settlements is due to the fast pace increase in population growth (Gilani et al., 2020). Deforestation and land degradation are increasing in many parts of Pakistan, and it is becoming a serious threat for the coming times, this deforestation due to the rising population and has an association with increase demand of woods, governance issues, and land cover changes due encroachment, where approx. 47% of the urban population lives in the 9 major cities of Pakistan which is exceeding to one million with each passing year (GoP, 2017).

The extent, severity, and the rate of recurrence at which the human collaboration take place and the alterations they produce to ecological developments and systems in urbanized places are reflected in the intense urbanization and rise in anthropogenic activities (Gilani et al., 2020). Furthermore, it hastens industrialization and urbanization, posing new ecological issues such as harmful air and water pollution (Bano and Khayyam, 2021; GoP, 2017). It has serious consequences for public health, urban pollution caused by urbanization and rapid industrial growth in Pakistan, causing other major problems such as, about 23,000 deaths are accredited due to the increased air pollution caused in by the increase of exhaust-belching automobiles most of them are powered by leaded gasoline (Kugelman and Husain

2018). In Pakistan, these environmental risks are more severe in urban areas than they are in rural ones (Ahmed et al., 2023).

Massive rural-to-urban migration, which has increased over the past several years, is a problem that the nation, and particularly its urban centers, must deal with. Push factors in rural regions include low cultivated land yield, landlessness, land subdivision, poor economic situation, and because of the improved educational and health opportunities available in the urban areas as compared to the rural one. These uncontrollable conditions that contribute to migration from rural to urban regions are the most powerful factors driving urban land cover alteration (Gilani et al., 2020). Islamabad, Pakistan's capital city, is the most diversified metropolis in the country and is home to a significant number of both domestic and international immigrants (Bokhari et al., 2018). This sizeable immigrant population from both inside country and abroad make Islamabad the most multicultural city of Pakistan (Yaqoob, 2017). The conversion of fertile, agricultural land and the urban green cover into the grey structure is the result of urban sprawl which is due to the record invasion of migrants into the urban areas (Beacco, 2018; Gilani et al., 2020).

Due to the restrictive zoning in Islamabad, there is increase in urban sprawl and it encourages the single-family home in the high-density city centers and specifically residential areas which are more aligned with this zoning structure and favors the single-family home as most preferable land use. As a result, land, a valuable resource for every city, is used inefficiently. Allowing some flexibility in zoning restrictions allows for urban renewal. Incorporating more industries into this urban rejuvenation will open endless opportunities for urban growth. (Hasan et al., 2021). Essential natural resources, disproportionate urban growth, natural landscape, and population have a strong link with each other (Sohail et al., 2023).

In the zoning of Islamabad, population growth has a lot of importance because of the multiple factors like replacement of the green spaces with grey structures and the other impermeable urban materials. It also left some negative impact on the characteristics of land surface which further fluctuates the energy of the land surface development due to the changes in the biophysical environment (Cai & Huang, 2016). The natural environment of the urban areas destroys when the vegetative cover is replaced with the concrete, and this is due to the increase in the anthropogenic activities. (Muhammad et al., 2016; Divine et al., 2016), impacting food production as well (Sohail et al., 2023). Rapid urbanization has resulted in the decrease of Islamabad's urban green zones, which were formerly abundant across the metropolitan cities. The new sectors of Islamabad will be developed on the space allotted for the green belts and the parking so that the issue of population growth can be tackled. A tour of Islamabad city reveals that urban green spaces are being used and urban sprawl is taking place (NDF, 2017).

In recent times, the natural and conservational condition of capital city Islamabad is not dreadful but if the current situation prevails than it can cause many environmental issues in the future (Naeem et al., 2018). Urbanites in Islamabad have experienced variations in summer and winter temperatures, as well as changes in rain fall patterns. The swift change in the land cover with water-resistant surfaces, more specifically in the developed urban areas is the main reason behind the rise in air and surface temperatures. Urbanization is expected to significantly contribute to universal change in environment, including land use and land cover change (LULCC) and climate change, as forecasted by several studies on population increase (Ahmed et al., 2023) However, Islamabad has better environmental conditions than other cities in Pakistan due to lower population density. With the passage of time vegetative area per person is decreasing and due to lack of climate green policies and landscape planning, no policy-based study on the changes in urban green spaces had been done yet (Naeem et al., 2018)

A lack of recent scientific methodologies and awareness, coupled with an immature developmental planning process and execution challenges, are all contributing factors to the damage and decline of urban green spaces (UGS). The absence of a participatory planning (PP) approach is another factor contributing to the alteration of green spaces within developed infrastructure. (Rayan et al., 2022). To claim that the real causes of climate disasters are only related to lose laws and their enforcement, an unclear legislative planning framework, and a response-focused planning strategy would be naive. However, the true causes are also related to the ineffective implementation of such laws and policies, which results in a reduction in the amount of natural green spaces (Rayan et al., 2021; Naeem et al., 2018). The systematic loss and depletion of natural green barriers has been caused by the lack of these policies and their implementation, endangering the health and well-being of people as well as the urban ecology. The systematic loss and depletion of natural green barriers has been caused by the lack of these policies and their implementation, endangering the health and well-being of people as well as the urban ecology (Naveed & Khayyam, 2022; Bano & Khayyam, 2021)

The undeveloped countries must seek to catch up with the climate change policies of the developed and industrialized countries (such as the Netherlands, Germany, and the UK), who have already put in place Urban Green Infrastructure (UGI) and Sustainable Climate Risk Management (SCRM) policies to plan (Rayan et al., 2022). Thus, protecting Islamabad's green areas is an urgent necessity. As a result, the initial stage is to create a detailed data-driven picture of green spaces located in Islamabad. This entails assessing the change in vegetation area in comparison to the original master plan produced by the Capital

Development Authority (CDA). It will aid in identifying places devoid of vegetation, allowing relevant authorities to make informed judgements based on the study's findings (NDF, 2017).

Pakistan is the most urbanized country in South Asia, and it is expected to become increasingly urbanized in the future years, resulting in 26resource depletion and fast deforestation. Not only this, increased urbanization because of rural-urban migration increases human activities, resulting in ecological changes that bring additional environmental concerns such as air and noise pollution. Islamabad, Pakistan's capital, has the most diversified population due to a massive number of immigrants because of rural-to-urban migration, which causes urban sprawl. This urban sprawl is caused by single-family dwellings, which use up too much land. Urban sprawl leads to land use and land coverage change (LULCC) and hence to climate change. Green spaces per person are shrinking over time owing to poor planning and a lack of capital development authority climate green infrastructure strategy.

Capital Development Authority, a public assistance establishment who is responsible for managing the landscape urban green space policies do not have any UGI and SCRM policies like the other developed nations. We will be able to determine urban heat island impacts caused by a lack of urban green areas, as well as how this affects the city's ecology, with the findings of this research. We will also identify locations that lack urban green spaces in Islamabad so that appropriate authorities may make informed judgements based on the study's findings.

1.3 Hypothesis

H: An increase in urban green areas contributes to sustainable development of Islamabad, Pakistan's.

1.4 Aim, Research Questions and Research Objectives

The aim of this research is to evaluate the current UGS in Islamabad, predominantly through the ecological UGS lens, which will be achieved by finding answers to the following research questions:

1. What are the significant levels of UGI indicators of (each) Urban Green Space (UGS) elements in Zone-II Islamabad?
2. What are the important UGS elements for Ecological UGI indicators in creating a green climate-resilience of zone II Islamabad?
3. To which extent does the reduction in ecological UGI indicators (as of NDBI) contribute to UHI effect in Islamabad?

Research Objectives

1. To study the significance levels of UGI indicators of (each) Urban Green Space (UGS) elements in Zone-II Islamabad?
2. To study the important UGS elements for ecological UGI indicators in creating a green climate resilience of Islamabad.
3. To study the extent of ecological UGS elements can contribute to halt UHI effect in Islamabad.

1.5 Conceptual Framework

The conceptual framework for the study “revitalizing the urban green spaces: replanning of urban green spaces for sustainable development of Islamabad, Pakistan aims to study the urban green space policies made by capital development authority in different zones of Islamabad. With this it will also investigate how the ecological urban green spaces can be useful to halt the urban heat island effect in Islamabad. This study proposes three dependent variables named ecological indicators, urban heat island effect and the local and global policy concerns regarding urban green spaces with one independent variable named urban green spaces.

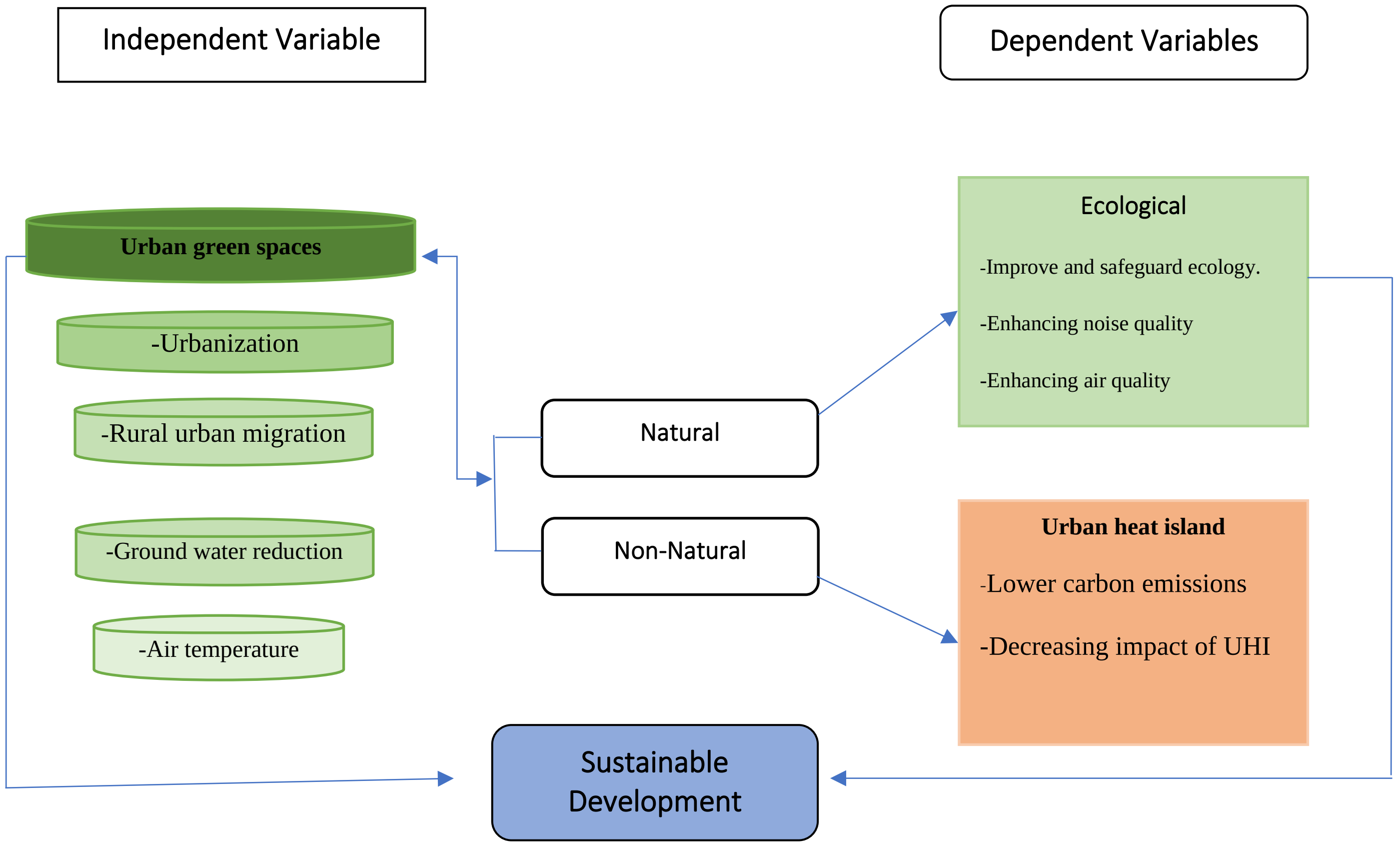

Figure 1 Conceptual frame-work for the study (Source: Author's own)

