ASSESSING THE ROLE OF GREEN ROOFS AS NATURE-BASED SOLUTIONS FOR ADAPTATION PLANNING AND URBAN RESILIENCE: A CASE STUDY OF ISLAMABAD, PAKISTAN

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Abstract

Green roofs, an opportunity to simultaneously mitigate environmental problems and create life-enhancing value, represent a class of technology that can be considered Bioengineering or Biomimicry. The purpose of this study is to explore institutional challenges and public perceptions towards green roofs development related to behavioral, social and demographic variables. To investigate citizen's attitudes towards participation in green roofs development, surveys was conducted in the districts of Islamabad. The statistical analysis of data is performed using SPSS. Results show the opinion of citizens about most important benefits and barriers of developing living roofs. While people were interested in installing rooftop gardens, but there were not volunteers. The financial and technical support by municipalities and urban managers is the main expectation of people. Overall, results helped identifying institutional challenges to implement green roofs in urban areas and also public perceptions regarding green roofs.

Keywords: *Climate change: Nature-based solutions; Green roofs; Adaptation planning; Urban resilience*

List of abbreviations

IPCC	Intergovernmental Panel on Climate Change
NCA	National Climate Assessment
UNDP	United Nations Development Program
UNDRR	United Nations Office for Disaster Risk Reduction
UNICEF	United Nations International Children's Emergency Fund
CDA	Capital Development Authority
NDMA	National Disaster Management Authority
IUCN	International Union for Conservation of Nature
BCE	before the common (or current) era
EEA	European Environmental Agency
TPB	Theory of Planned Behavior
WTP	Willingness to pay
UHI	Urban Heat Island
UGS	Urban Green Spaces
CAM	Climate Action in Megacities

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1. Introduction

1.1. Evolution of green roofs

Green roofs on the rooftops are not a very new technique. However, the way it is integrated in building these days is new. In the past, people usually build green roofs as rooftop gardens for thermal insulation of their homes and to lower the severe effects of urbanization. Going back in time, Hanging Gardens of Babylon constructed around 500 BCE, is one of the ancient green roofs. Going through the history of green roofs, Germany started the concept of modern green roofs in early 1960s. They started constructing green roofs as a solution to energy crises. In modern times, Germany is still known as leader of green roof technology. The reason behind this success is green roofs being designed and implemented on a large scale (X. Zhang et al., 2011). Reinhard Bornkamm, German researcher, published his work regarding green roofs in 1962. After the publication new developments related to green roofs started and never stooped. In 1973, roof gardens were initiated at Dubai trade fair in Essen in Germany. In early 1980s, green roofs market expanded and developed quickly.

Nowadays, 26% of cities with population more than 50,000 promotes green roofs and provides financial subsidies in Germany (Wolff, 2021). Guidelines regarding the construction of green roofs into building were published in 2005 and 2006 by Association of Standard and Testing Materials (ASTM). German FLL-green roofs guidelines explained planning, execution, and maintenance of green roofs in the report (Philippi, 2002). Later in 2009, United States Environmental Protection Agency (USEPA) released a report containing the benefits of green roofs when integrated into buildings. Till today, ongoing research regarding green roofs is conducted and shared among countries.

USA, Singapore, Canada, Japan, Australia, Hongkong, China, and South Korea are making fast-paced progress at integrating green roofs in new and existing buildings. In Canada, a building with floor area of $\geq 2000 m^2$ should apply green roofs on 20-60% of total roof area (Chen, 2013). In Japan, all new building must reserve area for green roofs. Moreover, a public building larger than 250 m^2 and private building larger than 1000 m^2 should reserve 20% of roof area for green roofs

(Badescu & Sicre, 2003). In Portland, 70% of areas in new buildings are encouraged to be reserve for green roofs. China and Hongkong are moving along other developed countries to integrate green roof practices in planning on a larger scale (X. Zhang et al., 2012). South Korea, the government is encouraging the public, private sector, and stakeholders to use green roofs to make cities safe, sustainable, and climate-change resilient.

Figure 1. Green Roof selected for 2016 Excellence Awards in buildings: green roofs on intensive commercial, small scale residential, interior green wall, and urban agriculture (Brier & lia dwi jayanti, 2022)

In Australia, there are regulations that govern the installation and maintenance of green roofs. These regulations vary by state and territory, and it is important to consult with the relevant authorities to ensure compliance (Razzaghmanesh et al., 2014). There are several successful green roof projects in Australia, including the One Central Park project in Sydney, which features a 116-meter vertical garden and has won several awards for its design and sustainability features. Other notable projects include the green roof at the University of Melbourne's Burnley Campus and the green roof at the City of Melbourne's Council House building.

Green Roofs for Healthy Cities are working towards sustainability, **figure 1** shows the *2022 Green Roof and Wall Awards of Excellence* recognized outstanding design projects in eight design categories, as well as Individual accomplishments in policy, research, and board recognition. The Awards ceremony took place in person during Cities Alive Philadelphia on October 18, 2022 (Brier & lia dwi jayanti, 2022). The research is more focused on low cost or innovative designs of green roofs that can provide multiple benefits in adaptation planning and making cities climate resilient. With such successful green roof implementations all around the world, it is gaining more consideration for climate change adaptation and mitigation.

1.2. Problem Statement

Resilience is the ability of an individual, a household, a community, a country, or a region to withstand, adapt to, and quickly recover from stresses and shocks (European Commission, 2012). Climate change has become the topic of concern among such stress factors. It has been discussed and policies have been implemented all around the world in terms of health, social security, biodiversity protection, and shield of infrastructure. Urban resilience is intimately linked to a city's economic history, because recovery and adaptation necessitate significant financial and infrastructure resources (Samuelsson et al., 2019). Recently, researchers are keenly studying urban resilience in the context of community planning and development, which has been highly integrated with human wellbeing (Liao, 2012). Moreover, socio-economic factors also influence urban resilience.

Energy demand is high in urban areas, it is responsible of approximately 36% of worldwide energy usage, which results in 39% of total energy related CO_2 emissions. Talking about the European level building sector energy demand is 20-40%, which results in approx. 35% of energy related CO_2 emissions (Parker & Simpson, 2020). This has highlighted the critical importance of taking a proactive approach to maintaining optimal indoor comfort conditions while using less energy. Consequently, adaptation and mitigation strategies supported by legal actions practical solutions have become significantly important for making cities sustainable and resilient. Globally, sustainable city is one of the inclusive aspect of Sustainable Development Goals (especially goals 11,12, and 13), targeting to make cities resilient, competitive, and resource-effective to mitigate the effects of climate change (Johnston, 2016). In this regard, standards and regulations have been issued for residential sector, aiming the goals to nearly zero-energy buildings (European Commission, 2012). Resultantly, adaptation planning and urban resilience have now entered the dictionary of global research community.

Green roofs have shown effective results in mitigating the effects of extreme climate i.e., urban heat island (UHI) and floods. They refer to a roofing system that is partially or completely covered with vegetation and soil, and can offer numerous benefits to urban environments, including reducing energy consumption, mitigating the urban heat island effect, improving air quality, reducing stormwater runoff, and increasing biodiversity (Shafique et al., 2018; Tam et al., 2016). These are particularly important in densely populated urban areas where high temperatures can lead to heat-related health problems. Majorly thesis explores (i) concept of green roofs for adaptation planning and urban resilience, (ii) environmental effects of green roofs on a spacious urban context including other benefits, (iii) institutional challenges in implementation of green roofs, (iv) public perceptions regarding green roofs, (v) barriers in implementing green roofs in buildings, (vi) policy recommendations and future perspectives. In this regard, it is necessary to not only assess the extent to which green roofs can improve climate resilience today, but also to forecast future implications.

1.3. Research questions

A comprehensive literature review has been performed on journal articles that supports a holistic approach regarding green roofs for adaptation planning and urban resilience. While reviewing literature following research questions were used as a guide:

RQ1: How green roofs will aid in building urban resilience and promote adaptation planning?

RQ2: What is public perception in implementation of green roofs in urban areas?

RQ3: What are institutional challenges regarding the implementation of green roofs?

RQ4: What are the policy recommendations and future directions regarding green roofs and climate change adaptation?

Considering the above research question, thesis was structured accordingly.

- The contribution of green roofs to the cities was explored.
- A framework concerning integration of green roofs in cities was examined, with emphasis on urban resilience.
- The contribution of green roofs in adaptation planning against climate change was explored.
- Different themes relevant to green roofs in urban context was identified.
- Challenges to institutionalize green roofs and public perceptions.
- The policy recommendations and future research perspectives regarding green roofs were highlighted for sustainable and resilient cities.

1.4. Research objectives

This study is aimed to know the public perceptions followed by urban and institutional challenges to implement green roofs in urban areas for adaptation planning and resilience. The objectives to be achieved are:

- To review the role of green roofs in adaptation planning and enhancing urban resilience.
- To assess public willingness and awareness regarding green roofs technologies and Nature-based solutions.
- To identify institutional challenges regarding green roofs for climate change and improving urban resilience.
- To suggest policy recommendations for enhancing urban resilience.

2. Literature Review

2.1. Bibliometric profile

2.1.1. Research query

The Web of Science was used as database to retrieve articles on green roofs and climate change with respect to urban resilience and adaptation planning. Keywords were chosen for retrieving were "green roof*" AND "climate change" (**see table 2**). The assessment of all previously identified themes and the compilation of those that overlapped or were closely connected formed the fourth stage of thematic analysis.

Table 1. Keyword search and results

Keyword Used	Database	Document type	Years	Data retrieved	Results
"green roof*" AND "climate change"	Web of science	Article	All years	12^{th} October, 2022	230

The ultimate theme definition and polishing was the last phase. The definition and concepts that were developed around the nominated themes from the previous steps served as the foundation for the narrative. Each finalized topic also included discussions on all preceding subthemes.

2.1.2. Author's keyword

The background of green roofs and climate change literature in the context of adaptation planning and urban resilience is thoroughly revealed by keyword analysis. The retrieved scientific publications were found to contain 835 distinct keywords. VOSviewer was used to find potential connections and co-occurrences between the terms listed by the authors of the shortlisted literature. Visualization overlay maps were developed to obtain a comprehensive understanding of the important themes. The map was made up of a number of circles with different diameters, each one displaying a keyword. Themes were represented by years and are linked to each other.

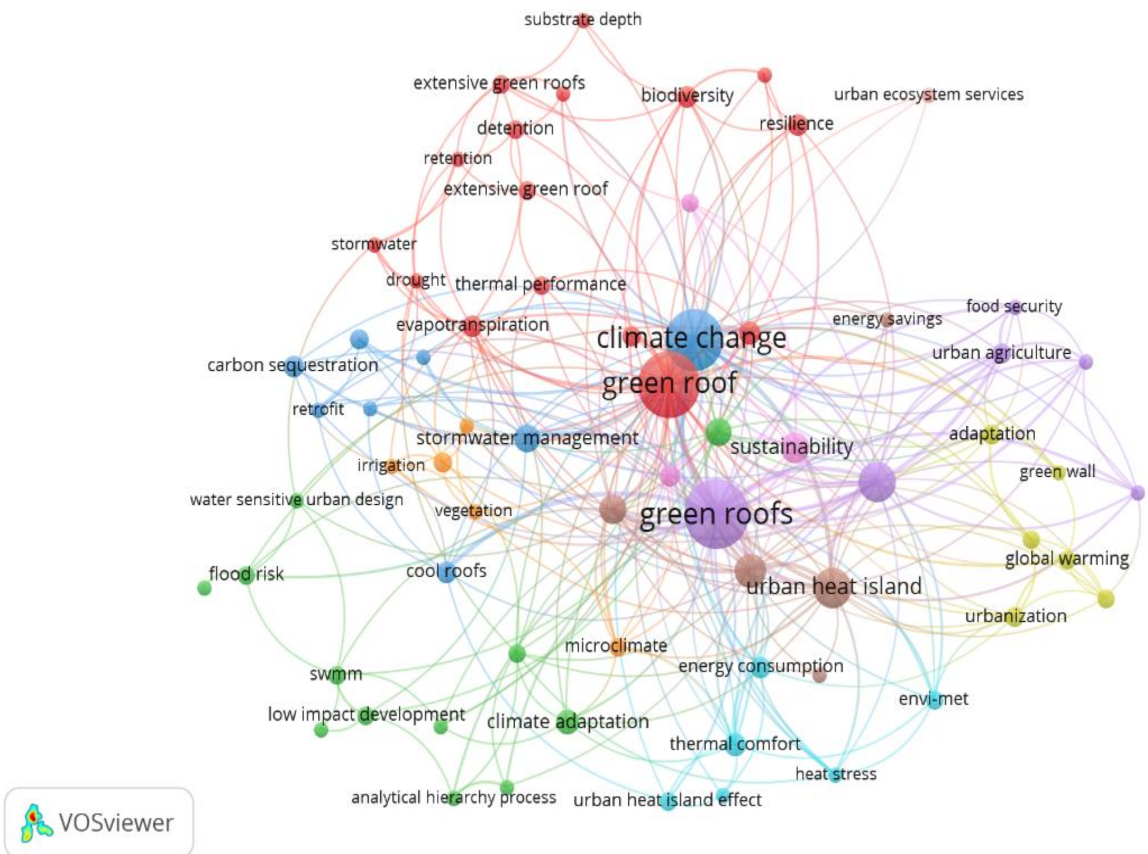


Figure 2. Network map of author's keywords (3 co-occurrence criteria with 68 Keywords). Retrieved on 12 October 2022

Once keywords clusters were visualized, it aids in interpreting the results to gain insights into the key themes and topics that are most prominent in the dataset. Moreover, it helped to identify trends, patterns, and gaps in the research literature, and guide future research directions. **Figure 6** illustrates the overlay map of 68 keywords that co-occurred at least three times in the selected publications. It can be seen that themes like "climate change", "urban heat island", "storm water management", "sustainability", and "resilience" are larger sizes which reflects the focus of these keywords in the research area.

2.1.3. Publication overview

An overview of the publications on green roofs and climate change in the context of urban resilience and adaptation planning provided interesting insights (**see table 2**). Two hundred and thirty research publications were retrieved from 138 journals utilizing the keywords. It is visible that collective citations of these journal articles are over 6800 with an average citation of 26 per article.

Table 2. Summary of publications in Web of science.

Fields	Summary of publications
Articles	230
Sources (Journals)	138
Citations	6880
Average citations per article	26.56
Authors	263
Author's keywords	835
Institutions	163
Countries	**56**

The authors used a total of 835 distinct keywords in their published papers. Moreover, 263 authors and 163 institutions were involved in publishing the journal articles on green roofs and climate change for urban resilience and adaptation planning.

2.1.4. Number of publications, authors, and sources

The number articles published annually was illustrated in the graph (**figure 3**). Over the years the number of publications has seen growing. The reason might be the increasing awareness regarding green energies, climate change, urban resilience, and adaptation. Such growth can also be associated with increasing heat waves, floods, and rising pollution that people are switching to green roofs.

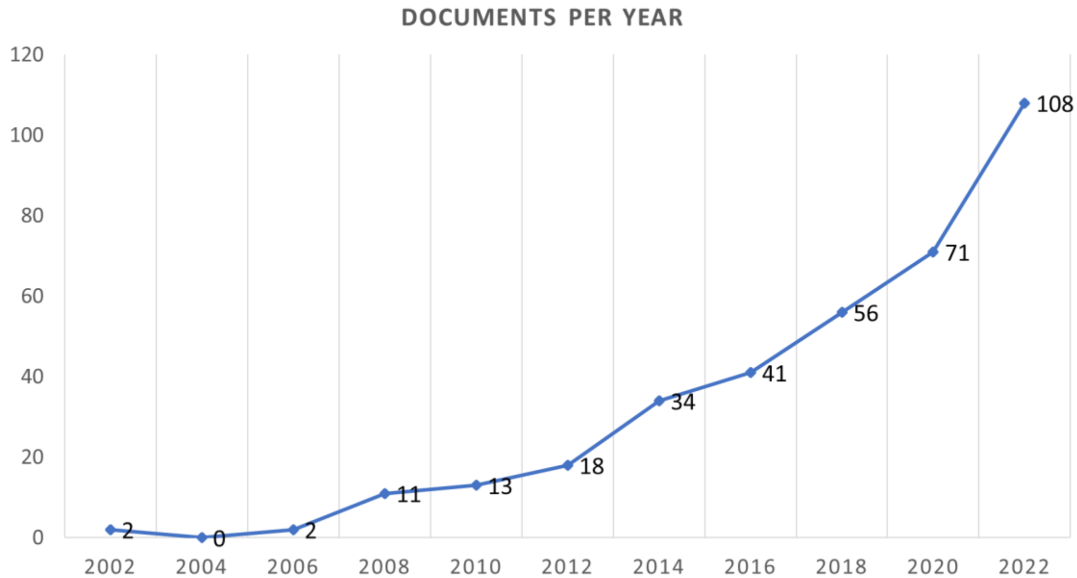


Figure 3. Annual number of publications related to social protection, disasters, and climate change (Retrieved 12 October 2022).

Top-ten authors to publish articles on green roofs and climate change in the context of urban resilience were illustrated (**figure 5**). A variation in publications can be seen, because as the awareness increases among people researchers find it their duty to come forward with facts and rationale logics to help public.

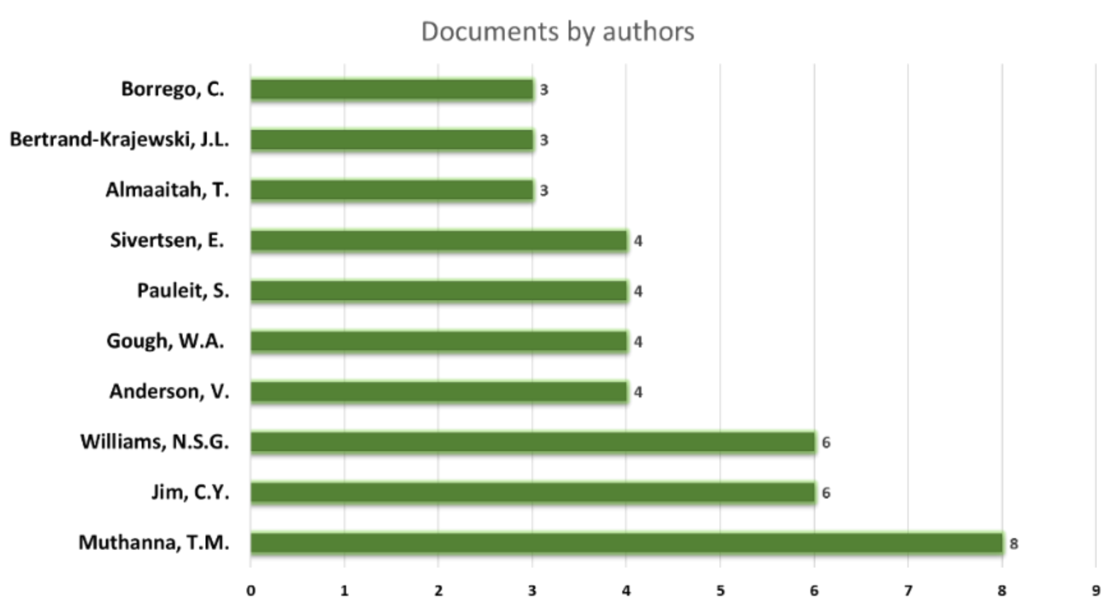


Figure 4. Top-ten authors published articles on green roofs and climate change

In terms of journals (publication sources as named by Web of Science), annual illustration of sources are shows **(figure 6)**. The majority of studies, both in green roofs and climate change discourses, were published in urban planning and environment-related journals. Publications by these sources are seen to be increase over the last decade. Most articles were published in 2020, a year after COVID-19. Public and professionals were inclining towards green solutions for urban sustainability and to stand robust against future calamities.

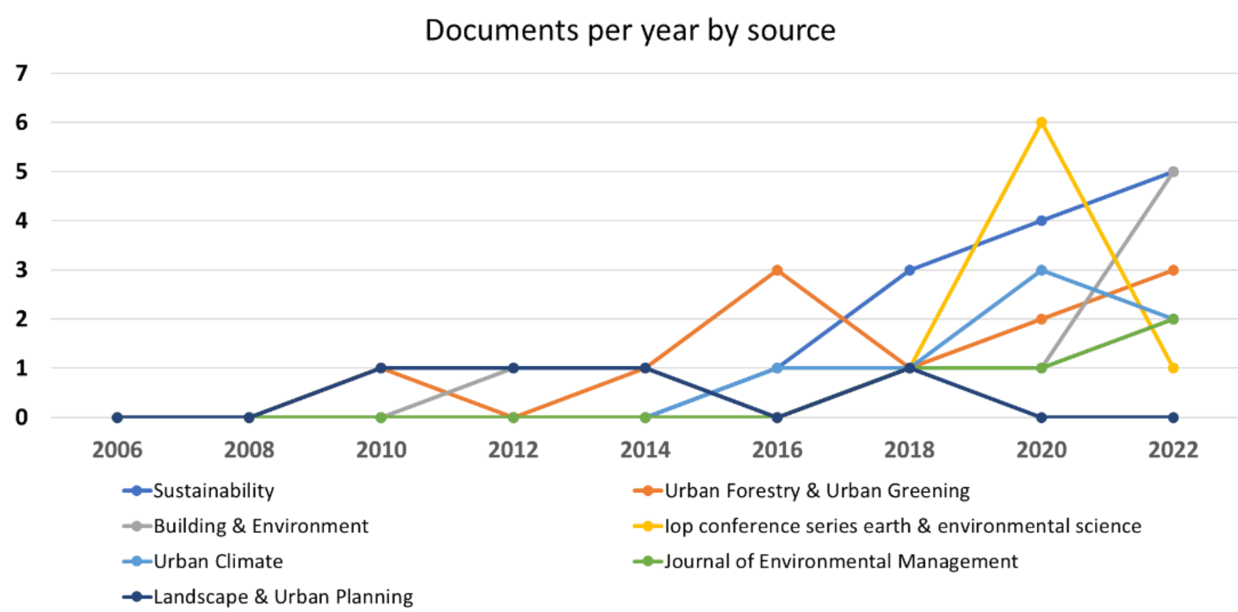


Figure 5. Top-7 journals to publish articles on green roofs and climate change

2.1.5. Country analysis

The country analysis shows the level of research in the field of green roofs and climate change in the context of urban resilience and adaptation planning. It can be observed that United States of America (USA) and Italy were the leading countries to published articles. In the context of green roofs and climate change USA, Italy, China was the top-three with approximately 17%, 14%, and 12% of published articles.

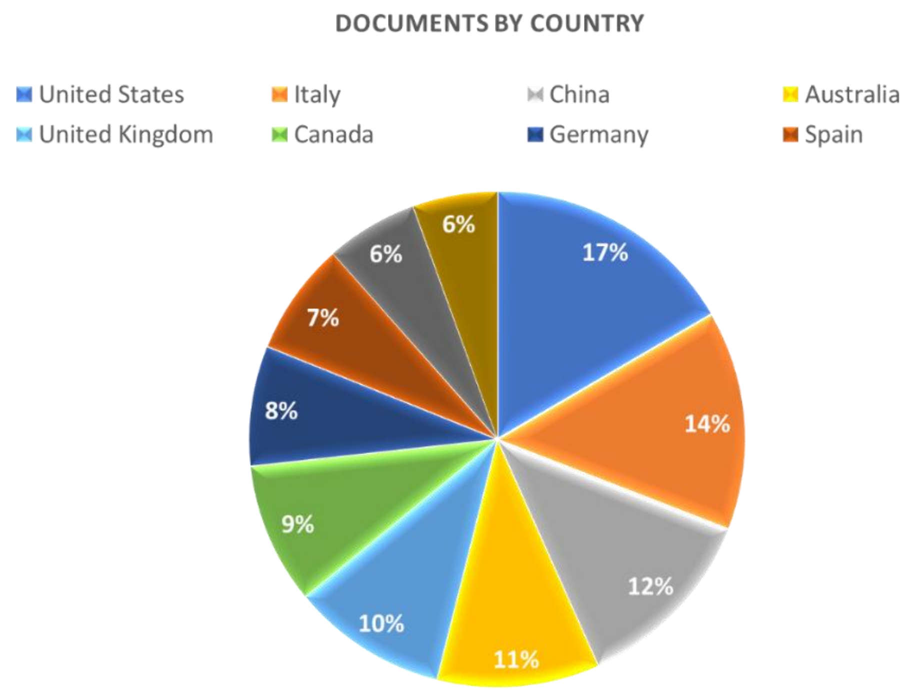


Figure 6. Top-Countries to publish articles on green roofs and climate change

As everyone are facing adverse effects of climate change, it is shocking to see only mainstream countries contributing to the cause. However, very least, or negligible searches have been contributed by Asian countries except China.

2.2. Green roofs as Nature-based solutions

Nature, species, and people are seriously threatened by climate change. If the international community takes action to protect, restore, and improve the management of our natural resources, nature can also offer important solutions for both storing carbon and fostering climate resilience (*The International Union for Conservation of Nature (IUCN)*, 2021). **Nature-based solutions** are those that are supported by and inspired by nature, cost-effective, and concurrently beneficial to the environment, society, and economy. They also help people become more resilient. By locally tailored, resource-effective, and systemic interventions, these solutions increase and diversify the amount of nature and natural elements and phenomena in cities, landscapes, and seascapes (European Environment Agency, 2016). A jointly published report analyze the role of nature-based solutions in mitigating the current state of climate change (Dickso, 2021). It demonstrates that a major contribution from NBS is both required and feasible to reduce global warming to 1.5°C and achieve net zero by 2050, if the necessary funding is made available. It evaluates the potential contribution of carbon offsets to the entire financial package.

According to the Paris Climate Agreement, efforts should be made to reduce warming to 1.5°C and below 2°C. Whether we can reduce global warming sufficiently between now and 2030 to avert the worst effects of climate change depends on the efforts taken by the international community (*The International Union for Conservation of Nature (IUCN)*, 2021). The risk of extreme weather and failing ecosystem grows when the limit exceeds 1.5°C. The latest IPCC report (Pallardy, 2022) clearly validates that nature-based solutions plays a significant role in managing climate change in a sensible manner. It involves reducing the demolition of forests, restoring ecosystem, and improving the land for farming; these are among the top five most effective strategies for mitigating carbon emissions by 2030.

Nature-based solutions addresses the climate change in three ways. (i) Reduce greenhouse gas emissions from land use and deforestation, (ii) Isolate and store carbon dioxide from the atmosphere, (iii) Improve resilience of ecosystem can help society adapt to climate-related risks like sea-level rise, droughts, floods, heatwaves, and wildfires. Nature-based solutions are not a fast-paced substitute of fossil fuels; they should be involved in a wide range of ecosystems (Seddon et al., 2021). NbS must involve local stakeholders; should be integrated with full engagement and public consent, and it must not violate public's cultural and ecological rights. The IUCN Global Standard for NbS should be used to create a strong and resilient NbS, so that nature and people can coexist in the future while addressing the urgent problems of climate change and biodiversity loss (*IUCN Global Standard for Nature-Based Solutions : First Edition*, 2020). Gaining in-depth knowledge of such concepts requires proper research.

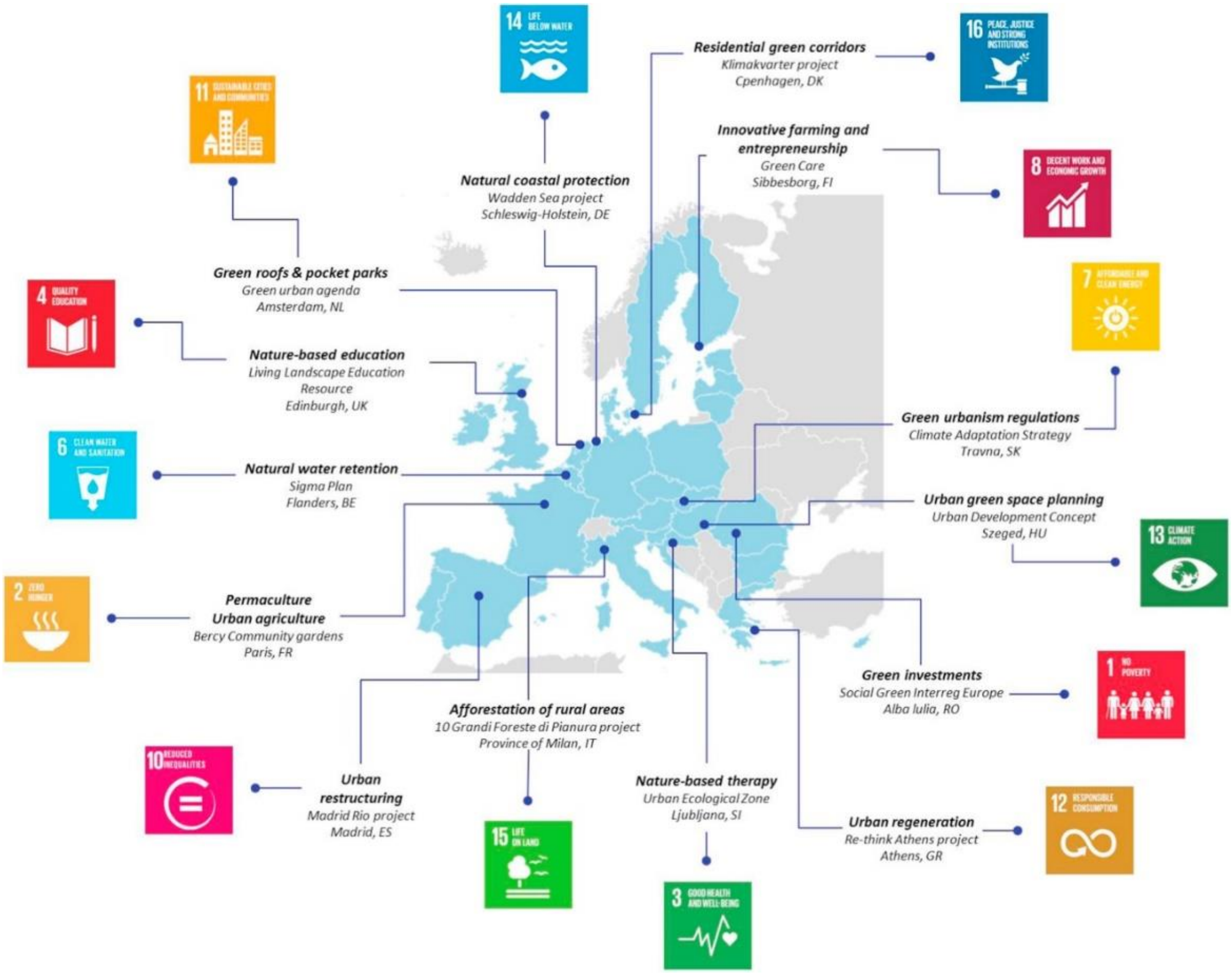


Figure 7. How Nature-Based Solutions address sustainable development goals: examples of approaches that use Nature-Based Solutions and measures linked to SDGs across Europe (Faivre et al., 2017)

Any change in the climate over time, whether brought on by natural variability or human activity, is referred to as climate change (*European Environmental Agency*, 2012). Human induced measures to lessen human effects on the climate system are referred to as climate change mitigation. Strategies for reducing greenhouse gas emissions and their sources as well as improving greenhouse gas sinks are part of the fight against climate change (*European Environmental Agency*, 2012). The modification in natural or human systems, such as metropolitan areas, in response to present or anticipated climatic triggers or their impacts is referred to as adaptation to climate change (*European Environmental Agency*, 2012). Strategies for adapting to climate change should minimize negative effects or seize positive chances.