The three dependent variables are divided into natural and non-natural variables. Ecological is the first dependent variable which is a natural variable indicates the enhancing of noise quality, enhancing air quality and improving safeguarding the ecology of the selected zones of Islamabad. With the help of urban green spaces, the air and noise quality can be improved which further enhances and safeguards the ecology. The second study variable is urban heat island which is a non-natural variable, indicated by the carbon emissions and urban heat island, the more urban green spaces will lead towards the lower carbon emissions, and it will also decrease the impact of urban heat island effect. Combinedly both the dependent and the independent variables will lead towards sustainable development which will be the outcome of this study.

1.6 Linkage with SDG's

Over 60% of the world's population will live in cities by 2030, accounting for half of the world's current population of 3.5 billion. Public health, freshwater supplies, sewage systems, and living conditions are all strained by the fast urbanisation of the world. In response to our planet's rising degradation, the United Nations endorsed the Sustainable Development Goals (or "SDGs") in 2015. These seventeen (17) SDGs were established as a worldwide call for assistance in protecting the planet by 2030. The SDGs are interconnected in such a manner that positive action in one area has a cascading effect on the others. Goal 11 of the SDGs titled as "Sustainable Cities and Communities", creates the importance of green spaces and green infrastructure in the development of urban areas (UNDP, 2021). To achieve the UN's Sustainable Development Goal 11—Sustainable Cities and Communities—collaboration is therefore more likely. Pakistan's government must implement and develop landscape planning policies (Naeem et al., 2018).

1.7 Organization of the Thesis

Chapter 2 introduces the narrative that this thesis engages to address the research questions laid out above. The literature on urban green space draws from a wide range of sources, which reflects the depth of study that looks at how urban green space relates to ecological and urban heat island concerns in urban environments. Additionally, the UHI impact brought on by urbanisation has been discussed in the literature. Lastly, the assessment of how the increased attention given by city authorities to urban quality of life and their growing understanding of the ecology of zone II Islamabad has made urban green space a crucial problem in urban planning and policy.

Chapter 3 gives a comprehensive look at the methodology used for the study. The Methodology chapter explains the study area of the research in detail while it also gives us insight about the sampling techniques and analysis techniques used for the study. This present study has employed the different techniques like relative importance index and interquartile range to study the ecology aspect of urban green spaces while it uses GIS and remote sensing to study the urban heat island effect and the normalized difference built-up index.

Chapters 4, provide the findings and analysis from my fieldwork, remote sensing data, and GIS. To address the effects of green space on the ecology of zone II Islamabad, this chapter connects the data gathered from the field survey and through the USGS Earth Explorer and analyses' them with the body of literature already in existence regarding sustainable development, urban green space, green infrastructure, urbanisation, and urban heat islands.

Chapter 5 gives the current study's conclusion. In order to do this, the empirical analysis from Chapters 4 will be examined in relation to the literature discussed in Chapter 2 on urbanisation, sustainable development, green infrastructure, urban heat island effect, and urban green space. In this chapter, Policy Implications from the present study are also given. It also has discussed further research areas with reference to the subject under investigation.

CHAPTER # 2: LITERATURE REVIEW

2.1.1 Storm Water Management and Urban Green Spaces:

A dispersed strategy to lower the volume and pace of runoff produced inside urban watersheds is known as "green infrastructure" (GI). Without needing to increase the conveyance capacity of the current sewage system, the purpose of GI is to lessen or prevent the incidence of CSOs by infiltration, evapotranspiration, and detention.

Research by Feldman et al. (2019) indicates that runoff from impermeable, off-site surfaces may be effectively managed in urban parks. As a result, rain gardens should be able to hold onto all of the intake from a 25 mm event nine times larger than the rain garden area. This demonstrates how urban park GI may effectively catch rainwater from nearby impermeable surfaces, reducing combined sewer overflows with little to no negative effects on the park's recreational activities.

As per the 2017 report by the Centre for Watershed Protection, trees can intercept rainfall through their canopy, release water into the atmosphere through evapotranspiration, and encourage water infiltration and storage in the soil and forest litter. Rain that falls on urban surfaces like roadways, parking lots, and lawns collects different contaminants when it runs off the terrain when there are no trees to filter the runoff (Dave, 2017). According to Zölch et al. (2017), green roofs and trees both improve the capacity of water storage, which lowers surface runoff.

But since trees can only infiltrate so far through the planting pit network, their primary function is to enhance interception and evapotranspiration. According to Ercolani et al. (2018) and Song et al. (2020), green roofs in urban areas are a useful tactic for lowering runoff peaks and volumes in urban drainage networks. However, the method works better for frequent small-scale storms than for sporadic large-scale storms.

2.1.2 Urban Green Spaces and Improve and Safeguard Ecology/Biodiversity

Senetra et al. (2018) defines urban green space as places that are covered with natural plants in ecology. It refers to naturally vegetated areas in urban planning that serve various purposes within the urban fabric. In landscape design, urban green space creates a “green structure” made of carefully selected plant species. Urban green spaces support human well-being and the quality of life of city dwellers by offering a broad spectrum of urban ecosystem services that can assist overcome continuing difficulties in urban growth (De La Barrera et al., 2016b). Green areas enhance the physical and emotional well-being of city dwellers by giving them access to nature. (Sun and Chen, 2017).

2.1.3 Urban Green Spaces and Air Quality Improvement

Rapid urbanization has resulted in significant issues for society, such as deteriorating environmental conditions, disappearance of natural habitats, and elevated hazards to human health due to air pollution, noise pollution, and heat waves (Zupancic et al., 2015). As indicated in the UN New Urban Agenda (UN, 2017), it is clear that urban air pollution is a serious environmental problem, and that the public would find it challenging to reduce it in the pursuit of healthier cities (UN, 2015). Research has demonstrated the value of urban green areas in lowering air pollution (selmi et al., 2016). In contrast to investing in the largest green spaces and already denser vegetation, Matos et al. (2019) suggest that the greatest gains in improving air quality could be obtained by concentrating on improving the smallest green spaces by increasing its green area and by increasing surrounding vegetation density.

The UGS offers residents in cities several benefits. They serve as the urban equivalent of lungs, releasing oxygen and storing pollutants. In addition, they balance the natural urban environment of the city, supply clean air, and aid in soil and water conservation (Cilliers et al., 2015). The study by Jayasooriya et al. (2017) found that out of all the GI taken into consideration, mix trees had the maximum capacity to remove air pollutants. The combination of various green infrastructure elements, such green walls and roofs with trees, has improved building energy efficiency but has not resulted in a noticeable increase in the improvement of air quality.

An essential tool for assessing the present condition of the urban green infrastructure in terms of air quality is an ecological indicator like lichens. These indicators may also be used to plan and direct management decisions aimed at enhancing air quality. Lichen-based measures may be used to confirm the impact of newly constructed or changed urban green areas on air quality, such as by increasing their size or vegetation density (Matos et al., 2019)

2.1.4 Urban Green Spaces and Noise Quality Improvement

Maksymenko et al. (2021) state that green infrastructure can serve as a buffer or barrier between urban inhabitants and noise sources in the event of noise pollution. The level of noise pollution in surrounding regions can be decreased by the absorption and deflection of sound waves by trees, shrubs, and other vegetation. Furthermore, green infrastructure may give locals a more comfortable and serene atmosphere, which can lessen the detrimental effects of noise pollution on mental health and general wellbeing. Green walls can minimize both forward transmission and backward noise reflection by adjusting their design and substrate (Attal et al., 2021).

The most effective way to minimize noise is with a green roof. Depending on the design of the roof, this effect can reach up to 7.5 db, possesses other significant environmental advantages, including the ability to absorb carbon dioxide, enhance air quality, lessen the impact of the urban heat island, boost urban biodiversity, and improve the aesthetics of streets and rooftops (Ilic et al., 2021).

City green corridors are elongated patches of vegetation. They are made beside roads, railroads, and other man-made features in addition to natural features like rivers. This study demonstrates that linear plantings can lower noise levels by around 20 dB. One innovative strategy to help cities become more ecologically friendly is green parking. They make the living environment more green and less grey, but they also have no discernible impact on the amount of noise in cities (Maksymenko et al., 2021)

The results show that early noise generation and transmission may be significantly reduced by planting green spaces in a compact, linked layout next to the primary sources of noise pollution, such as traffic networks. (Sakieh et al., 2017). According to the study conducted by Margaritis and Kang (2017) Investigate the correlation between the green spaces and traffic noise pollution and as result it was concluded that there is strong correlation with the value ranging between 60% to 79% and the further cluster analysis combines with the land over data revealed that there was lower noise pollution with the high green spaces coverage.

2.1.5 Urban Green Spaces and Lower Carbon Emissions:

According to findings from another study, one of the main factors contributing to the release of carbon emissions is not just deforestation but also forest degradation. As a result of deforestation and forest degradation, 74 developing countries emitted 2.1 billion tons of carbon dioxide between 2005 and 2010 (Pearson et al., 2017). Carbon emissions, carbon storage, and green space are interdependent. First, the distribution of green spaces has a significant impact on CS. It is seen to be one of the most promising ways to lessen carbon dioxide (CO2) emissions into the atmosphere because of urban growth and may be thought of as the value of urban land with vegetation (Richards et al., 2017).

Chen (2015) released a study that looked at how urban green infrastructure may affect 35 significant Chinese cities' carbon balances. By the end of 2010, the combined land area of these cities—which includes the main components of urban green infrastructure—accounted for 51.7% of all Chinese cities' total urban green spaces, or 6.38% of all Chinese cities' total land area. It was determined that 18.7 million tonnes of carbon were stored in the vegetation of the urban green infrastructure of 35 cities, with an average carbon density of 21.34 t/ha.

According to Brazilian research that was published in Nature Climate Change, if deforestation in that area is curbed, carbon emissions from land used for cattle grazing might be decreased. According to the study's findings, for 24 years, deforestation increased carbon emissions by 40% (Silva et al., 2016).