2.3. Challenges to institutionalizing green roofs in urban areas

Green roofs are an innovative and promising approach to mitigate urban environmental challenges such as air pollution, stormwater management, and urban heat island effects. Green roofs refer to the practice of cultivating vegetation on rooftops, which provides various benefits, such as improving thermal insulation, reducing energy consumption, enhancing biodiversity, and creating recreational spaces. Despite these benefits, the institutionalization of green roofs in urban planning faces several challenges that hinder their widespread adoption and integration into city policies and regulations.

Potential of green infrastructure in promoting urban and regional resilience, as well as the institutional challenges that hinder its implementation are discussed by several authors. (Schiappacasse & Müller, 2015) argues that green infrastructure, which includes green roofs, parks, wetlands, and other natural and semi-natural systems, can provide multiple benefits, such as reducing the risk of flooding, improving air and water quality, enhancing biodiversity, and promoting human health and well-being.

It highlights the importance of institutional frameworks in facilitating the implementation of green infrastructure projects. The authors argue that institutional challenges, such as limited funding, lack of inter-agency coordination, and insufficient public participation, can hinder the adoption and integration of green infrastructure into urban and regional planning processes. Successful examples of green infrastructure projects and policies from various countries are presented, such as the European Union's Green Infrastructure Strategy, the Singapore Green Plan 2012, and the Portland Watershed Management Plan.

Authors successfully provided a comprehensive overview of the potential of green infrastructure in promoting urban and regional resilience and the institutional challenges that must be addressed to achieve this goal. Emphasis on the need for institutional frameworks that promote collaboration, innovation, and public engagement is particularly noteworthy.

2.4. Public perceptions & willingness to pay

Public perceptions play critical role when it comes to climate change policy making. It can either compel or hinder the political, economic, and social actions that address climate change mitigation and adaptation. For instance, how public perceive the hazard of global climate change will have a significant impact on whether the public supports or opposes climate policies (such as agreements, regulations, taxes, incentives, etc.). Despite the potential benefits, the adoption of green roofs has been slow due to several factors, including the perceived cost and lack of public awareness. Therefore, it is important to understand public perceptions and willingness to pay for green roofs in urban areas.

Several studies have shown that public awareness and knowledge about green roofs are low, and people tend to overestimate their costs. However, once informed about the benefits and costs of green roofs, people are generally willing to pay for them. In a study conducted in the United States, it was found that people are willing to pay an additional $5-$10 per square foot of green roof installation (Leiserowitz, 2006). Moreover, people who are environmentally conscious and those who live in urban areas are more likely to support green roofs and pay for them. The willingness to pay for green roofs can also depend on the type of building and its use. For example, in a study conducted in Canada, it was found that people are more willing to pay for green roofs on commercial buildings compared to residential buildings (Loder, 2014). This is because commercial buildings are seen as more visible and have a greater impact on the environment. Similarly, people are more willing to pay for green roofs on buildings that serve a public purpose, such as schools, hospitals, and government buildings.

In addition to public perceptions and willingness to pay, it is also important to consider the potential economic benefits of green roofs. Green roofs can reduce energy consumption, which can result in cost savings for building owners. They can also extend the lifespan of the roof by protecting it from UV radiation and temperature fluctuations.

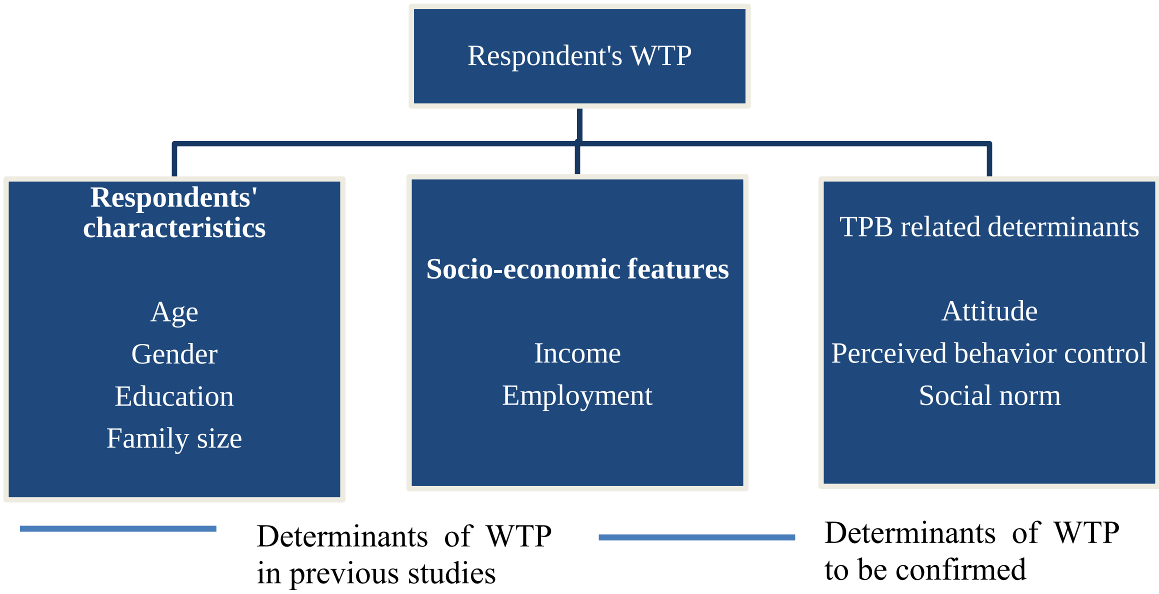


Figure 8. Hypothetical framework to determine public perception and willingness to pay (L. Zhang et al., 2019)

Moreover, green roofs can increase property values and improve the aesthetics of urban areas. Moreover, green infrastructure (green roofs and green walls) has been recognized as one of the solutions to tackle rising temperature in urban areas. In such context, green roofs are major contribution to enhance building performance i.e., thermal comfort and lower use of energy (Raji et al., 2015). They are providing benefits on a large scale. Building green roofs restore the natural elements and reduces impervious surface, and resultantly reduces surrounding temperature. Also, vegetation has the quality to absorb pollutants and improves air quality (Yang et al., 2008). Green roofs aids in rainwater management, that lowers the load on urban drainage system and prevents urban flooding. In addition to additional socio-economic and environmental advantages including habitat development and biodiversity protection (Benvenuti, 2014), the widespread implementation of green infrastructure has numerous other advantages.

Despite the current awareness of pro-environment behaviors (Thøgersen & Noblet, 2012), the global acceptance of green infrastructure faces a noticeable number of challenges. That is why we only see these solutions promoting in certain countries. To overcome such issues and challenges there is the need to prioritize socio-environmental benefits of green roofs over the traditional solutions and personal economic and political interests (Xie et al., 2017). Numerous studies have investigated the willingness of individuals to pay for ecosystem services, including climate change mitigation (Derkzen et al., 2017), reduction of the urban heat island effect (Kim et al., 2016), sustainable stormwater drainage in cities (Chui & Ngai, 2016), environmental benefits (Park et al., 2013), and energy efficiency (Banfi et al., 2008). Similarly, few has focused on urban sustainability (Robinson et al., 2016; Zalejska-Jonsson, 2014). However, only a limited number of studies have directly examined green infrastructure and the perceptions of consumers, as well as the maximum part of their finances they are willing to invest to obtain the potential benefits. These studies have discovered diverse profiles of consumer, investors, and other stakeholders, and their perceptions of different types of green roofs.

2.5. International policies on green roofs

Policy makers can choose to promote full range of policies for urban resilience and adaptation planning. Policies from different countries regarding green roofs was reviewed (see **table 4**). Soft public policies dominate on green roofs in the context of adaptation planning. It includes research funding in the field, networking, awareness, and informational campaigns, demonstrative project initiatives, technical guidelines and green roof construction standards (Enzi et al., 2017; Irga et al., 2017). Moreover, economic instruments for green roofs and climate change are not as strong. It includes both direct and indirect funding i.e., tax reductions. Regulatory instruments for green roofs on particular new or existing buildings and dense urban areas can be a thoughtful way for building and construction of green roofs (Irga et al., 2017), but they are not as much common.

A decade ago it was declared that certain green roof policies are linked to certain advantages and disadvantages (Carter & Fowler, 2008). It has come to the point, that financial incentives as subsidies should be provided as motivator to install green roofs. However, strong foundation is required to keep the funding secure for such projects. Compulsory policies are politically unimportant, but they have the capacity to provide highest level of insurance. And buildings which become eligible to install green roofs will in fact install the green roof (Carter & Fowler, 2008). So the most suitable and promising solutions is the mix of market and hierarchical arrangements co-exists (Mees et al., 2014), and a policy including financial and regulatory framework seems to work perfectly find.

However, this evidence is based on a small number of retrieved empirical cases. This paper contains recent green roofs policies. Unfortunately, several constraints were restricted availability of policies to view for public. Germany being the largest market in green roofs, no robust legal requirements were found before 2018. Moreover, the policy overviews regarding green roofs in most European countries were incomplete. For instance, a source states about financial incentives in 200 municipalities in Germany as legislation for green roofs as well necessary legal regulations in 145 municipalities in Germany (Philippi, 2002). However, the source was not clear and sound to present it for future research. So, the solution is to perform literature analysis and get the impression of green roof policies.

Table 3. Overview of international policy/law

City	Law/Policy	Year	Implementation Provision
Basel, Switzerland	Building and Construction Law	2015	Green roofs required on all new and refurbished flat roofs (Climate adapt, 2015).
Copenhagen, Denmark	Green roof policy	2010	Requires green roofs on all new buildings with roof slopes of less than 30 degrees (Chino, 2010).
France (nationwide)	Biodiversity Act & Green roof Statement	2015	Developers must build either green roofs or solar panels on all new commercial buildings (*In France, Green Roofs and Wall Conference*, 2015).
Portland, Oregon	Eco-roof requirements	2018	Imposes a requirement that all new buildings with a net building area of 20,000 sqft or more have green roofs, with the exception of rooftop parking spaces, certain equipment, and green substitutes (which can cover up to 40% of the roof) (Planning and Zoning, 33.510 Central City Plan District, 2018).
San Francisco, California	Better roofs ordinance	2017	On most new construction projects, between 15 and 30% of the roof space must be made up of solar, green roofs, or hybrid (zoning administrator (za) bulletin no. 11: better roofs ordinance, 2017).

Toronto, Canada	Green roof bylaw	2019	It includes new or existing building with floor space of more than 2,000 m^2 should have green roofs. (City of Toronto Green Roof Bylaw, 2019).
Washington DC	Stormwater Fee Discount Program	2013	Eligible for a discount of up to 55% of the stormwater charge offered by the District's Department of Energy & Environment (Department of Energy & Environment; Stormwater Fee Discount Program, 2013).
Tokyo, Japan	Green roof law	2001	Green roofs are on roofs with 1000 sqm area and has flat surface (Kuronuma et al., 2018).
Hamburg, Germany	Green roof strategy	2019	Building owners who put in green roofs are eligible for subsidies that can pay up to 60% of the installation costs (*Four Pillars to Hamburg's Green Roof Strategy: Financial Incentive, Dialogue, Regulation, and Science*, 2019).

3. Methodology

3.1. Selection of study area: Islamabad

Islamabad, capital of Pakistan, laying on Potwar Plateau, located 9 miles from Rawalpindi, which is the former interim capital. North and northeast is surrounded by Margalla Hills, whereas southern portion is all plain. Capital is drained by Kurang River and Rawal Dam holds 50,000 acre-feet of water. The majority of the city's foreigners and expatriates live there. Reasons are simple: its welcoming, moderate climate, its picturesque, lush landscape, and first-rate basic infrastructure.

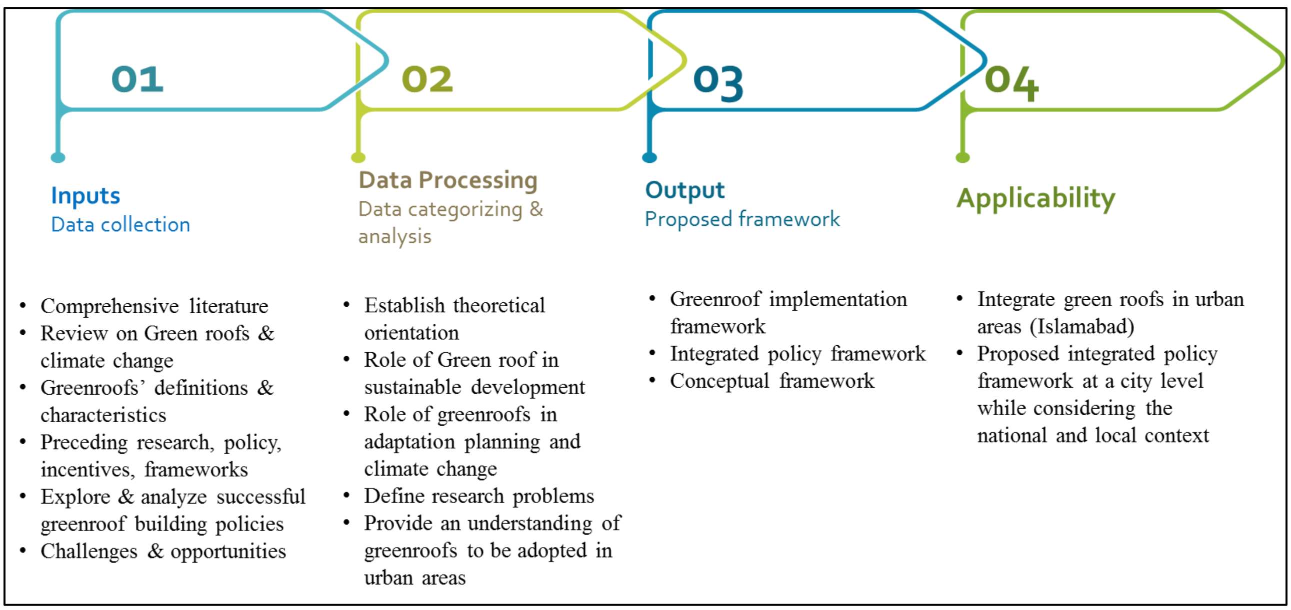


Figure 9. Methodology farmwork adopted for this research thesis

Additionally, the city serves as a resting place for travelers who want to travel to the country's northern regions to engage in mountaineering, adventure sports, trekking, and hiking. Islamabad has a subtropical humid climate that is unusual in that it has cold winters and hot, humid summers that are accompanied by a monsoon season.