2.2 Urban Heat Island (UHI)

2.2.1 Urban Heat Island (UHI) and Role of Urban Green Spaces.

Urban green spaces plays and important role in hindering the effect of UHI, according to (Li et al. 2018) in the big cities like berlin, UHI has been found effecting the urban ecology of the cities which further increases the level of air and water pollution. Urban green spaces have the potential to reduce the effect of UHI to create the safe havens for the residents due to the capabilities and potential the urban green spaces have, increase the intensity and density of cooling (Aram et al., 2019) as green spaces supports sustainable production of ecosystem services and foster urban resilience (McPhearson et al., 2015).

Various UGI scenarios, according to research by Zölch et al. (2016), can aid in lowering the urban heat island. The largest effect was from planting more trees, which reduced UHI by 13% on average. In addition to providing evapo-transpiration cooling, trees shade open areas. Green facades are another excellent adaption option; they have a 5%–10% moderating impact. On the other hand, there was very little impact from green roofs. This study's findings also show that the amount of UHI decrease did not immediately correlate with an increase in the fraction of green cover. It is more efficient to strategically plant plants in heat-exposed locations rather than just aiming for a high proportion of green cover.

Furthermore, trees mitigate the urban heat island (UHI) impact by reducing surface and air temperatures through evapo-transpiration, as well as by offering shade and humidity (Schwarz and Manceur, 2015; Scheuer et al., 2017). Effective UGSs have been highlighted as one of the solutions for lessening the impact of UHI, according to Taleghani's (2018) review study. It has also been shown, by considering six Urban Parks Studies (UGS), that these areas are crucial in reducing UHI. According to the other review by Jamei et al. (2016), a UGS's size and form affect both thermal comfort and the impact of reducing UHI. This study shows that a UGS's plant cover and tree shade area are directly proportional to how cool it is. Norton et al. (2015), explains that green areas are crucial for reducing the maximum and variance of urban air temperature. Urban forestation, or the widespread planting of trees in urban settings, is thought to be particularly successful at generating cooler places (Brown et al. 2015; Yoshida et al. 2015).

2.2.2 UHI and Urbanization

The average yearly rate of change in the percentage of the population living in urban areas between 1950 and 2018 was 0.92 percent. This represents the rate of urbanisation during that time. The world's population first shifted from being primarily rural to predominantly urban in 2007 as a result of this fast urbanisation (United Nations, 2018). According to X. Li et al. (2017) the intensity of UHI tends to increase with the increase of urban expansion. UHI is predicted to become a significant obstacle in future urban living as the ratio of the world's urban population to total population is predicted to rise from 54% in 2016 to 60% in 2030 (UN, 2016).

Cities are becoming more and more urbanised, which not only causes complex changes in land cover but also has an impact on the surrounding area, vegetation coverage, surface albedo, and surface roughness. These changes in turn have an impact on the circulation of urban hydrological and ecological systems, altering the near-ground climate and the urban environment (Academic Press, 2020). The study carried out by Isufi et al. (2021) revealed that vegetation plays the most significant role in mitigating the effects of urban heat island (UHI). Conversely, an increase in the built-up index amplifies the UHI impact.

2.2.3 UHI and Islamabad

Most cases of the urban heat island effect have been reported in Pakistan's Islamabad Capital Territory (ICT) (Sadiq et al., 2020). The Pakistan Environmental Protection Agency (Pak-EPA) defines it as the accumulation of heat in regions that are hotter than the connected rural vegetated areas. A metropolis with two million or more residents may have an annual mean air temperature that is 1.8–5.4 °F (1-3 °C) warmer than that of its surrounds (Khan, 2018). As the population of Islamabad increases, there have been notable changes in land use and land cover, which have contributed to the development of the urban hotspot, according to Ali et al. (2022). The LULC patterns, on the other hand, are related to a UHI's strength.

Surface temperature intensification has been mostly caused by declining plant cover, a significant decline in the amount of shade trees and other vegetation, and increased urbanisation in recent years. According to the LST data, the areas above Barakahu, DHA, the southwest, and the housing developments along the Islamabad Motorway had the greatest temperature range, which was 39–47oC. The amount of developed land in these places increased quickly. Given that the maximum temperature is positively impacted by thermal conductivity, thermal diffusivity, and heat capacity. Because of the unique thermal characteristics (heat capacity and conductivity) of man-made materials, one of the causes of the higher temperatures in these areas was the increased heat storage of urban surfaces on bright, extremely warm summer days. Islamabad's urban expansion is accelerating and having a parallel impact on other social strata; the patterns of vegetation and arid terrain have shifted. Because of the built-up area's greater ability to absorb solar radiation, such places have higher surface temperatures (Yasmeen et al., 2021).

2.3 Research Gap

After reviewing all the literature available for the urban green spaces, urban green infrastructure, and the urban heat island in relation to the urbanization a research gap has been identified. In relation to the available literature, it has been found that studies have been conducted on urban green spaces in relation to the urban green infrastructure and urban green elements in western world but in context of Pakistan only 3 studies are available which worked regarding the urban green infrastructure framework, but the study area remains different, study areas for that research were district Mardan, Peshawar and Charsadda of KP province (Rayan et. al., 2022a, 2022b, 2021). In case of Islamabad and specially zone II, not a single study has been conducted to check the importance level of UGI indicators and the important UGS elements for them, with the urbanization has also not been study with the reference to the urban heat island effect.

As this area of research is still lacking, the aim of the present study is to investigate the importance of UGI indicators and elements and how these elements help to halt the UHI effect in zone II of Islamabad within the context of urbanization. Analysis of German UGS policy can help to plan the UGS in Islamabad.

CHAPTER # 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Study Area and its Climate

Islamabad is the capital city of Pakistan and the country's 9th largest metropolis. Islamabad was founded in 1960 as a “planned city” and is located at 33°28′1″ N-33°48′36″ N latitude and 72°48′36″ E-73°24′ E longitude. Islamabad's elevation ranges from 400 to 700 meters, while its height ranges from 457 to 1240 meters above sea level. Islamabad has a total area of around 906 km2 (CDA, 2021). Islamabad is divided into 9 different zones consist of commercial regions, residential, educational, industrial diplomatic and administrative enclave (Butt et al., 2015). Islamabad was split into five zones in 1992 when the CDA published the Zoning Regulation. Only CDA could buy property for construction in Zone 1. Private housing societies might undertake building operations in Zones 2 and 5. Zone 3 was a designated region. Zone 4 was set aside for a variety of actions such as the National Park, agro-farming, educational establishments, and research and development. (Hassan et al., 2022).

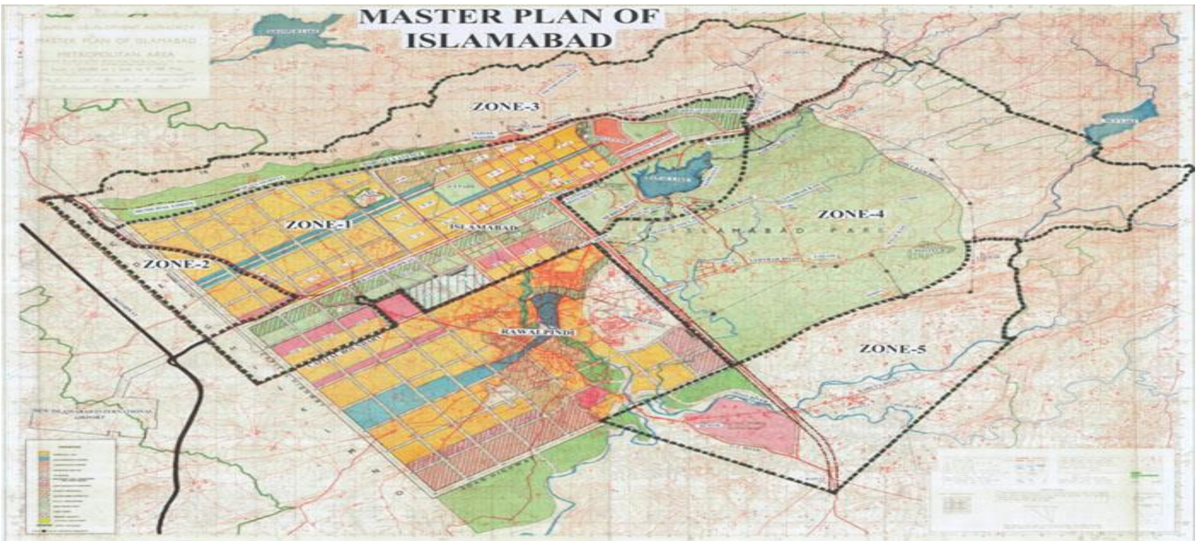

Figure 2 Map of Islamabad with 5-Zones boundary line (Source: CDA, 2021)

The famed Margalla Hills surround the city's northern edge (Figure 1). Islamabad provides over 1-1.5% of the national economy and has a population of around 241.49 million people (GoP, 2023). The city's climate ranges from tropical to subtropical, with four distinct seasons. The average annual temperature is 20.9 degrees Celsius, with a yearly precipitation total of 1323.4 mm (Liu, 2021). Tropical-evergreen wide leaf forests and subtropical evergreen coniferous and deciduous woods are the dominating natural vegetation (Liu, 2021). Islamabad's one-of-a-kind Master Plan offers the city real individuality as a sustainable model. The overhead picture of Islamabad shows the city in a 'Grid-Iron Pattern,' with distinct green areas and parks constructed expressly to mitigate the city's heat island impact. Furthermore, the city has been meticulously constructed to blend parks and natural places into the urban city environment. Margalla Hills National Park, for example, is home to various flora and wildlife in the region, whilst Fatima Jinnah Park is Asia's largest park in terms of size (CDA, 2021).