Table 4. Table shows the climate of Islamabad

Seasons	Avg. High	Avg. Low
Winter (Oct-Mar)	16.6 °C	3.4 °C
Summer (Apr-Sept)	34.2 °C	24.4 °C
Year Average	28.5 °C	14.1 °C

Islamabad experiences stifling, muggy, rainy, and clear summers and brief, chilly, partly overcast winters. The average annual temperature ranges from 38 to 100 degrees Fahrenheit, rarely falling below 33 or rising over 107.

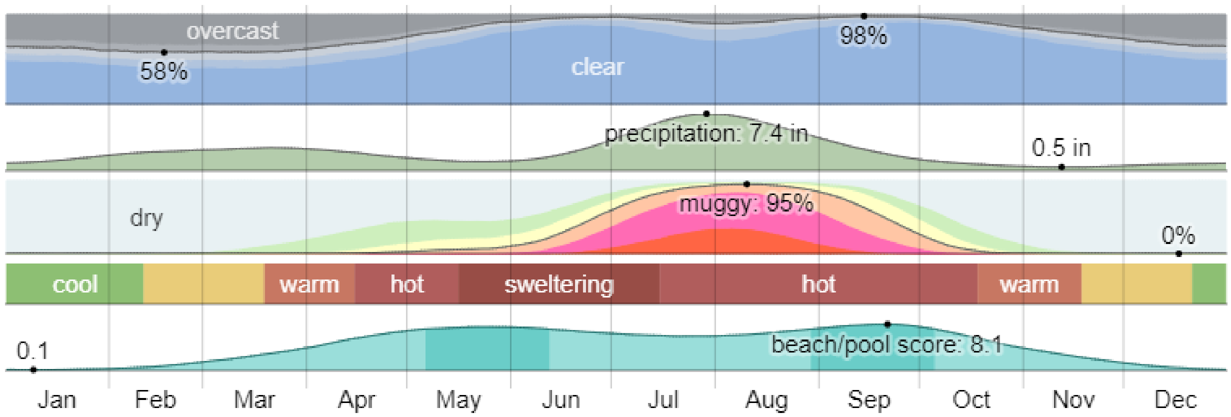
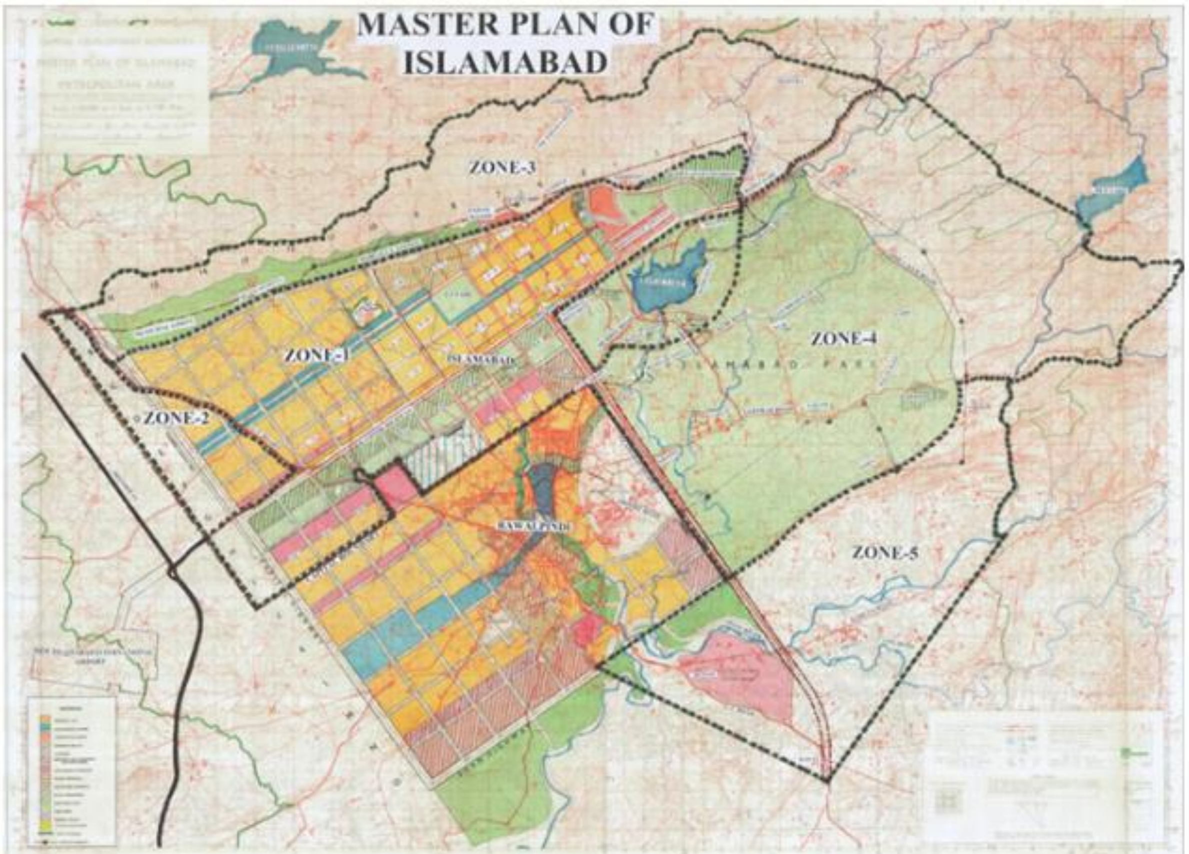


Figure 10. Average Weather in Islamabad Pakistan Year-Round, 2022 (Source: Weather'spark.pk)

Islamabad is divided into five major zones: Zone I, Zone II, Zone III, Zone IV, & Zone V. The planned area of Islamabad is 906 sq. km (220.15 sq. km of urban area), at the expanse of natural terraces and meadows that surround the city. **Figure 11** shows the master plan of Islamabad, and all of the five zones are clearly pointed out on the map. **Figure 12** shows the area selected to conduct household survey is Zone-I of Islamabad. The following map shows the sectors that comes into the boundary of Zone-I.

Islamabad Captial Territory Map



Zone	Area	
	acres	km^2
I	54,958.25	222.4081
II	9,804.92	39.6791
III	50,393.01	203.9333
IV	69,814.35	282.5287
V	39,029.45	157.9466

Figure 11. Master Plan of Islamabad Capital Territory (Source: CDA)

Figure 12. Zone-I of Islamabad Capital Territory (Source: CDA)

3.2. Sampling, questionnaire design, and data collection

This study adopted a case study research design. The primary data was collected through household surveys using a semi-structured questionnaire (**Annex-A**) in November 2022-March 2023 to get insight into the local community's perceptions regarding green roofs. The questionnaire was divided into different sections, namely the profile of the respondent, socioeconomic impacts, theory of planned behaviors, and risk perceptions, respectively. Furthermore, a section for open-ended questions was also added to know the opinion of the local community and the way forward to be proposed.

In scientific research, a large sample size is generally believed to be more authentic and worth trusting, especially when dealing with unknown variables. However, this is also responsible for the waste of time and resources. On the other hand, a small sample size will be more economical and time-saving, but the precision and accuracy of the same are uncertain to some extent. Keeping the two extremes in mind, the sample size for this study is calculated using Yamane's formula

$$n = \frac{N}{1+ne^2} \qquad \textit{(Eq 1)}$$

where,

n = sample size

N = population size

e = margin of error

Taking a 95% confidence level, the sample size came out as 399. However, as per the availability of the residents, 300 questionnaires were filled. As many as 72 responses were received online via google form while other households were surveyed to get the required primary data.

On the other hand, to record the urban challenges and to highlight key institutional challenges faced by the concerned authorities in mitigating climate change and green roofs, 43 expert interviews were also conducted from the key officials in the study area. These semi-structured expert interviews were conducted in Jan-Feb 2023, with representatives of the different government and non-government organizations across Islamabad city regarding the challenges and problems faced in implementing green roofs as a solution for climate change adaptation. A semi-structured questionnaire mainly containing qualitative and open-ended questions was designed to get the desired outcome (**Annex-B**). The respondents range from key government officials to the representatives of non-government organizations working in the planning and development sector of the region. The questionnaire included questions related to the key challenges faced by institutions in knowledge of green roofs, mitigating climate change, policies adopted to combat the impacts of climate change, and implementation of green roofs. The respondents were also requested to provide recommendations about green roofs and climate change adaptation.

3.3. Data analysis

The following data analysis tools were applied to know about the institutional challenges and public perceptions regarding green roofs and climate change, respectively.

3.3.1. Thematic analysis

Qualitative content and systematic/thematic analysis are two of the most commonly used approaches in qualitative data analysis (Vaismoradi et al., 2013). Qualitative data is mainly based on interpretations and thus requires intensive explanation (Alhojailan & Ibrahim, 2012). This is because massive amounts of qualitative evidence is gathered and furthermore it becomes very difficult to distinguish between data collection and its analysis process due to the overlap of analysis and interpretation to reach a conclusion (Cassell & Symon, 2017). Systematic or thematic analysis is described as an important tool for combining and summarizing the results of multiple studies (Mian et al., 2007). The stages of systematic analysis include firstly the formulation of a questionnaire to extract the required data, followed by screening of the data. After that, the data is managed, synthesized , and finally the results are extracted from it (Naeem & Rana, 2020).

Thematic area analysis is used in the study to analyze the data collected through semi-structured interviews with experts of both public and private practicing officials, respectively. Firstly, the opinions of all the respondents were recorded via semi-structured interviews, and the repeated ideas/challenges as identified by the key respondents were grouped into different thematic areas. Subsequently, the challenges and issues highlighted by the experts during the interviews were reexamined and grouped into a distinct theme after a detailed scrutiny of the responses.

3.3.2. SWOT analysis

SWOT is a commonly used tool to analyze internal and external factors of environment simultaneously. Strengths, weakness, opportunities, and threats make a systematic approach to analyze and finalize decisions. The internal factors (strength and weaknesses) and external factors (opportunities and threats) are grouped together and are referred as the strategic factors. Well, the overall goals of applying SWOT on a project/situation is to come up with rational strategies to implement a certain policy or strategy as a good fit after reviewing all of the four factors. The purpose of strengths is to overcome weaknesses. On the other hand, threats must turn into opportunities. Moreover, it also gives us insight into the existing situation and what parts need improvement and how it should be done. SWOT analysis entails methodical consideration and thorough diagnosis of variables pertaining to a new invention, technology, organization, or strategy.

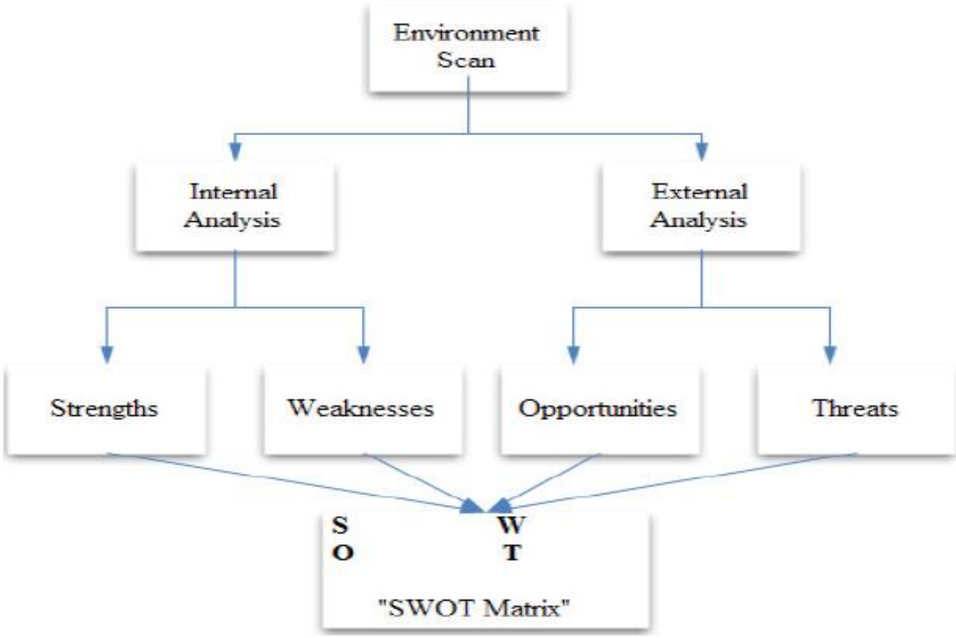


Figure 13. SWOT analysis framework implemented

3.3.3. Descriptive analysis

Descriptive analysis is a method used in research to describe and summarize data. It is a crucial step in analyzing data as it provides researchers with an understanding of the basic characteristics of the data and can reveal patterns, trends, and relationships. It involves examining and summarizing data using statistical measures such as mean, median, mode, standard deviation, and variance. These measures are used to describe the central tendency, dispersion, and shape of the data. Researchers may also use graphical representations such as histograms, scatter plots, and box plots to visualize the data and gain a better understanding of its characteristics. One of the main uses of descriptive analysis in research is to summarize data collected from a sample or population.

3.3.4. Selection of indicators

An approach based on indicators was adopted for this study to quantify the perceptions associated with green roofs and also to assess institutional challenges. After a detailed literature review, indicators were selected to get insight into the public perception of the local community and institutional challenges. Each of the selected indicators was extracted from empirical studies related to green roofs as Nature-based solution for adaptation planning and urban resilience (**Table 5**).

Table 5. Shows indicators and empirical studies from which they are identified

Complex Variables	Indicator	Empirical studies
Intentions towards ecosystem	Health status Living environment existing/childhood Community participation Traditional practices	(F. Liu et al., 2021)
Theory of planned behavior	Social norms Behavior towards environment Attitude of public	(L. Zhang et al., 2019)
Subjective perceptions on green roofs	Knowledge of green roofs Willingness to pay for green roofs Acceptance of green roofs Face obstacles in investment Importance of green roofs for residents	(Y. Liu, 2020)
Climate change risk perceptions	Believe in the phenomenon (climate change) Awareness Preparedness Worry Past experience	(Bradford et al., 2012; Howe et al., 2019)
Economical dimension	Energy savings Real estate benefits Installation & maintenance costs Incentives	(Rosasco & Perini, 2019)
Institutional dimension	Policy development or improvement Govt. behavior towards green roofs Public trust on government Political constraints	(Roggero, 2020)
Benefits of green roofs	Social cohesion Ecological support Thermal comfort Hydrological support Support biodiversity	(F. Liu et al., 2021) (Y. Liu, 2020)
SWOT factors		

Strengths	Ability to reduce flood risk Lowers urban heat island Urban quality & aesthetics Energy savings	(Brudermann & Sangkakool, 2017)
Weaknesses	Structural & static challenges Higher implementation and maintenance cost Possible damage	(Brudermann & Sangkakool, 2017)
Opportunities	Climate change Public acceptance & environmental awareness Green policies in cities	(Brudermann & Sangkakool, 2017)
Threats	Legal & political constraints Uncertainty of potential adopters Lack of knowledge	(Brudermann & Sangkakool, 2017)

4. Results

4.1. Assessing institutional challenges

Climate change is no less dangerous than rest of the disasters, but it is even more catastrophic. Climate change evolves slowly over time and causes a large-scale disruption in every aspect of our lives. Moreover, we also have to consider the rising speed of climate change over the past decade and increasing vulnerability of infrastructure (Achour et al., 2015). In fact, the vulnerability keeps increasing if buildings are not renovated and upgraded with time. Climate change impacts are higher in urban areas as compared to rural areas, because of high concentration of carbon emissions, high temperature, and air pollution. This causes urban heat island, floods and put lives at risk. To cope with climate change impacts, local government should address community's concerns and effectively come up with climate change adaptation strategies.

4.1.1. Respondent's profile

The dataset shows almost equal number of female and male expert's being interviewed. The gap comes into the scene, because still most of public and private offices has more male officials as compared to female officers.

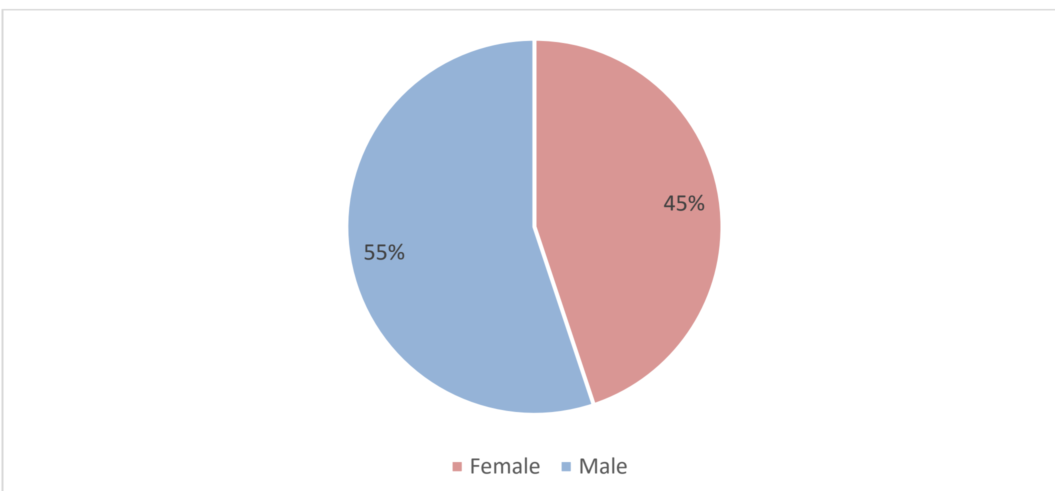


Figure 14. Shows the gender distribution of dataset (Source: Interviews with expert's)

So, I managed to interview 45% of females (19) from both public and private authorities working in urban planning field. On the other hand, 55% (24) male officers were interviewed.

Male and female in the dataset has different educational background. This was crucial as to evaluate their understanding of green roofs, climate change, adaptation planning, and urban resilience at different educational level.

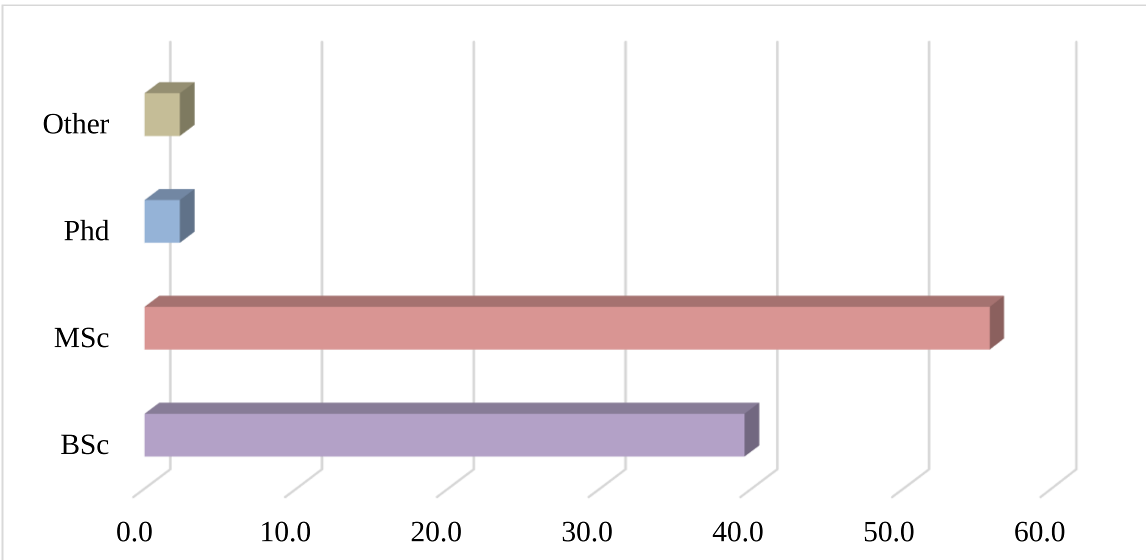


Figure 15. Shows educational level of experts involved in dataset (Source: Interviews with expert's)

The graph shows 40% of people in data set were BSc graduates, approx. 55% people were MSc graduates, and 2% PhD and rest non-degree qualifications or diplomas. It gave the insight of how people from different educational background think about green roofs and climate change.

To improve the understanding of institutions role in implementing green roofs for adaptation planning, the scope was enhanced. Both male and female officers from different professions were interviewed. However, the main professions that were focused were town planners, architects, and civil engineers.

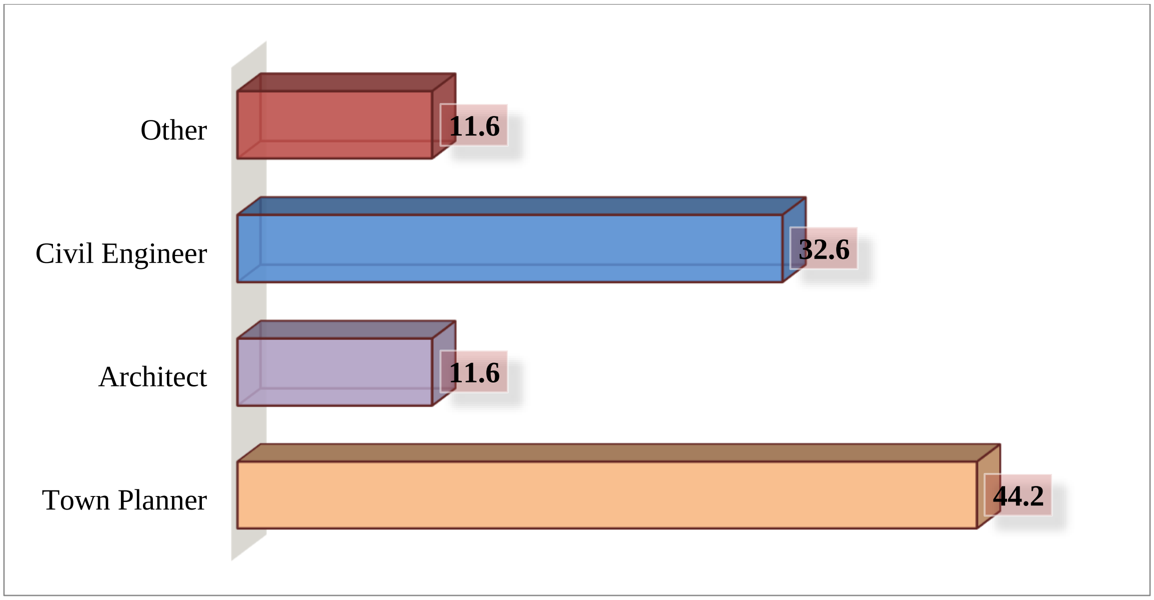


Figure 16. Shows profession of experts involved in dataset (Source: Interviews with expert's)

Although these professions are interlinked either by policies, interests, or city-scale projects. However, when we talk about a city these professions come into mind. 44% of town planners were part of dataset. The reason they are such a great portion of dataset, is because the aim of research is to understand and assess the role of green roofs in the context of urban planning. What other profession will better understand this concept and themes related to green roofs. 11% architects were interviewed, and they managed to share their view on building design, structure, and related challenges. Lastly, 32% civil engineers were part of the dataset, they suggested rational insights on how green roof can be build and its material requirement. Rest of the dataset were environmental engineers and landscape designers.

4.1.1. Economical dimension

Economic dimension of green roofs is extremely important if we are looking forward to implement such green initiatives in urban areas of Pakistan. Expert's response on included economical dimensions of green roofs gave the insightful understanding of where we stand. Each member of dataset was asked thoroughly regarding green roofs and how they can contribute to our urban areas economically. Following graph shows their likelihood towards each of the variables included in economical dimension.

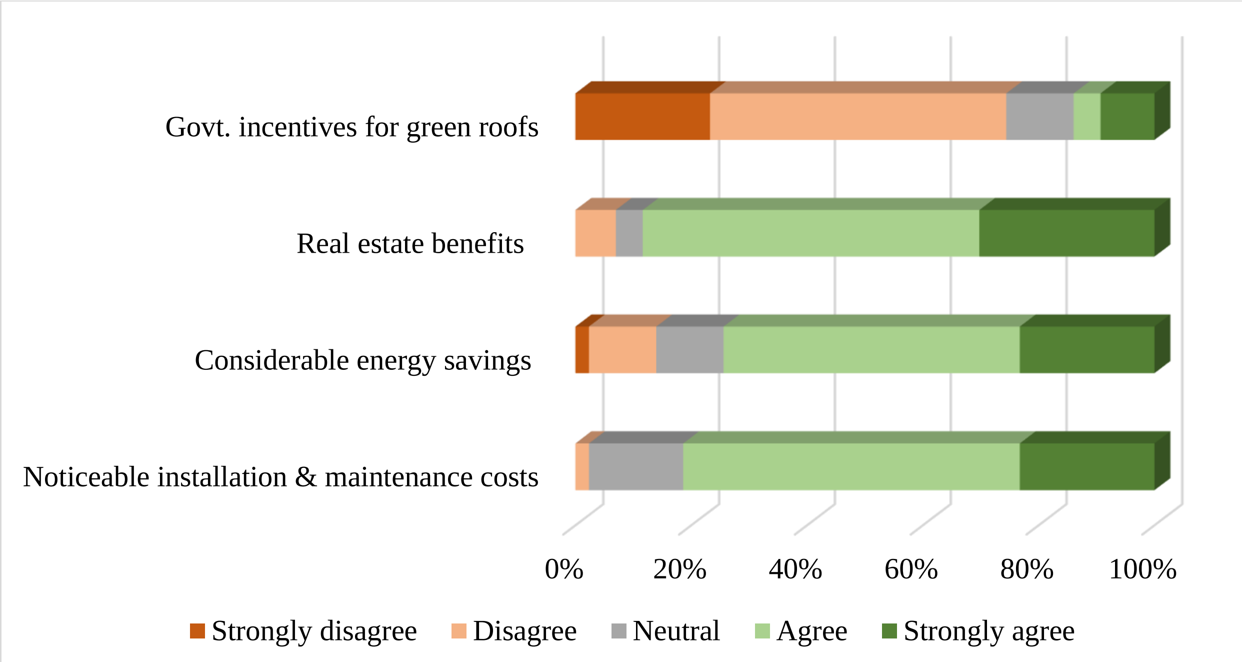


Figure 17. Shows expert's response to economical dimension of green roofs (Source: Interviews with expert's)

Installation cost is the amount to be paid to the company that are installing green roofs on your roof top. It includes materials, labor, and other expenses. 58% of experts agree that green roofs do require a handsome amount of initial investment. As public are not experts, so they always need to hire a company. Well, the lifespan of a green roof is 40-45 years, but it requires regular maintenance. This includes renovation cost of the project. Green roofs come with multiple benefits, it provides a shade, thermal comfort, lowers surrounding temperature, eliminate pollutants from air, and much more.

One of the major benefits is energy savings, as the surface temperature is lowered, residents rely less on artificial air conditioners and hence it saves energy. 51% of experts agree that green roofs contribute to savings energy in a household. Due to aesthetic benefits associated with green roofs, it raises a building's property value. 58% of experts interviewed agreed to that real estate benefits of green roofs. 51% disagree and 23% strongly disagree that any incentives or subsidies are being provided by government to initiate such green projects. Moreover, they added in suggestions that most projects are accepted on the basis of their political and economic interests.

4.1.2. Statutory and policy response

Institutions deal with legal, statutory, and policy response to green roofs and climate change. Institutions are perceived as a collective force that implement rules and regulations to shape social and economic aspects. Some of the readers are not as educated as our experts on official posts. So, consider this example. To buy a certain good on the market, on must ensure that good meets the standard of quality. Additionally, one needs to know they can exchange currency to get a certain good, and that supplier accept the currency. These are just the basic rules of exchange between goods and currency. Similarly, institutional and political interests also have set rules and regulations. Stakeholders and policy makers must ensure that all actions must be abide by these rules.