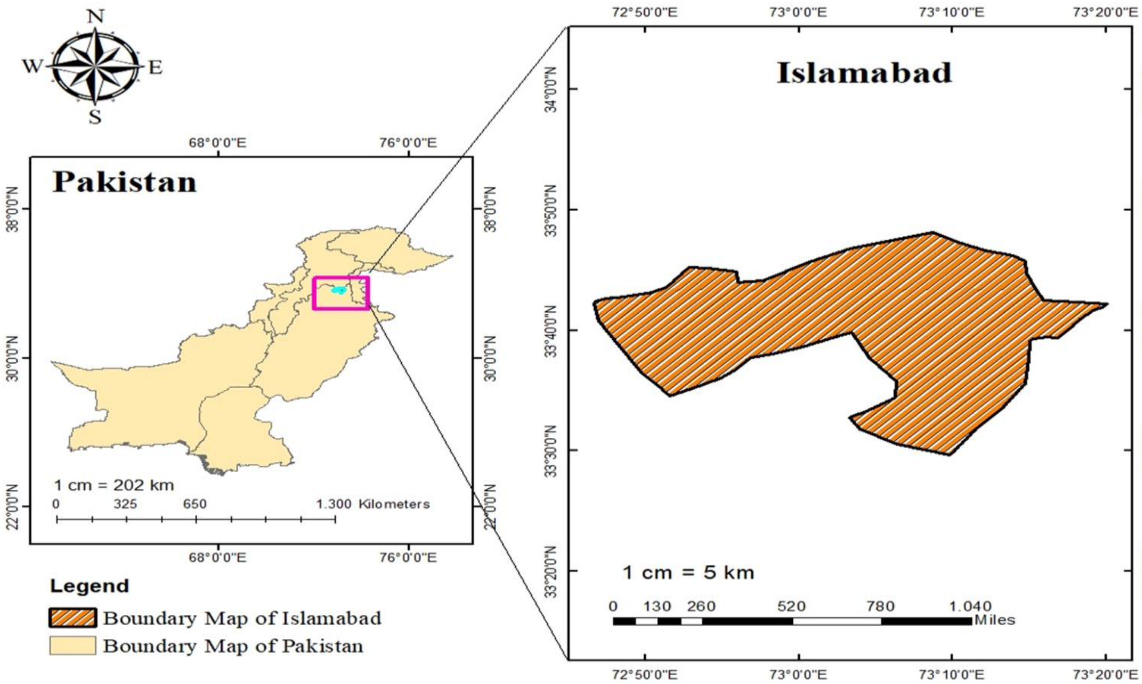

Figure 3 Map of Islamabad with Zone II (Source: Author's own)

3.2 Study Variables

No.	Variables with Indicators	Explanation of Indicators	Sources
	Urban Heat Island		
1	**Decreasing the impact of urban heat islands**	Increasing the percentage of green surfaces will decrease the mean radiant temperature.	(Jacobs et al., 2015)
	Ecological		
1	**Improved and preserved urban ecology**	Ecology helps to endorse the concept of connectivity and mobility between urban green spaces.	Rayan et. al., 2022
2	**Optimize storm water management**	Urban green spaces help in reducing floods and are suitable for handling rainfall.	Rayan et. al., 2022
3	**Eenhancement of noise intensity**	More urban spaces will help to reduce the intensity of noise	Rayan et. al., 2022
4	**Improvements in atmospheric air**	The urban green spaces help to reduce the impurities and improves air quality.	(Bano & Khayyam, 2021)
5	**Decreased carbon emissions greenhouse gas emissions via greenery)**	Urban green spaces help in lowering the carbon emissions by planting more trees for shade and lower the land surface temperature.	(Rayan et. al., 2022) (Qiu et al., 2021)

3.3 Sampling Technique and Sample Size

Islamabad was split into five zones in 1992 when the CDA published the Zoning Regulation. Only CDA could buy property for construction in Zone 1. Private housing societies might undertake building operations in Zones 2 and 5. Zone 3 was a designated region. Zone 4 was set aside for a variety of actions such as the National Park, agro-farming, educational establishments, and research and development. (Hassan et al., 2022).

For this study Multistage sampling technique was used. Firstly, selection of the zones: Zone II was selected the first sample (Ahmed et al., 2023) as it is still under development and has less urban green spaces as compare to the Zone-I and secondly; the selection of sectors in zone-II, because in the sectors of zone-1 land can be purchased under a phased program and it can only be developed by capital development authority's master plan of Islamabad, while in Zone-2 private sector or institutions are allowed to purchase/acquire land and develop residential schemes in accordance with the pattern of residential sectors planned in zone 1. (CDA, 2020). As zone-I of Islamabad is already comprised of a lot of urban green spaces, the data was collected only from zone-II which involves the sectors G-15, G-16, D-17, D-18, F-15 and B-17.

A total of 216 households participated in this research, as the total population in this area is unknown, therefore, to gauge the exact representative sample was difficult. Yet, 216 households were consulted with the average house/family size in the area equal 6 (GoP, 2023) so the sample size remained 1296 individuals which was far beyond 385 figure – a representative sample size for results generalization for the unlimited population (GoP, 2023)

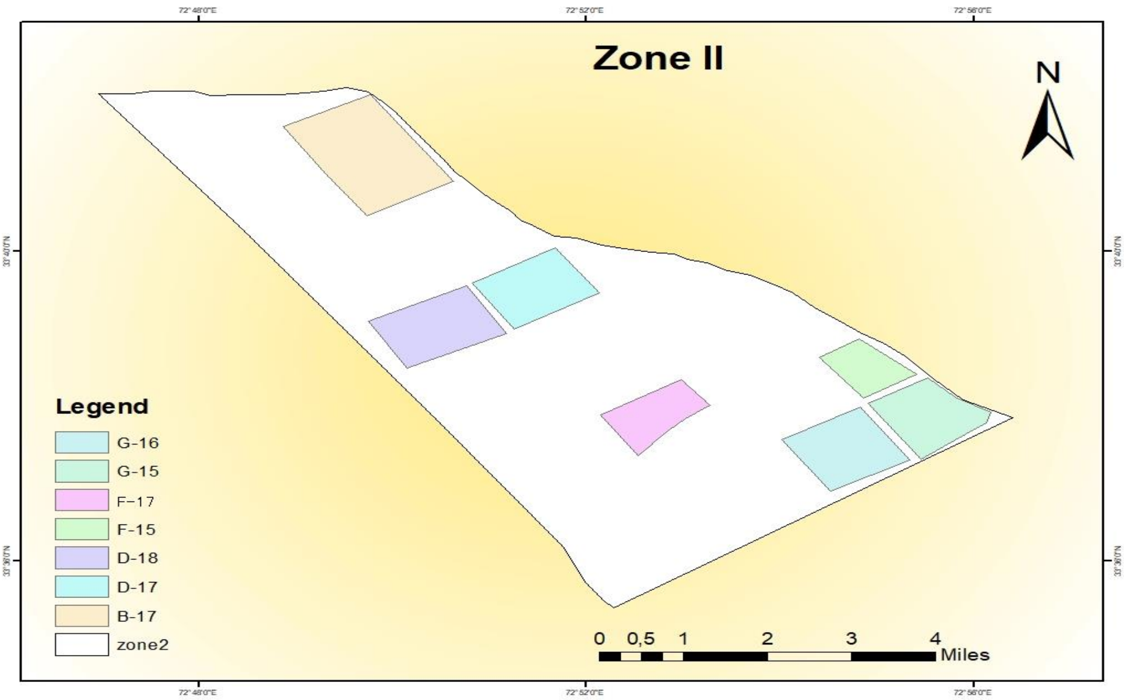

Figure 4 Map of different sectors within Zone-II (Source: Author's own)

3.4 Data Collection Method

As the first objective of this study is to check the important UGS elements for ecological UGI indicators in creating a green climate-resilience of Islamabad, A structured questionnaire was designed for the purpose of data collection, containing two sections: Section A and Section B — both consisting of closed ended questions. Section A was comprised of demographic information of the respondents for the purpose of validating the profile, knowledge, and location of the respondents. Section B was comprised of proposed Ecological Urban Green Infrastructure (UGI) Indicators and inter-linked multiple green infrastructure elements and technologies. It was designed to authenticate the knowledge of native community and their views regarding the concept of urban green spaces, the ecological urban green space indicators (UGI) i.e., optimizing storm water management, air quality improvement, noise quality, reduced carbon emissions and, enhanced and protect urban biodiversity. Each ecological indicator was comprised of various questions which describe and govern the importance of UGS elements and its connection with the sustainability of different UGI indicators (Rayan et. al., 2022a, 2022b, 2021; Khayyam, 2016).

The structured questionnaire helped to select the dynamic arrangement of the UGS elements which further helped to develop stainability factor in zone-II Islamabad, not only this, but it will also help to rebuild the concept of urban green spaces in the zone-II of Islamabad that is also resilient against the constantly rising threats such as increased environment temperature (Munir et. al., 2021). A 5 Likert-scale approach was implemented with 1-2= highly insignificance to slightly insignificant, 3=neutral or not sure, while 4-5=slightly significant to highly significant (Rayan et. al., 2022) to record the natives community response on the perspective of UGI and their relationship with the green elements in the urban environment.

To achieve the second objective, to what extent ecological UGS elements can contribute to halt the UHI effect in zone-II of Islamabad. For this purpose, first we analyzed the land surface temperature (LST) of zone II Islamabad by using the LANDSAT-8 OLI TIRS data which have been acquired through United States Geological Survey (USGS) Earth Explorer for the year 2013-14, 2016-17, 2019-20 and 2022-23. 3 years intervals were used to measure the long term UHI trends in the selected study area. To calculate the LST band 4,5 and 6 were used while to calculate the Normalized Difference Built-Up Index (NDBI) band 10 was used from LANDSAT-8. After calculating the LST and NDBI, UHI for zone II was calculated.

3.5 Data Analysis Technique

Given the quantitative nature of both our UGI indicators and UGS components, the relative importance index (RII) stands a right approach to analyze the responses of native community which further helped to make the possible UGI model. RII helped to determine the satisfaction level of the community regarding the selected UGS elements and UGI indicators in the locally built environment which is according to Rayan et. al., (2022); Gurmani, (2018); Jacobs et al., (2015) also done in the previous studies for ordinal scale surveys. Based on RII (outcomes), the significance level of every UGI indicator and UGS element was calculated. Enough UGS indicators and crucial UGS components were guaranteed by RII (for corresponding RII UGI indicators).

The next approach used to find a particular cut-off point in the RII Values (RIV) of UGS components was the Interquartile Range (IQR) strategy. For calculating the difference between the medians of the RII data sets lower (Q3) and upper (Q1) quartiles, the IQR was a useful and active method (Gurmani, 2018). Additionally, depending on each UGI indicator's original geographical context, it enables the selection of a critical (manageable) number of UGS components. A cut-off point that helps define the significant UGS elements for each unique UGI indication is thought to be at 0.70. This strengthens the urban system's resistance to the negative effects of human climate change.

Correlation helped to determine the relationship between the NDBI and UHI to check how and to what extent UGS are contributing to halt UHI effect in zone II of Islamabad. The UHI map and NDBI were classified into 10 classes for each year and the break values of NDBI and UHI were correlated. This technique has further explained that the linear relationship between urbanization and UHI is either negative or positive.

CHAPTER # 4: RESULTS AND DISCUSSION

4.1 Reliability Statistics:

The following section gives you an overview of the research findings, the data was then analyzed in SPSS version 27 and Microsoft excel. Starting with reliability statistics, the reliability statistics were calculated for all the 5 UGI indicators. All the variables have reliability statistics > 70% which means that the collected data was reliable. The highest reliability of 90.2% was for the Reduced carbon emission (e.g. avoided greenhouse gas emission through passive way) while the lowest reliability of 82.7% was for the enhanced and protect urban biodiversity.

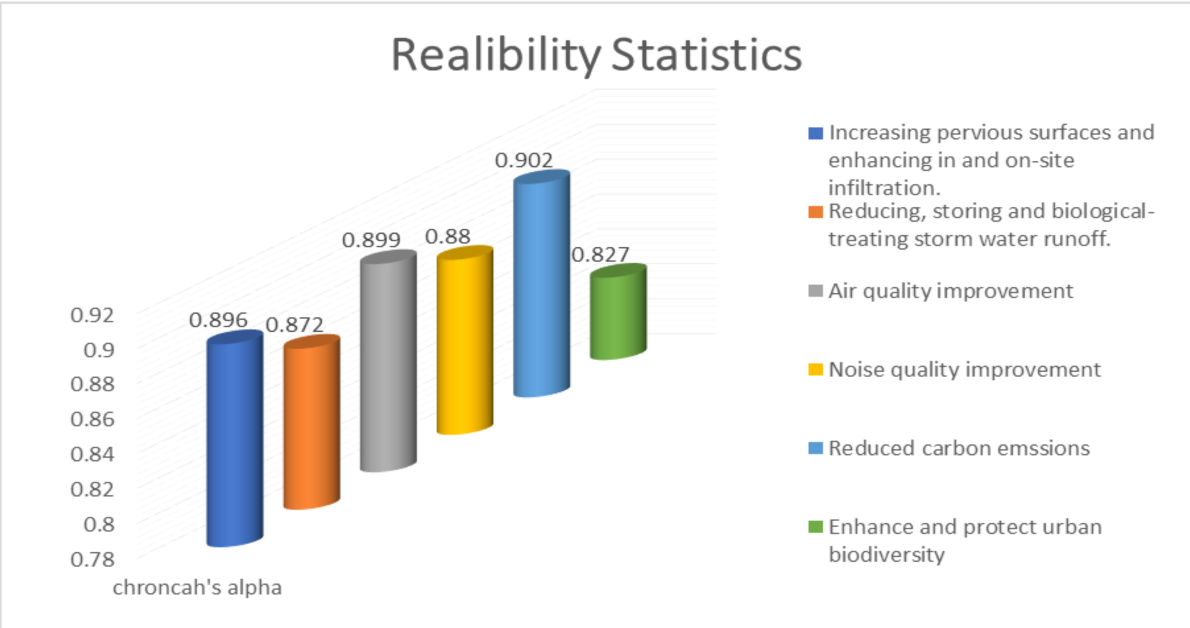

Figure 5 Graph illustrating Cronbach's Alpha of UGI indicators *(Source: Author's own)*

4.2 Descriptive statistics:

Moving on to further analysis, descriptive statistics were used to analyze the demographics of the participants of the research. Table 4.1 shows the result for the sector of the respondents in which residing, a total of 7 sectors of zone II were selected for the research.

The highest percentage of the respondents belongs to the sector the sector D-17, which is 33.8%. A total of 27.8 % of the respondents belong to sector G-15, 13.9% of the respondents reside in sector G-16, 10.3 % of the respondents were from sector F-15 while the remaining 2.3% and 2.8% of the respondents reside in sector F-17 and B-17 respectively.

Table 1 Frequency analysis of the sectors of research participants *(Source: Author's own)*

Sector	Frequency	Percent
G-15	60	27.8
G-16	6	2.8
F-15	22	10.2
F-17	5	2.3
B-17	30	13.8
D-17	73	33.8
D-18	20	9.3
Total	216	100.0

Moving on to the next demographic information which was about the residency of the respondents that either they are the permanent residents of that sector or living for a short time-period. According to the results, 51.4 respondents were permanent residents of that sector while the remaining 48.6% were temporary residents of that sector (Table 4.2)

Table 2 Frequency analysis of Type of Residency *(Source: Author's own)*

Residency	Frequency	Percent
Temporary	105	48.6
Permanent	111	51.4
Total	216	100.0

The time-period of residency in the sector also matters because it tells us about the ecological experience of the respondents residing in that sector, how and what type of ecological changes they have observed in the sector. According to the study findings (Table 4.3), around 39% of the respondents have been residing in the sector for 1-3 years, 34.7% of the respondents have been living since 4-6 years while only 5% of the respondents have been living in the sector for around 10-12 years. This result shows that most of the people have been living for a short period of time.

Table 3 Frequency analysis of number of years of participants residing in the sector *(Source: Author's own)*

Years of Residence	Frequency	Percent
1-3 years	84	38.9
4-6 years	75	34.7
7-9 years	32	14.8
10-12 years	13	6.0
More than 13 years	12	5.6
Total	216	100.0

4.3 Ecological Results

The empirical results of this section has constituted the answer for the research question 1 that, What are the important UGS elements for ecological UGI indicators in creating a green climate-resilience of Islamabad ? this section was grouped into two components, (i) identification of the important urban green spaces (UGS) elements that creates the importance the of each urban green infrastructure (UGI) indicator; (ii) finding the essential UGS components that improve the UGI indicator's quality and, in turn, aid in developing the UGI model that supports the development of a green climate resilient in Zone II Islamabad. To do so, first we have calculated the RII for UGI indicators.

4.3.1 Relative Importance Index (RII) of Sustainable UGI Indicators

Using the RII approach, potential ecological indicators were grouped based on their weights, along with gauging significance of all the ecological indicators according to the respondent's perspective. To verify the significance level of UGS elements the RII was calculated for each of the UGS elements based on respondent's responses. 5-point Likert scale was used to recognize the significant level of each of the UGS elements with their respective UGI indicators. Based on 5-point Likert scale, with 1-2= highly insignificance to slightly insignificant, 3=neutral or not sure, while 4-5=slightly significant to highly significant. All the 5 UGI indicators have achieved the highly significant (level 5). None of the values were found between 1-2=highly insignificant to slightly significance and 3= neutral or not sure. The overall results show that most of the UGI indicator falls under the significant category. This portrays the significance of all the UGI indicators based on the responses.

To identify the important UGI indicators, the interquartile range (IQR) strategy was implied after the RII. Based on the IQR values which ranges from 72% to 78% (0.72- 0.78) with the cutoff-point of 0.75 which was calculated by taking the average of IQR data set. These results highlight the important UGI indicator for the better ecology of zone II Islamabad. As the RII value for each UGI indicator was > 0.70 which means that all the UGI indicators assist in enhancing the ecology of zone II, still there is a need to determine the key UGI indicator that performs a highly significant role in strengthening the ecology which help to create the resilience against the ecological and climatic variations in the urban planning of zone II Islamabad. According to the results 3 UGI indicator were accepted as RII >0.75 and rest of the 3 were not accepted as RII < 0.75. after this the UGI indicators were ranked based on RII values and the highest rank 6 was achieved by Reduced carbon emission (e.g., avoided greenhouse gas emission through passive way) with the RII value of 0.79 while the lowest rank was achieved by UGI indicator noise quality improvement with the RII value of 0.72.

4.3.2 Relative importance index (RII) value of UGS elements with regards to the sustainable UGI indicators

Based on the empirical values, RII was calculated for each of the UGS elements to determine the significance of UGS elements that helps to advance the eminence of each UGI indicator which further helps to make the cities inclusive, ecofriendly, and creating resilience against any ecological and climatic changes. The RII values for each of the UGS elements varies between 71% to 100% while the average value for each of the UGS elements was above 70%. From these percentages it is implied that each of the UGS element has different characteristics according to their UGI indicators and Each and every UGS component helps to improve the effectiveness of the UGI indicators because the UGS elements with an RII >0.070 have the ability to improve the UGI indicators' resistance to any ecological and climatic changes in the context of urban development. This correlation of RII values of UGS

Table 4 Ecological Indicators

Ecological Green Infrastructure Indicator	Participant	Overall, Weight	Relative Index RII = ΣW/(N × A)	Interquartile Range Technique (IQR) (Q3-Q1)	Rank Order Based on RII Value
1. Improve the control of stormwater					
a. expanding the number of pervious surfaces and improving infiltration both on and off site.	216	797	0.73	0.73	2
b. lowering, storing, and regulating rainwater runoff biologically.	216	802	0.74	0.74	3
2. Improvements in atmospheric air (such as removing pollutants and changing wind direction)					
Implementing green impermeable screen in a street canyon and planting higher concentration of green trees	216	845	0.78	0.75	5
3. Eenhancement of noise intensity					
The use of green sound barriers can reduce noise levels both significantly and more.	216	782	0.72	0.77	1
4. Decreased carbon emissions (by passively avoiding greenhouse gas emissions)					
planting more trees to provide shade and evaporate material for landscape design (such as bricks, etc.)	216	863	0.79	0.75	5
5. Improved and preserved urban ecology					
Encourage movement and interconnectedness among urban green areas.	216	834	0.77	0.78	4

Table 5 Important UGI Elements

Ecological Green Infrastructure Indicator	Community gardens	Urban pocket parks	Groves / mix forms of trees	Green streets and alleys	Rain gardens / planter box and bio swale	Green parking lots and permeable pavement	IQR median	IQR mean	cut off point	selected UGI elements	selected green elements
1. Improve the control of stormwater											
a. expanding the number of pervious surfaces and improving infiltration both on and off site.	0.71	0.73	0.73	0.76	0.73	0.77	0.734	0.79	0.79	1	GPP
b. lowering, storing, and regulating rainwater runoff biologically.	0.73	0.71	0.75	0.79	0.76	0.71	0.742	0.79	0.79	2	GPP; GSA
2. Improvements in atmospheric air (such as removing pollutants and changing wind direction)											
Implementing green impermeable screen in a street canyon and planting higher concentration of green trees	0.74	0.81	0.83	0.77	0.75	0.78	0.755	0.79	0.79	3	GPP: UPP; GT
3. Eenhancement of noise intensity											
The use of green sound barriers can reduce noise levels both significantly and more.	0.72	0.76	0.74	0.72	0.70	0.71	0.780	0.79	0.79	1	GPP
4. Decreased carbon emissions (by passively avoiding greenhouse gas emissions)											
planting more trees to provide shade and evaporate material for landscape design (such as bricks, etc.)	0.81	0.77	0.83	0.80	0.77	0.81	0.755	0.79	0.79	**4**	**CG; GT; GSA; GPP**
5. Improved and preserved urban ecology											
Encourage movement and interconnectedness among urban green areas.	0.74	0.71	0.76	0.82	0.80	0.80	0.781	0.79	0.79	3	GSA; RG&BS; GPP

elements regarding the UGI indicators helps to build the sustainable UGI indicators model which helps in the formulation of more urban green spaces' strategies in the context of urban planning. These urban green spaces strategies further help to improve and sustain the ecology and climate resilient environment in the urban planning of different sectors of zone II Islamabad.

4.3.3 Identifying the Key UGS Elements

To identify the important UGS elements with respect to their UGI indicators for their functional linkage, the interquartile range (IQR) strategy was implied after the RII. Based on the IQR values which ranges from 73% to 81% (0.735- 0.812) with the cutoff-point of 0.79 which was calculated by taking the average of IQR data set. These results highlight the important UGS elements for each of the UGI indicator. As the RII value for each of the UGS elements with respect to their UGI indicator was > 0.70 It implies that every UGS component helps to increase the UGI indicators' positive effectiveness still there is a need to determine the key UGS elements that performs a highly significant role in strengthening the UGI indicator which help to create the resilience against the ecological and climatic variations in the urban planning of zone II Islamabad. According to table 2, the highest number of key UGS elements is for the UGI indicator "reduced carbon emission". From the above results it can also be established that the urban planning of zone II Islamabad can also be improved through different mixed-use green spaces not only this, but it can also be improved through the green parking lots and permeable pavements (GPP); urban pocket parks (UPP); and groves/ mix form of trees.