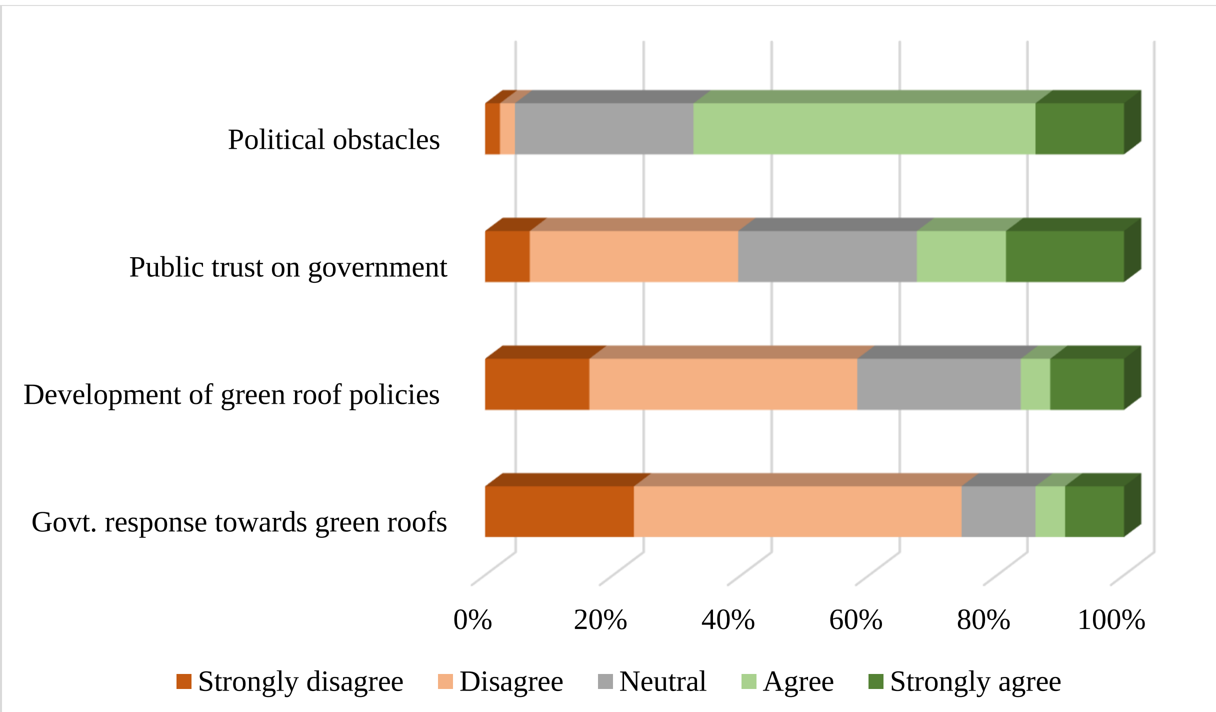


Figure 18. Shows expert's response to institutional dimension of green roofs (Source: Interviews with expert's)

Above graph shows expert's response to statutory and policies related to green roofs for adaptation planning and resilience in urban areas of Pakistan. While interviewing 51% of experts disagree towards the government's positive response towards green initiatives. Few of the experts, 10%, believe that government is working on green roof policies. However, after reviewing literature it was confirmed that there is no policy regarding green roofs. 42% experts disagree when asked about any policy formation in the pipeline. A policy is successful once public trust the government in making choices for the future of their residential area and city on a large scale. 32% experts voted negative response when it comes to public trust on government. Well, such situation is caused by previous failed projects. Most of the projects and policies are formed and implemented on the basis of political interests. 53% experts agree to the fact that political constraints majorly contribute in implementing policies regarding any sustainable initiative.

4.2. SWOT Analysis

Literature review and understanding the impact that green roofs may have on Islamabad environment, institutions, and public, following strengths, weaknesses, opportunities, and threats are identified.

Table 6. SWOT factors identified to assess the challenges of implementation of green roofs

	Positive	Negative
Internal	***Strengths*** S1: Ability to reduce flood risk S2: Urban heat island mitigation S3: Urban quality & aesthetics S4: Energy savings	***Weaknesses*** W1: Structural & static challenges W2: High implementation & maintenance costs W3: Possible damage
External	***Opportunities*** O1: Climate change O2: Public acceptance & environmental awareness O3: Green policies in cities	***Threats*** T1: Legal & political constraints T2: Uncertainty of potential adopters T3: Lack of knowledge

4.2.1. Strengths

Strengths are the positive internal factors that are directly related to a certain technology/product. Following strengths of green roofs are identified in the context of its role in adaptation planning and urban resilience.

S1: Ability to reduce flood risks. One of the major strength and contribution of green roofs towards climate change adaptation is reducing the risk of floods. Green roof has the ability to become part of urban drainage systems and manage rainwater runoff. Big cities are at risk of floods and related disasters, and the reason is the impenetrable soil, that means surface covered with asphalt and concreate. In case of heavy rainfall, green roof can serve as a storage for water, so the dwellings will not be flooded. Green roofs help prevent system failure by storing rainwater, reducing the amount of rainwater entering sewage systems, and reducing peak demands. Green roofs can cut peak runoff by up to 65% in wet weather (Sproul et al., 2014). As seen in the **figure 19** this strength has medium-high impact according to professionals.

S2: Mitigate urban heat island. Green roofs have multiple benefits as mentioned in literature earlier. The experts provide a meaningful insight into green roofs contribution to the environment. They have positive influence in the climate via evapotranspiration, which means evaporative cooling in simple terms: In this phenomenon the water in the green roofs evaporates into the lower atmosphere, thus lowers the urban heat island effect. The urban heat island is also lowered because of the fact that green roofs absorb less heat as compared to the concrete roofs due to the greenery and soil. Moreover, it has also been discovered that green roofs having variety of plants, small trees, and shrubs supports biodiversity (Benvenuti, 2014; Molineux et al., 2015). They also provide home to birds, insects, bees, and preserve overall ecology (Berardi et al., 2014). It should be noted that green roofs can easily be used in conjunction with other ecologically beneficial technologies, such as solar photovoltaics. Given that lower temperatures are thought to extend the life of solar modules, green roof areas, which are cooler than regular roofs, provide a more favorable environment for these technologies. As per the views of experts that were interviewed green roofs highly contribute to UHI mitigation. Reference **figure 19**.

S3: Urban quality & aesthetics. Another strength of green roofs mentioned in literature and by experts is how green roof has aesthetic benefits and positively impact the urban quality. Green roofs integration in urban areas gives a new look to the appearance and leaves a positive impact of public. Apart from contributing into human wellbeing and thermal comfort of residents, green roofs also provide a buffer from noise (Connelly & Hodgson, 2013). The best quality of green roofs is that it can be an integral feature of multi-functional buildings.

S4: Energy savings. As mentioned, multiple times throughout the research green roofs majorly contributes in saving energy. It provides a shade on the roof, which lowers surface temperature, and provide thermal comfort to the residents. In the result residents rely less on artificial air conditioners, which saves energy. Same goes in winters, the roof provides insulation, so less heating is required.

4.2.2. Weaknesses

Weaknesses are the negative internal factors that are directly linked to the technology/product, in case of this particular research the technology is green roofs. Strengths have been mentioned frequently in the literature, whereas very little attention was gives to the potential weaknesses of green roofs. While this was also cross checked with expert's that were being interviewed for the research.

W1: Structural & static challenges. Green roofs comes with structural challenges as pointed out by (Bianchini & Hewage, 2012). The main reason is that green roof comes with a high deadload as compared to a conventional roof. The weight of soil, plants, buffered water, and necessary structural adaptations. Moreover, depending upon the type of green roofs, weight can fluctuate. Large trees can put excessive weight on the static loads and can cause major issue in the long run. **Figure 18** shows the response of experts on this weakness of green roofs.

W2: High implementation & maintenance costs. The second drawback is that, when compared to standard roofs, green roofs require more construction capital as well as more maintenance time. This covers the price of the plants, the expense of the required layers, and the cost of managing the water on the roof (drainage and irrigation). The costs of disposal at the end of the roof's lifespan should also be taken into account (Peri et al., 2012) .Costs may increase due to the green roof's incorporation into the building's overall architectural and aesthetic design. Long-term energy savings are likely to balance some, but not necessarily all, of the necessary investments (see S4).

W3: Possible damage. The potential for damage to the structure or the plants. For instance, larger plants' roots breaching the waterproofing and leaks could damage the root barrier layer. The building could experience water damage as a result of this. Many of the questioned specialists stated that, while it's still possible, this issue is largely irrelevant to (well-managed) present initiatives.

4.2.3. Opportunities

Opportunities are the positive external factors that are linked to any technology. **O1: Climate change**. According to (Williams et al., 2010), green roofs can be used as a strategy for both climate change adaptation and mitigation. Additionally, climate change is linked to warmer summers in (most) North American, Asian, and European cities, resulting in extended plant growing seasons. With enough irrigation or rainfall, one may anticipate generally better plant development. Green roofs may also prove particularly valuable in climate change since they can reduce the urban heat island effect and increase evapotranspiration in urban areas.

O2: Public acceptance & environmental awareness. The general high degree of public acceptability of green roofs and high level of awareness regarding environmental issues and climate change in industrialized countries. The questioned experts also point out that there haven't historically been many protests opposing green initiatives (mentioned solar roofs) and that feedback on ongoing projects has generally been good. However, there is resistance towards green roofs in public and they lack the knowledge of its benefits to the environment and society.

O3: Green policies in cities. The general public and decision-makers appear to be becoming more aware of sustainability. This is also demonstrated by the rise in cities enacting "green policies," which is the third opportunity. Legislative requirements are constantly changing to make it simpler for communities to become green. In fact, green roofs are being specifically supported as part of public policy in several countries around the world. However, Pakistan is a bit slow in the race. Reviewing capital development authority policies, no such green policy has been identified. Questioned experts pointed out that green initiative policies are in formation, but are not yet revealed due to political interests. They mentioned, as we lack open spaces for parks and recreational areas, green roof is the best alternative to be integrated into urban planning. Green roofs can also be incorporated into the new smart cities plans that are under construction in Islamabad, and they aim to use modern technology to enhance service effectiveness and urban quality of life.

4.2.4. Threats

Finally, threats are the negative external factors that are directly linked to the technology. Supported by literature and expert's interviewed, threats are not given attention as much as opportunities.

T1: Legal & political constraints. This threat is very obvious as new technologies face high political hinderance to be implemented, and it is complicated to combine existing and new architecture. Existing building roofs in Pakistan are not very supportive of green roof retrofitting, and the concept is not supported by any urban planning strategies. Public supporting green initiatives in a city won't change the fact that they will not receive any political support until official observe some kind of personal interest. And the major hinderance is funding, urban planners or planning authorities are not allocated any kind of fund to initiate green projects for the safeguard of city and people. Subsidizing green roofs and integrating them with other renewable energy technologies have received little attention. Thus, it appears that advocates of conventional roof solutions in the construction sector are competing with green roof proponents and other technologies like solar PV.

T2: Uncertainty of potential adopters. There appears to be no general information about green roof approaches. There are occasionally concerns about leaks, which the experts in our sample claimed had been an issue in previous projects (see W3). However, there is still mistrust among potential adopters. This is perhaps also because the spread of green roofs is still in its early stages in most nations. Surprisingly, lower energy demand as a result of green roof still couldn't clear the doubts of potential adopters. According to experts Solar Panels generates less energy, not aesthetical pleasing, and are very expensive to buy and install on roofs. Most people are still inclined towards them. Note that in this scenario, the high level of public acceptance on the one hand and the doubts of potential adopters on the other are not mutually exclusive. This is only a result of the varied stakeholder groups, including roof owners who take on costs and hazards and the broader public who benefits from green roofs (see S1, S2, and S3).

T3: Lack of knowledge. The general ignorance of how to install green roofs is the last threat identified in the research. This covers both the absence of knowledge among pertinent companies and the lack of understanding among potential adopters. The majority of roof construction companies still only provide traditional solutions and do not offer green roofs. The same goes for a significant number of urban planners and architects.

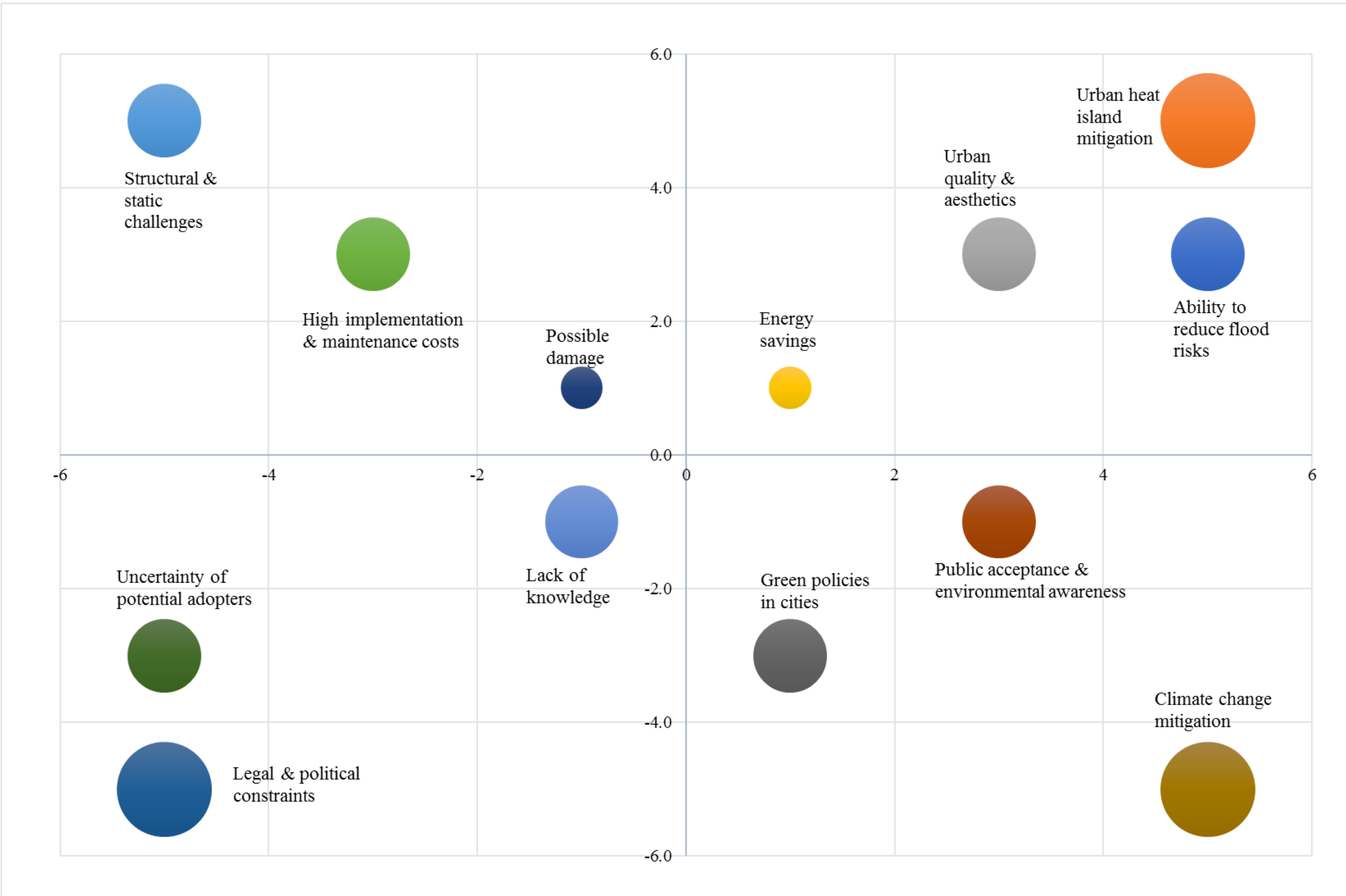


Figure 19. Statistical analysis of internal and external factors of green roofs (Source: expert's interviews)

This chart summarizes the impact of each of the strengths, weaknesses, opportunities, and threats after the responses of experts.

4.2.5. Limitations

The method used to identify internal and external factors of green roofs are subjected to a few limitations. Firstly, the analysis is obtainable irrespective of the type of green roof (i.e., extensive and intensive green roofs). However, the aim to make a general statement on green roofs. Second, to allow for the processing of any further analysis, factors frequently have to be simplified or aggregated, and specifics have to be partially deleted. Third, the impacts of each factor depend on the response of expert's perceptions and hold no scientific background. Fourth, although the sample is large enough to conduct a SWOT analysis, it is not evenly distributed among the various stakeholder groups since adopters of green roofing and city officials are not adequately represented. Lastly, the analysis results of the research may not be suitable for other cities with different climatic, political, social, and economic conditions.

4.3. Public perceptions and awareness

4.3.1. Respondent's demographic profile

Statistics that characterize populations and their features, such as age, education, housing, and income, are created using data from demographic surveys. The following data was collected through household survey in Islamabad. Noted that results are based on preliminary data collected from the field. Gender is a major part of any research especially based of perceptions. It gives different point of views based on gender.

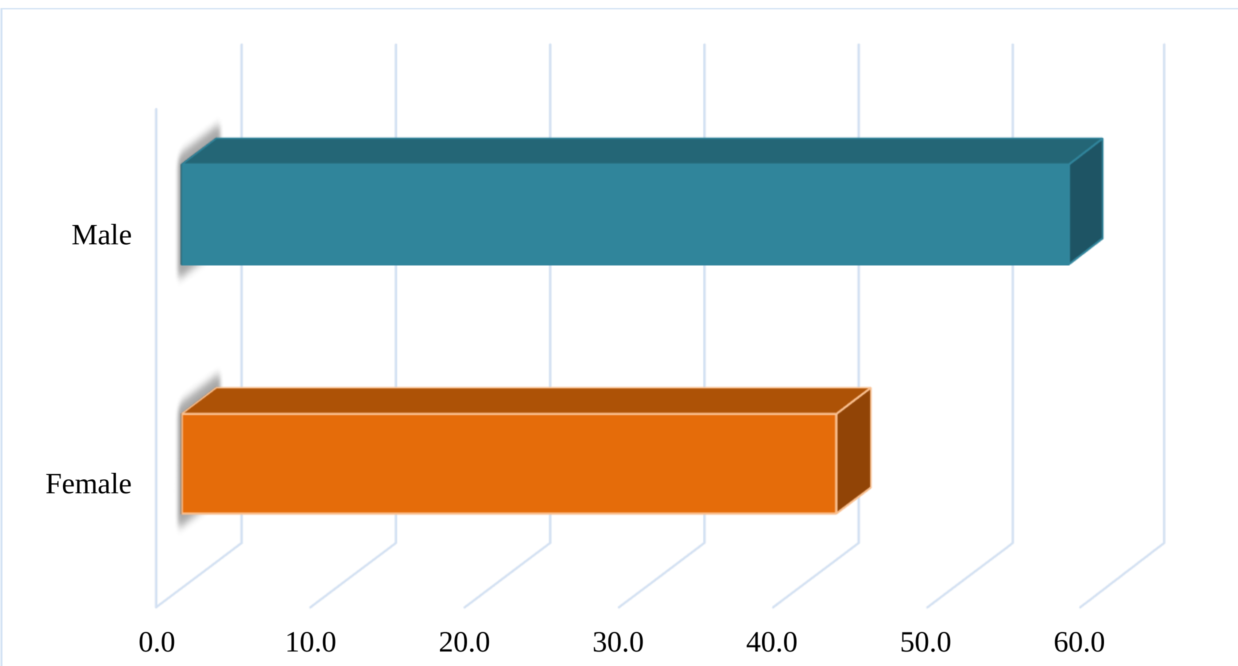


Figure 20. Gender distribution of respondents in the dataset (Source: household survey)

The analysis includes 42% females and 57% males. The difference can be explained on the base of facts that females are not as much approachable when it comes to household survey. Males on the other hand are more present outdoors, so they are approachable.

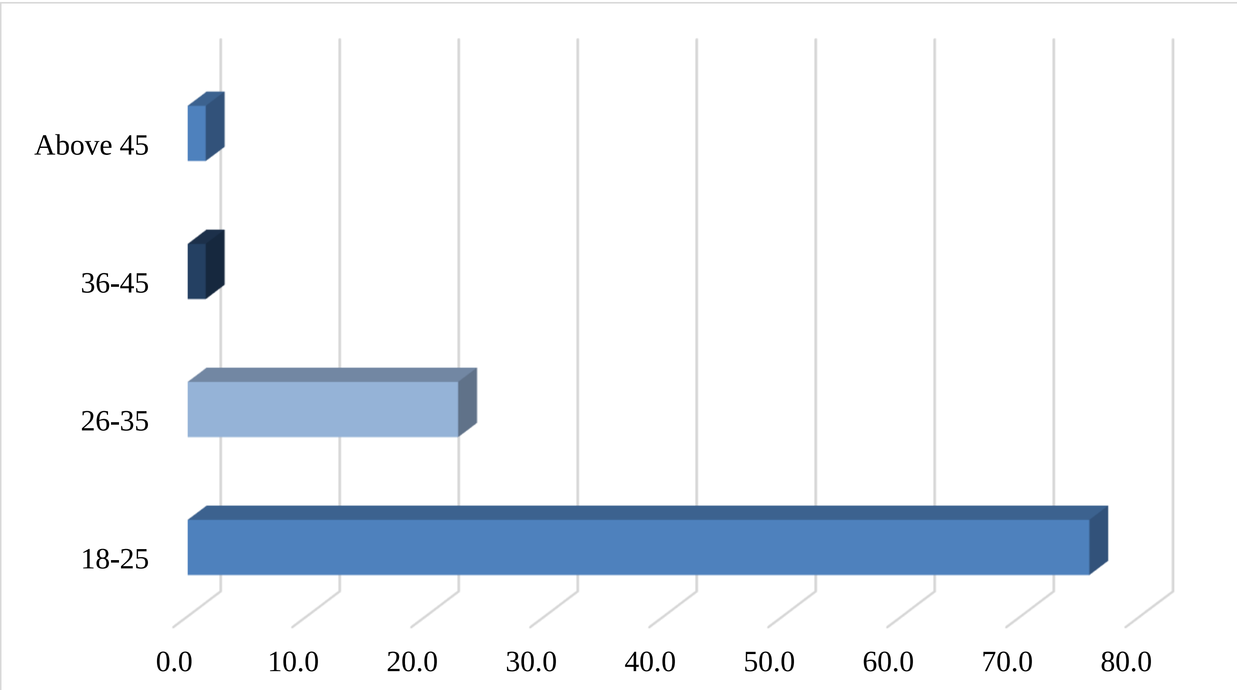


Figure 21. Age distribution of respondents in the dataset (Source: household survey)

Initially the age of respondent's to be included in the survey was 18 years and older. More that 70% of respondent's lie in the age interval 18-25 years and 22% of respondents are from age 26-36. Different range of ages were part of the dataset, as to record the response of different age groups towards green technologies. Very small percentage of respondent's lie in age group 36-45 and above 45. Young respondents are more available and approachable as compared to people who are older. Another reason is that younger age group was more interested and eager to learn about green roofs as compared to older age group.

Next comes the income distribution, it is essential to know where people stand financially. The only reasoning behind this specific variable is to assess whether these respondents are able to afford green roofs in their home or not.

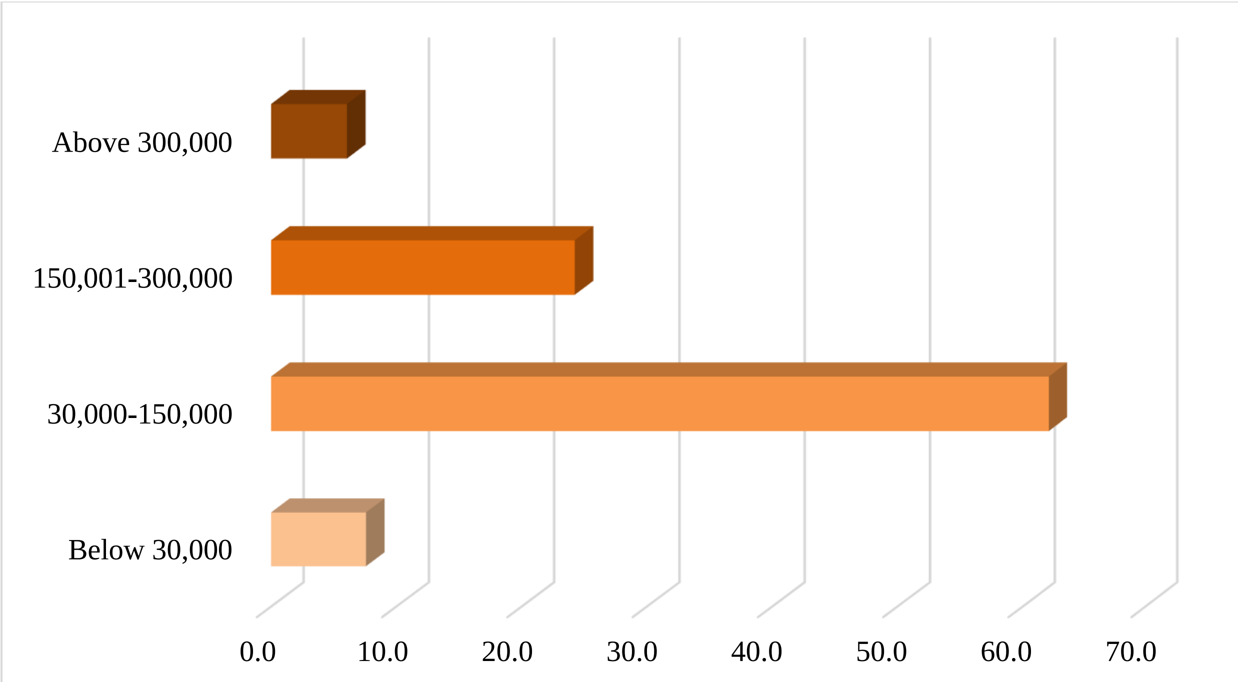


Figure 22. Income distribution of respondents in the dataset (Source: household survey)

Majority of respondents lie in the middle-class income group. As mentioned earlier green roofs comes with high implementation and maintenance costs (see W2), so only people having enough capital will be able to support green roof technology. Moreover, this will give us insight into the need for incentive and subsidizes that government should offer. These will work as a motivator to encourage people to install green roofs.

Educational level provides meaningful insights into the thinking capability of individuals and level of their concepts. Most people were educated in the dataset, and few were those who never got any level of education in their lives. Educations aids people to learn about things that they can never learn and experience at home. That is why variation in behaviors and attitude was observed when it comes to illiterate and literate respondents.

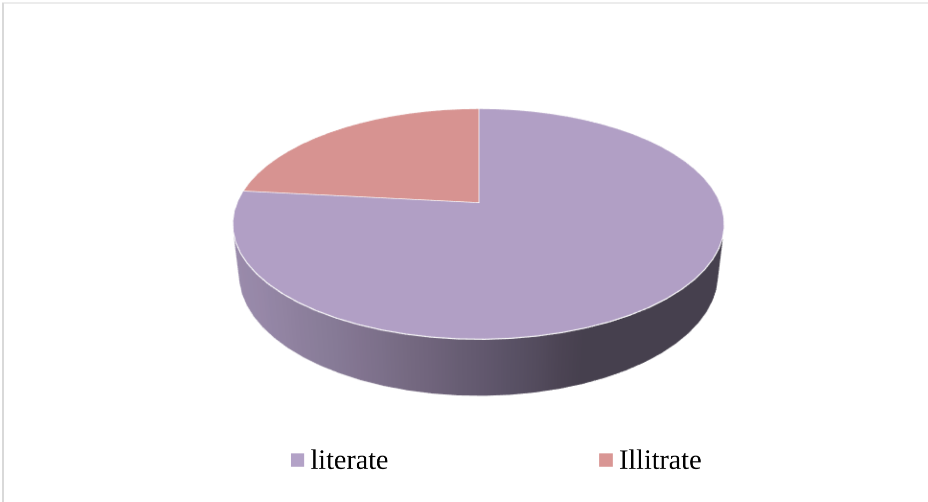


Figure 23. Educational level of respondents in dataset (Source: Household survey)

The above graph shows percentage distribution of respondents into two groups, that are literate and illiterate. 76% of respondents had received primary, college, and university level education. On the other hand, 24% of respondents has never received any level of education.

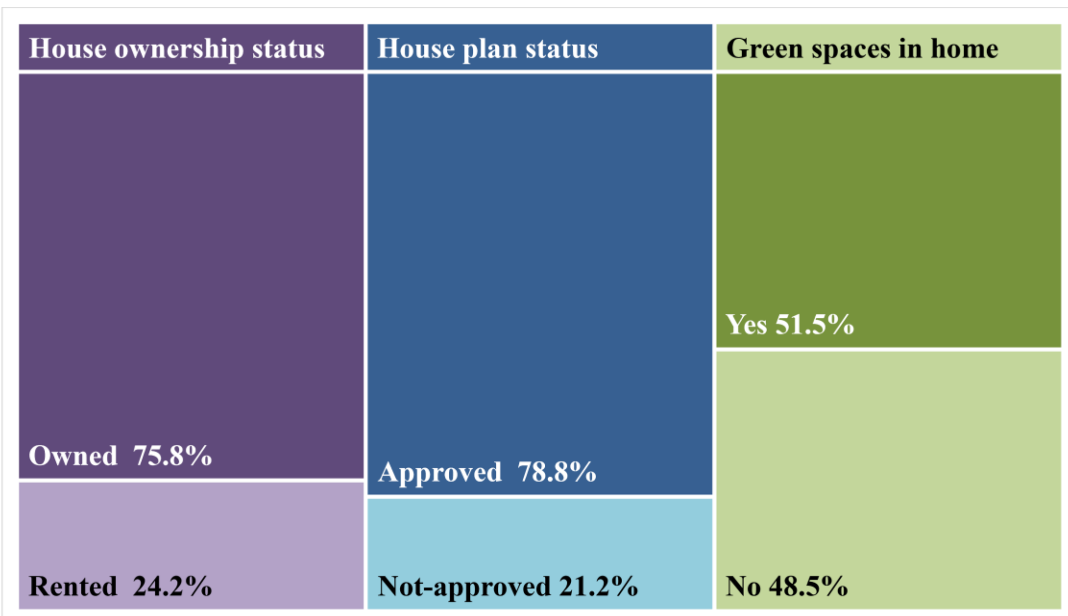


Figure 24. Graph shows house characteristics of respondents included in the dataset (Source: Household survey)

Figure 23 shows the house characteristics of respondents. It is evident from the results that 75.8% of respondents own the property, and 242% are living in rented homes. It is also observed in the survey that people who lives in owned home are more willing to listen and understand green roof concepts as compared to other group of respondents. Moreover, it is a fact represented by (Tian et al., 2022), that people who grew up surrounding greenery and pleasant environment have positive behavior towards sustainable and green initiatives. The results are completely opposite for the people who have never lived in environment-friendly surroundings. As shown in the **figure 24**, 51.5% of respondents lives in home with existing green spaces (lawns, gardens, backyards). Moreover, people who are either living surrounded by greenery or grew up around greenery have better self-rated health status.