4.4 UHI Results

The research relationship between UHI and NDBI has also been developed to answer the research objective 3 that which extent the UGS elements can contribute to halt the UHI effect in Islamabad. The above GIS figures show the UHI and NDBI of zone II Islamabad at 4 different time points: 2013-2014, 2016-2017, 2019-2020 and 2022-2023. NDBI and UHI maps for Islamabad zone II were prepared from satellite data (LANDSAT-8) which represents the spatial distribution of urban heat island effect in the highly built-up or urbanized areas, has been done in ArcGIS. To evaluate the NDBI Band 6 and Band 5 data of the satellite was used to describe the built-up index of zone II (figure below shows the ArcGIS maps of NDBI of zone II), with that UHI maps of the study area were also prepared, Showing the spatial distribution of UHI effect within the study area.

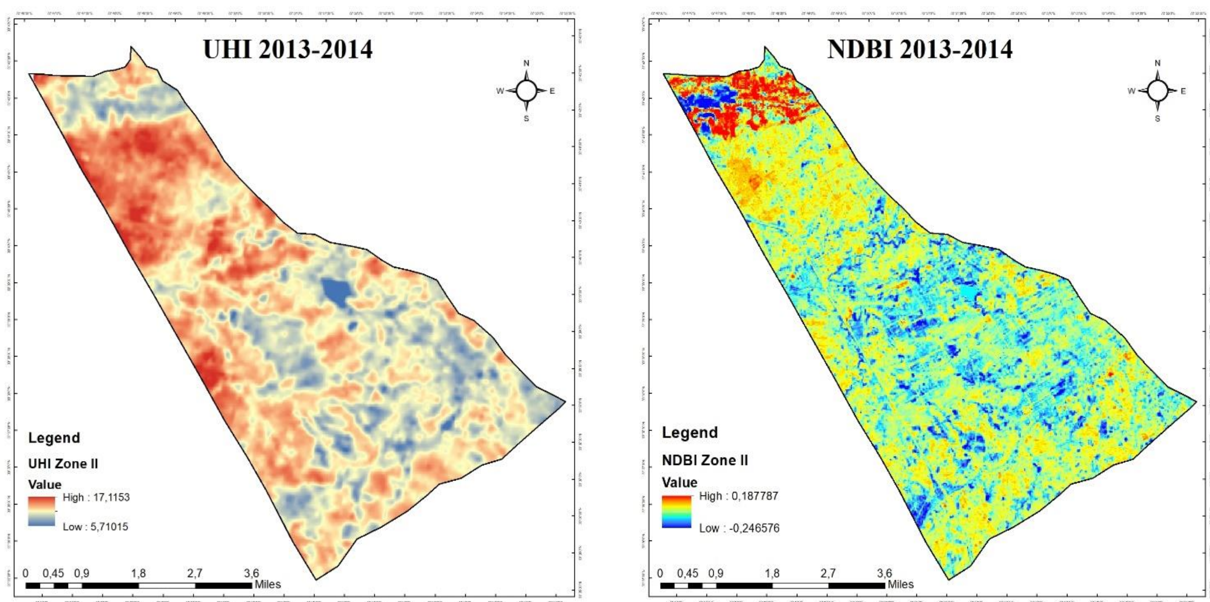

Figure 6 UHI and NDBI map for time-period 2013-2014 (*Source: Author's own*)

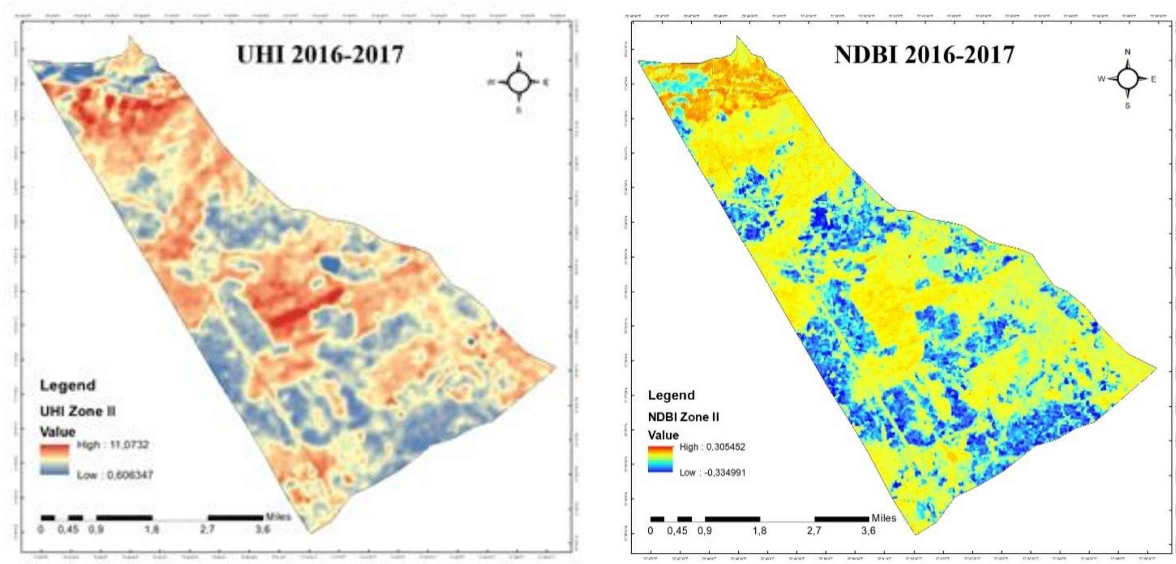

Figure 7 UHI and NDBI map for time-period 2016-2017 (*Source: Author's own*)

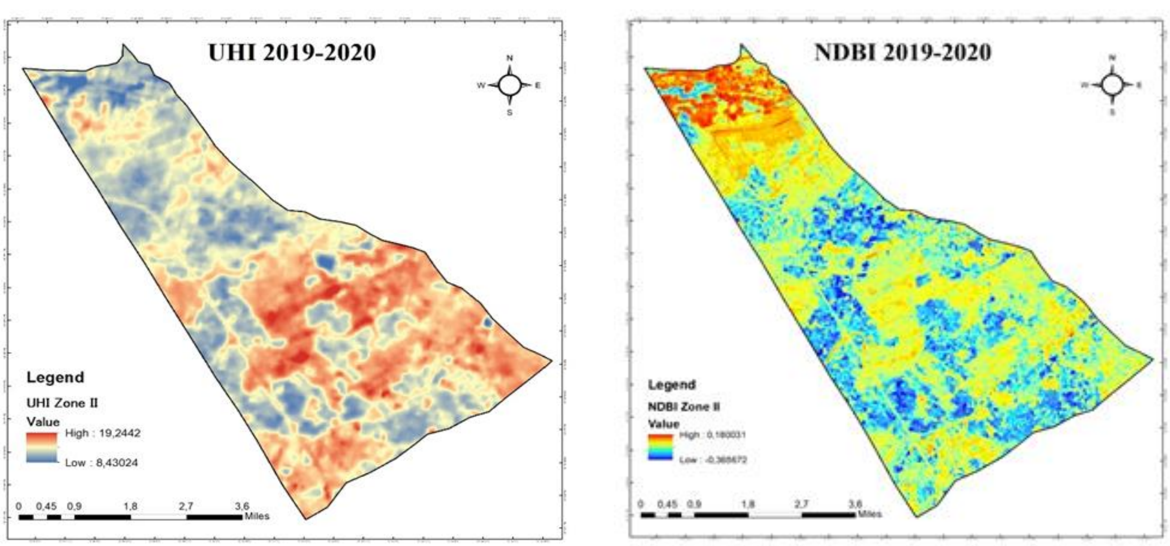

Figure 8 UHI and NDBI map for time-period 2019-2020 (*Source: Author's own*)

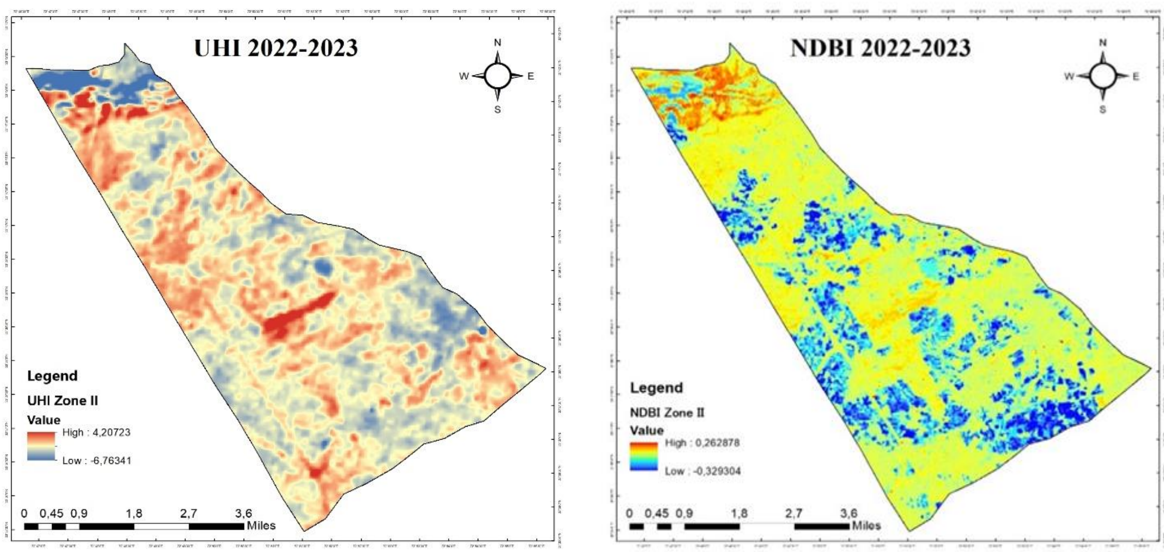

Figure 9 UHI and NDBI map for time-period 2022-2023 (*Source: Author's own*)

Also, the minimum and the maximum ranges of NDBI and UHI were calculated for the 4 different time points. The minimum and the maximum values vary for each year given in Tables 6 and 7.

Table 6 Minimum and Maximum value of UHI for different time-period *(source: author's own)*

Year	Minimum UHI	Maximum UHI
2013-2014	5.71	17.11
2016-2017	0.6	11.07
2019-2020	8.43	19.24
2022-2023	-6.76	4.207

The Urban Heat Island (UHI) values for different time-period provide insights into the temperature differentials between urban areas and their surroundings of zone II. In the period of 2013-2014, the UHI ranged from a minimum of 5.71 to a maximum of 17.11, showcasing a substantial variability in temperature within urban environments. The subsequent years, 2016-2017, exhibited a narrower range with a minimum UHI of 0.6 and a maximum of 11.07. Notably, the UHI values for 2019-2020 showed an increase in both the minimum (8.43) and maximum (19.24) UHI, indicating a potential escalation in urban heat. However, the most recent data for 2022-2023 presented a unique scenario with a negative minimum UHI of -6.76, suggesting instances where urban areas were cooler than their surroundings, while the maximum UHI was 4.207. This unexpected negative UHI may be attributed to specific climatic or environmental factors influencing the thermal characteristics of the urban landscape. Overall, these UHI statistics provide valuable information on the thermal dynamics of urban areas over the specified time-periods.

Table 7 Minimum and Maximum value of NDBI for different time-period *(source: author's own)*

Year	Minimum NDBI	Maximum NDBI
2013-2014	-0.246	0.1877
2016-2017	-0.334	0.3054
2019-2020	-0.365	0.18
2022-2023	-0.329	0.262

The Normalized Difference Built-up Index (NDBI) values for the different time-period reveal the extent and changes in built-up areas within zone II, Islamabad. In the period of 2013-2014, the NDBI ranged from a minimum of -0.246 to a maximum of 0.1877, indicating the presence and variability of built-up surfaces. Moving to 2016-2017, the NDBI exhibited a slightly broader range with a minimum value of -0.334 and a maximum of 0.3054, suggesting potential shifts in urban development during this period. The subsequent years, 2019-2020, displayed a range from -0.365 to 0.18, showcasing fluctuations in built-up indices and potentially reflecting changes in land use or urban planning strategies. The most recent data for 2022-2023 revealed a NDBI range from -0.329 to 0.262, providing insights into the ongoing dynamics of built-up areas. Negative NDBI values typically indicate non-built-up or vegetated areas, while positive values signify built-up surfaces. These statistics serve as valuable indicators of the spatial distribution and changes in urban development over the specified time periods.

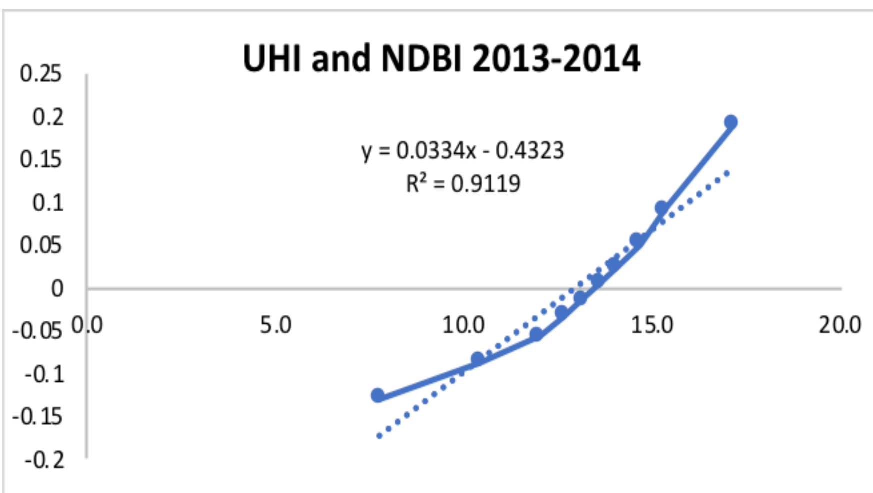

Figure 10 Correlation between NDBI and UHI for time-period 2013-2014 *(Source: Author's own)*

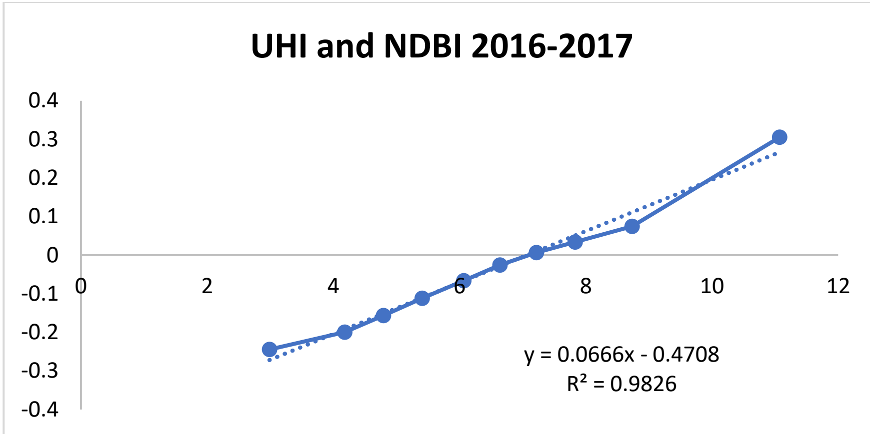

Figure 11 Correlation between NDBI and UHI for time-period 2016-2017 *(Source: Author's own)*

During the study the relationship between UHI and NDBI was also developed and found the direct relationship between them in each time-period. The results show the maximum UHI in the built-up areas. According to correlation results, A strong positive correlation was found between NDBI and UHI which means that the more built-up areas have the more UHI effect in the surroundings. NDBI and UHI correlation for the year 2013-2014 was significantly correlated (R^2=0.911). NDBI and UHI correlation for the year 2016-2017 was significantly correlated (R^2=0.982). NDBI and UHI correlation for the year 2019-2020 was significantly correlated (R^2=0.998). NDBI and UHI correlation for the year 2022-2023 was significantly correlated (R^2=0.971).

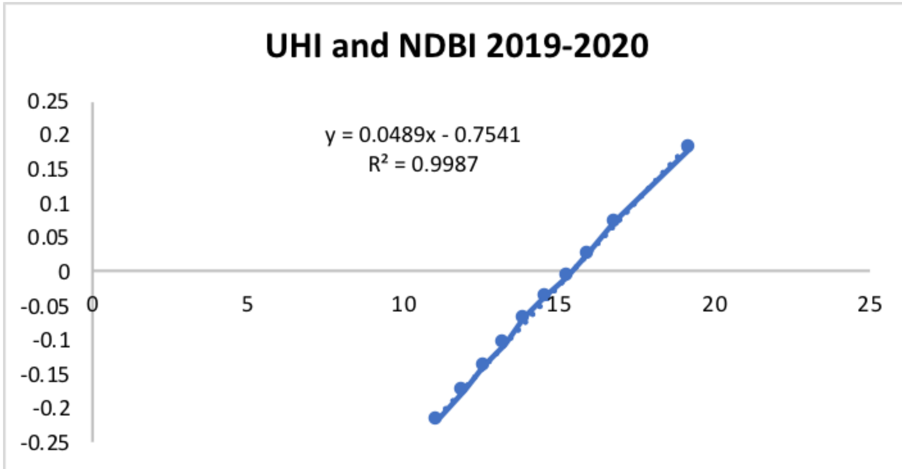

Figure 12 Correlation between NDBI and UHI for time-period 2019-2020 *(Source: Author's own)*

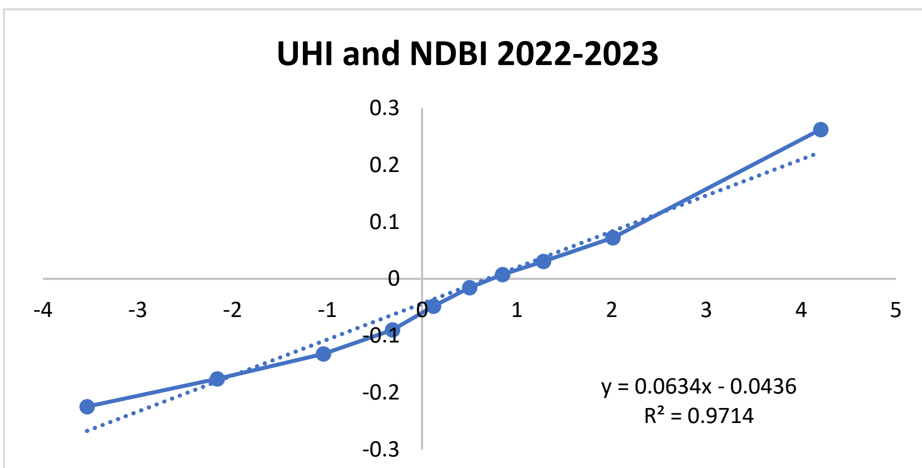

Figure 13 Correlation between NDBI and UHI for time-period 2022-2023 *(Source: Author's own)*

The strong positive linear correlation between UHI and NDBI of zone II Islamabad is displayed in the graphs above. Thus, it can be proved by this study that NDBI is the important factor used to analyze and predict the UHI effect in any area and provides a reliable basis for the planning of urban green spaces. As NDBI can be used to characterize the devolution and reduction in the ecological UGS elements.

4.5 Discussion

This research contributes to investigate about the importance of urban green elements for the ecological urban green infrastructure indicators in creating the climate-resilience of the zone II of Islamabad Pakistan, because Urban green infrastructure and the sustainable development of the country are interlinked (Hanna and ComiN, 2021). The empirical result of this study explains that UGI indicators plays an important role in enhancing the process of urban planning (Rayan et al. 2022)

According to the findings of this research the most important indicator for the urban green infrastructure is the reduced carbon emission which aligns with the previous study of Pearson et al. (2017), the green spaces and the carbon emissions are closely related because the carbon storage is strongly dependent on the distribution of the green spaces while the second important UGI indicator for the Urban green infrastructure is air quality improvement. Selmi et al. (2016), findings explains that urban green spaces are of much importance to reduce the air pollution in the city, results of the present study also prove that implementing green impermeable screen in a street canyon and planting higher concentration of green trees can also help to reduce the air pollution in zone 2 of Islamabad. This result also aligns with the findings of study conducted by Jayasooriya et al. (2017) that mix trees have the highest capability among the different ecological GI indicators to provide the capability of removing air pollution.

Just like the reduction in air pollution, noise quality is also improved by the green infrastructure, as it acts a buffer between the source of the noise and the urban area, ecological urban green infrastructure indicators help to reduce the noise pollution or upsurges the noise quality which aligns with the study of Maksymenko et al. (2021) that green infrastructure provides more pleasant and calming environment by reducing the noise pollution for residents. In case of the UGI indicators elements green parking lots and permeable pavements are the elements that helps in increasing the noise quality and decreasing the noise pollution which has also been proved by Maksymenko et al., (2021), in the previous studies.

The urban green infrastructure also helps to protect and enhance the ecology of the city and the biodiversity. The previous studies of Senetra et al. (2018) and De La Barrera et al. (2016b) has proved that the urban green spaces fitful the functions of urban fabric and provides the resident the whole range of urban ecosystem to enhance the urban biodiversity in sustainable development of urban areas. To enhance and protect the urban bio-diversity UGI elements like green streets and alleys refers to trees in the streets and helps to foster the pollutants concentration in area, this empirical evidence is also supported by (Yli-Pelkonen et al., 2017a; 2017b). Green infrastructures play an important role in ecological services and biodiversity preservation also proved in the previous study of (Hanna and ComíN, 2021)

In this research we also developed the relationship between the urban heat island effect and the NDBI by using correlation to study the extent of ecological UGS elements that can contribute to halt the UHI effect because according to li et al. (2018), urban green spaces plays and important role in hindering the effect of UHI. Zone II of Islamabad was again the focus of the study as the findings of Sadiq et al. (2020) elucidate that urban heat island effect has been observed in Islamabad, the capital of Pakistan.

Consequently, we developed a positive relationship between the UHI and NDBI, and according to the results that if the built-up index of the zone II is increasing than the UHI effect is also increasing in the surrounding area in the different time-period. These results align with the study of Ali et al. (2022), that due urbanization there is a significant change in the LULC, and it means that the green spaces are shrinking, and the grey structure of the zone II is increasing causing the increase in UHI effect, according to Yasmeen et al. (2021) built-up area has more capacity to absorb the solar radiation that results in the rise of temperature over those regions. The correlation analysis developed a positive linear relationship between the NDBI and UHI in this study which also aligns with the study of Isufi et al. (2021), that NDBI has the strength to increase the UHI intensity.

CHAPTER # 5: CONCLUSION AND POLICY IMPLICATIONS

5.1 Conclusion

As climate change has become a global issue, it has severe impacts on the ecology of the city. With the increase in climate change, the need for urban green spaces has been increased to cater the climate resilience. The novel concept of urban green spaces is becoming a more powerful tool in urban planning for the purpose of sustainable development. Urban green spaces hold an important place for the city's component. The rapid urbanization is directly linked to the LULC which is converting the green spaces into the grey areas. The present research focuses on the zone II of Islamabad, Pakistan to study the ecological urban green infrastructure of zone II, the increase in the built-up index which is directly correlated to the increase the UHI effect of zone II Islamabad. Also, the importance of urban green spaces and the planning of urban green spaces and the UGI indicators in the German context.

In the lieu of present research, the important UGS ecological indicators were found, and they were ranked according to their relative importance index according to the results the important UGI indicators was reduced carbon emission, that planting the higher concentration of trees can reduce the carbon emissions and increases the carbon storage. With that, the ecological UGI indicators help to improve the air quality in the urban areas and the noise quality. After studying the important UGI indicators, the relative importance index (RII) of UGI elements was also calculated. To know the important level of UGS elements for the green infrastructure. According to the findings, reduced carbon emissions have the greatest number of UGS elements which includes community gardens, mix form of trees, green streets and alleys, and green parking and the permeable pavement.

This study also focuses on the UHI effect in the zone II od Islamabad, Pakistan. To study the UHI effect the spatial analysis was done for the 4-year time-period which included 2013-24, 2016-17, 2019-20 and lastly 2022-23. Maps OF NDBI and UHI were prepared in ArcGIS to elucidate the findings more clearly. The findings indicate that there is a direct correlation between NDBI and UHI which means that whenever the built-up index is increased the UHI intensity also increases in zone II of Islamabad. this result further elaborates that when the NDBI increases the vegetative cover (refers to the green structure) also decreases and due to the reduction in the vegetative land cover the UHI increases because urban green infrastructure plays and important role in hindering the UHI effect.

With these findings of the present research, it has been concluded that urban green infrastructure which is referred to the urban green space plays an important role in the quality urban ecological environment by knowing the importance of urban green infrastructure elements which further helps to reduce the UHI effect in zone II of Islamabad, Pakistan.

5.2 Policy Implications

Through the significant findings of the present research the importance of urban green spaces in the context of UGI indicators and UGI elements has been proved. Also, the urban green spaces elements which contribute to halt the effect of UHI. The analysis of European policy related to the urban green spaces has also some suggestion regarding the policy implications for the planning or urban green spaces in zone II of Islamabad Pakistan.

5.2.1 Integration of Green Infrastructure policies into Urban Planning

As this has been already proved by Slätmo et al. (2019) that 11 of the 32 countries from the European policies that are particular to GIs have been established or are being developed. Luxembourg, Norway, Denmark, Sweden, the Netherlands, Germany, Belgium, the United Kingdom, and France are among the nine nations whose per capita GDP was higher in 2017 than the average of the European Union. It is possible that this suggests economies that are doing well are better suited to change their national GI policies. Still, these findings need to be interpreted cautiously because no discernible pattern has been found. Certain nations, like Finland, Austria, Ireland, Iceland, Switzerland, and Liechtenstein, have GDPs per capita that were higher than average but no GI-specific laws. This implies that in order to design and implement a GI strategy, political will is also essential. CDA policies may need to emphasize the integration of green infrastructure into urban planning processes. This could involve updating zoning regulations, land use plans, and building codes to encourage and require the incorporation of green spaces. Integrate green spaces, parks, and tree canopy coverage into urban planning in Zone II. Policies should encourage the inclusion of green roofs, urban forests, and other green infrastructure elements to reduce the heat island effect.

5.2.2 Stormwater Management Policies

This research has demonstrated the critical function that green infrastructure plays in stormwater control. The application of green infrastructure to manage runoff, lessen flooding, and enhance water quality may require policy attention. This might entail implementing permeable pavements, green roofs, and other sustainable drainage techniques, such as the green storm water management techniques used in Germany (Nickel et al., 2015). Adopt water management regulations that take into account how heat affects water supplies. Guidelines for water saving, effective irrigation techniques, and the creation of green stormwater infrastructure to filter and cool runoff are a few examples of this.

5.2.3 Community Engagement and Education

Policies may promote community involvement in green infrastructure development and upkeep. Campaigns for public awareness and educational initiatives can enlighten locals about the advantages of green spaces and include them in their maintenance. Campbell-Árvai and Lindquist (2021) state that incorporating community design goals into the land is necessary. In addition to providing residents with meaningful opportunities for input and collaboration in urban landscape planning and design, the info design tool assists them in designing their green infrastructure. This aligns with the growing interest in democratising the design, management, and governance of public spaces.

5.2.4 Heat-Ready Infrastructure

Ensure that infrastructure projects in Zone II are designed to withstand and adapt to rising temperatures. This includes incorporating heat-resilient materials for roads, bridges, and other critical infrastructure.

Policies should encourage collaboration between government agencies, private sector entities, non-profit organizations, and local communities. Partnerships can help pool resources, share expertise, and implement comprehensive green infrastructure initiatives.

Also, to implement comprehensive UHI mitigation strategies. Public-private partnerships can facilitate the exchange of knowledge, resources, and best practices.

5.2.5 Incentives for sustainable development

Policies should address the long-term maintenance of green infrastructure. This includes establishing funding mechanisms, such as dedicated budgets or user fees, to ensure the ongoing care and sustainability of green spaces. provide incentives for developers and businesses that incorporate sustainable and heat-resilient practices in their projects. This could include tax incentives, expedited permitting processes, or other financial rewards for projects that meet specific criteria.

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QUESTTIONNAIRE

Section A: Personal Information					
Sector:					
Residency:	Temporary		Permanent		
No. of years residing in this sector:	1-3 years	4-6 years	7-9 years	10-12 years	More than 13 years
Section B: Proposed Ecologoical Urban Green Infrastructure (UGI) Indicators and Inter-linked mutiple Green infrastructure elements and technologies					
Ecological Green Infrastructure Indicator	**1-Highly Insignificant**	**2-Slightly In significant**	**3-Neutral / not sure**	**4-Slightly significant**	**5-Highly significant**
Please rate your opinion between,					
1. Improve the control of stormwater					
a. Increasing pervious surfaces and enhancing in and on-site infiltration.					
How important **community garden** expanding the number of pervious surfaces and improving infiltration both on and off site.					
How important **urban and pocket parks** expanding the number of pervious surfaces and improving infiltration both on and off site.					
How important **groves/mix forms of trees** expanding the number of pervious surfaces and improving infiltration both on and off site.					
How important **Green streets and alleys** expanding the number of pervious surfaces and improving infiltration both on and off site.					
How important **Rain garden , planter box and bio swale** expanding the number of pervious surfaces and improving infiltration both on					
How important **Green parking lot and permeable pavements** expanding the number of pervious surfaces and improving infiltration both					
b. Reducing, storing and biological-treating storm water runoff.					
How important **community garden** lowering, storing, and regulating rainwater runoff biologically.					
How important **urban and pocket parks** lowering, storing, and regulating rainwater runoff biologically.					
How important **groves/mix forms of trees** lowering, storing, and regulating rainwater runoff biologically.					
How important **Green streets and alleys** lowering, storing, and regulating rainwater runoff biologically.					
How important **Rain garden , planter box and bio swale** lowering, storing, and regulating rainwater runoff biologically.					
How important **Green parking lot and permeable pavements** lowering, storing, and regulating rainwater runoff biologically.					
2. Improvements in atmospheric air (such as removing pollutants and changing wind direction)					
Implementing green impermeable screen in a street canyon and planting higher concentration of green trees					
How vital **community garden** Implementing green impermeable screen in a street canyon and planting higher concentration of green trees					
How vital **urban and pocket parks** Implementing green impermeable screen in a street canyon and planting higher concentration of green trees					
How vital **groves/mix forms of trees** Implementing green impermeable screen in a street canyon and planting higher concentration of green trees					
How vital **Green streets and alleys** Implementing green impermeable screen in a street canyon and planting higher concentration of green trees					
How vital **Rain garden , planter box and bio swale** Implementing green impermeable screen in a street canyon and planting higher concentration of green trees					
How vital **Green parking lot and permeable pavements** Implementing green impermeable screen in a street canyon and planting higher concentration of green trees					
3. Enhancement of noise intensity					
The use of green sound barriers can reduce noise levels both significantly and more. (i.e for limited noise; thick hedges with a small piece of grassland can be provided and higher noise; broadleaved deciduous trees, thick layers of bamboo can be provided .					
How vital **community garden** The use of green sound barriers can reduce noise levels both significantly and more.					
How vital **urban and pocket parks** The use of green sound barriers can reduce noise levels both significantly and more.					
How vital **groves/mix forms of trees** The use of green sound barriers can reduce noise levels both significantly and more. .					
How vital **Green streets and alleys** The use of green sound barriers can reduce noise levels both significantly and more.					
How vital **Rain garden , planter box and bio swale** The use of green sound barriers can reduce noise levels both significantly and more.					
How vital **Green parking lot and permeable pavements** The use of green sound barriers can reduce noise levels both significantly and					
4. Decreased carbon emissions (by passively avoiding greenhouse gas emissions)					
planting more trees to provide shade and evaporate material for landscape design (such as bricks, etc.)					
How fundamental **community garden** planting more trees to provide shade and evaporate material for landscape design (such as bricks, etc.)					
How fundamental **urban and pocket parks** planting more trees to provide shade and evaporate material for landscape design (such as bricks, etc.)					
How fundamental **groves/mix forms of trees** planting more trees to provide shade and evaporate material for landscape design (such as					
How fundamental **Green streets and alleys** are for enhancing the concentration of trees to reduce carbon emission .					
How fundamental Rain garden , planter box and bio swale planting more trees to provide shade and evaporate material for landscape					
How fundamental **Green parking lot and permeable pavements** planting more trees to provide shade and evaporate material for					
5. Improved and preserved urban ecology					
Encourage movement and interconnectedness among urban green areas.					
How vital **community garden** Encourage movement and interconnectedness among urban green areas.					
How vital **urban and pocket parks** Encourage movement and interconnectedness among urban green areas.					
How vital **groves/mix forms of trees** Encourage movement and interconnectedness among urban green areas.					
How vital **Green streets and alleys** Encourage movement and interconnectedness among urban green areas.					
How vital **Rain garden , planter box and bio swale** Encourage movement and interconnectedness among urban green areas.					
How vital **Green parking lot and permeable pavements** Encourage movement and interconnectedness among urban green areas.					