4.3.2. Planned behavior determinants

Green roof has multiple benefits and this research majorly focuses on the ability of green roofs to reduce flood risk and lower urban heat island. Majority of previous researches have pointed out the willingness of respondents to pay for green roofs, and acceptance of the technology. However, very few have worked on the public behaviors, attitude, and social norms regarding green roofs.

During the last few decades, environmental legislators have grown more concerned about individual responsibility for environmental challenges. Individual behaviors are receiving more attention, and people are increasingly seen as consumers of natural resources. According to this research, the theory of controlled behavior (Sheppard et al., 1988) and its extension, the theory of planned behavior (Ajzen, 1991), contributes significantly to understanding the respondents' pro-environmental behavior.

In this research, positive attitude does have a significant influence on the choice of individuals. 51% of respondents (see **figure 25**) have statistically good sentiments towards the urban environment and social norms promoting environmental conservation, whereas the remaining respondents feel difficulty. According to my research, this theory does a good job of predicting respondents' pro-environmental behavior. TPB theory can assist future studies in exploring the theoretical foundation for comprehending the affecting aspects of WTP.

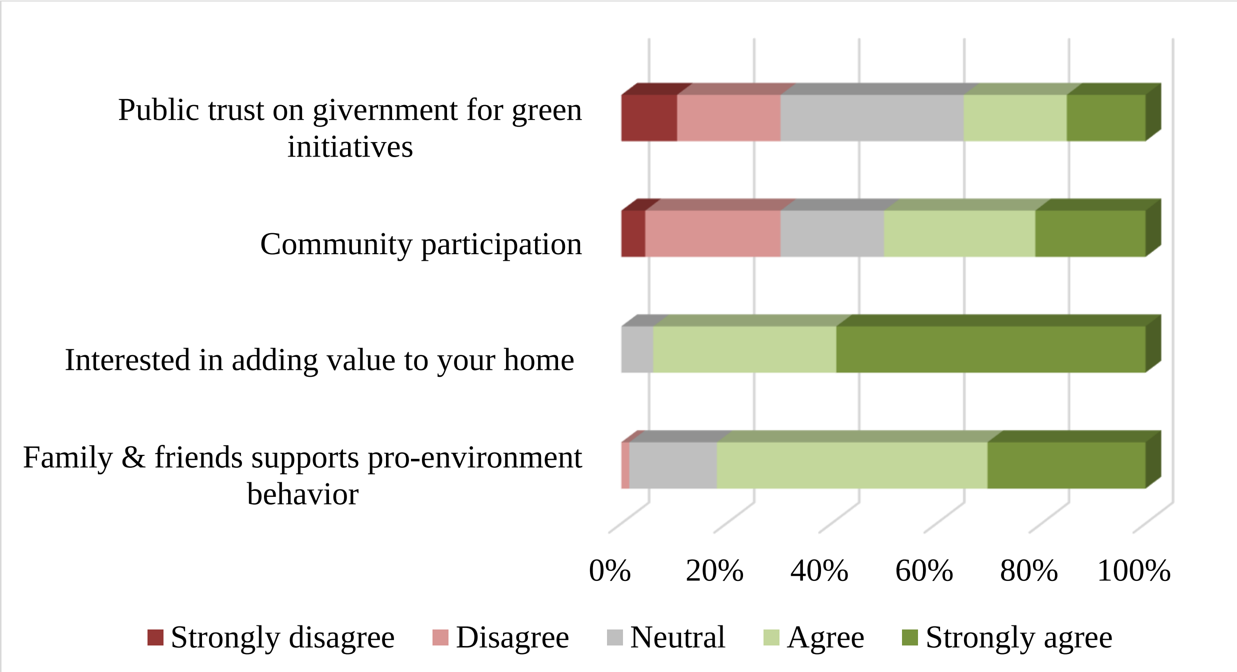


Figure 25. Respondent's behaviors, attitude, and response towards green roofs (Source: Household survey)

According to the results, there were mixed responses on whether public trust government for such initiatives or not. 19% agree, 19% disagree, and surprisingly 34% respondents have no views on this specific question. While conducting survey, I have noticed that public hesitate to answer or share views on government regarding any kind of initiatives.

4.3.3. Subjective perceptions of public

Figure 24 shows respondent's perceptions regarding green roofs and its implementation in urban areas. To understand the level of benefits, acceptance, awareness, and knowledge of green roofs of respondent's this specific indicator was selected. Results shows (see figure 26), 34% respondents disagree that they have any kind of knowledge regarding green roofs and 18% agree to this question. However, while talking to the public during the survey, it is clear that their response changed after researcher explained them about green roofs. Majority of sample agree (44%) to opt. green roofs only if government will provide incentives or other financial support programs. 54% respondents agree to install green roofs to save energy in their homes, but the downside is 50% of respondents faced obstacles to fulfil the initial investment.

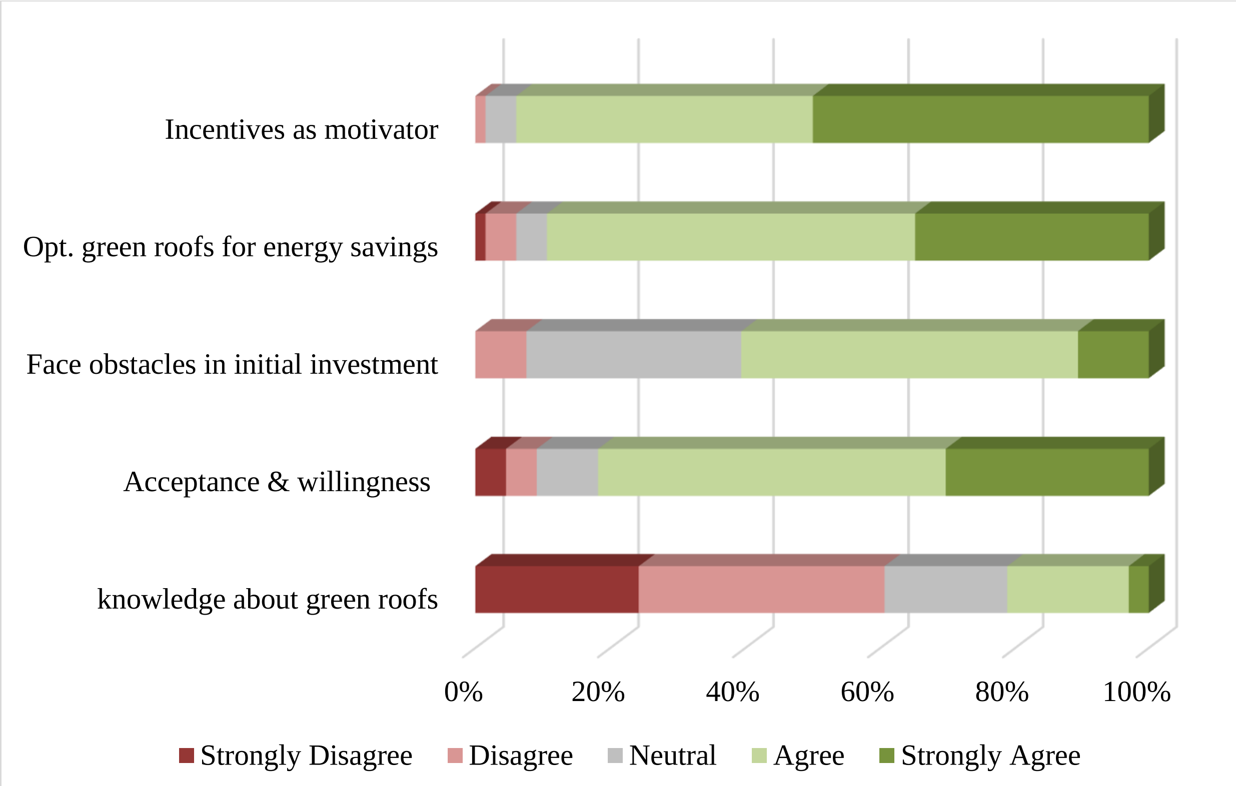


Figure 26. Shows stats of respondent's subjective perceptions on green roofs (Source: Household survey)

When listed multiple benefits of green roofs (i.e., energy saving, comfort, lower surface temperature, aesthetic value, increase property value) 51% of respondents inclined towards accepting this technology and are even willing to pay for it. As we have discussed earlier (**see figure 22**) that majority of respondent in the dataset belong to financially strong background, they are more inclined to pay for such initiatives. The reason stated was personal interest and increase in the property value.

4.3.4. Climate chance risk perceptions

Public perceptions of flood risk and heat waves and the information about these disasters are often overlooked while developing risk management plans. Extreme temperature can be observed every year, which has put public at significant perceived risk. As we all know that flood risk management plans have been failed in the past. Sindh and Baluchistan were hit by flood (2022/2023) and more than 90,000 people lost their homes. No such evacuation routes and early warning system were observed to save people from such green loss.

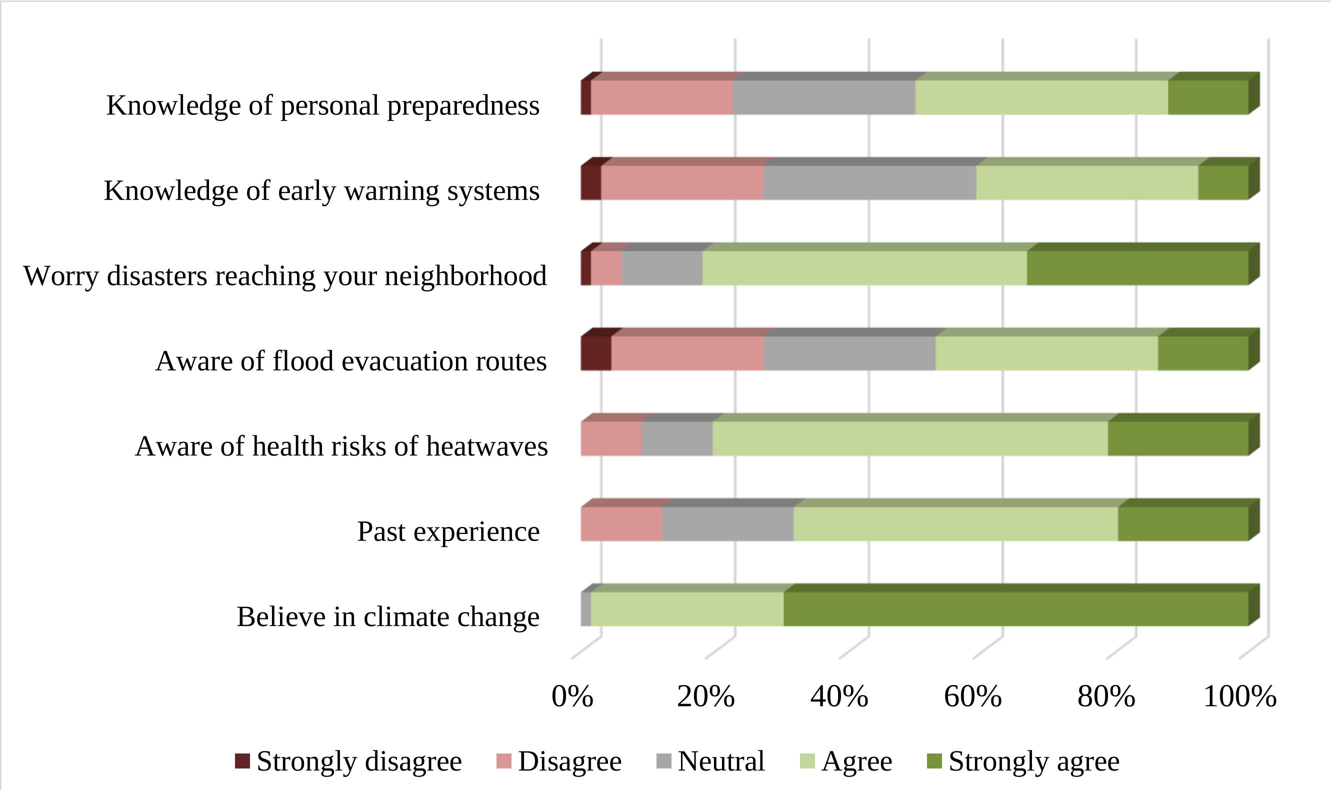


Figure 27. Climate change risk perceptions of respondents- Floods and Heatwaves (Source: household survey)

In my view the greatest loss of our public is that majority of people (70%) strongly agree that they believe in climate change, however, 33% agree they have knowledge about early warning systems, and only 37% of public are aware of any kind of preparedness. People living in Islamabad (60%) agree that they have knowledge regarding health risks of heatwaves and precautionary measures. However, facts state otherwise. Pakistan had some of its greatest temperatures in the recent 60 years from March through May 2022 (International Amnesty Statement, 2022). Although the real death toll in Pakistan is unknown, it is estimated to be 65, with at least three of those deaths being linked to the heat wave and including children. Particularly for youngsters, the elderly, those with impairments, and those who suffer from chronic illnesses, extreme heat can be fatal. Heat waves can have negative effects on the body's capacity to regulate temperature, which can lead to heat strokes, cramps, and an aggravation of pre-existing conditions. It can cause fatalities or hasten the onset of chronic disorders like diabetes.

Talking about the state of past experience and worry that disaster may reach their neighborhoods are high. 48% of respondents had faced one of the two mentioned disasters (flood & heatwaves) and 48% worry about these disasters again hitting their neighborhoods, but only 12% respondents strongly agree that they are prepare for the consequences.

5. Discussion

5.1. Green roofs and urban resilience

Retrofit[1] green roofs are becoming an increasingly popular strategy to enhance urban sustainability in developed countries (Wilkinson & Dixon, 2016). In developed urban centers most of the infrastructure has been already laid. At this stage it is a bit challenging to install green infrastructure to achieve its complete benefits. 40-50% of area in develop cities account for roofs, so we can utilize this area to install green roofs on buildings. Select the best type of green roof to achieve maximum benefits and improve the environment. Moreover, it will help lowering the adverse effects of climate change in urban areas. An implementation framework (**figure 8**) is prepared utilizing the data retrieved from literature under study. This framework will help achieve urban resilience with integration of green roofs in urban areas.

Green roofs are not only the best technical solution against climate change, but also feasible to integrate in existing buildings (Baciu et al., 2020; Castleton et al., 2010; Joshi & Teller, 2021). Green roof retrofitting is studied by different researchers at different locations. First green roof at Sydney, Australia, is a timber frame structure and second at Rio de Janeiro, Brazil, by utilizing block work construction. Authors investigated and compared green roof benefits with conventional roofs regarding thermal comfort. Both retrofit green roofs shows promising results. However, the performance can be more effective using good quality material (Wilkinson et al., 2017). The timber frame shows more insulation properties and cooling effects as compared to the block work structure. Study done in Italy, shows that thermal insulation is significantly important for the comfort of residents (Gagliano et al., 2016). It suggests that green roofs can be the effective solution for climate change adaptation in dry mild climate with hot, dry summer and Mediterranean area.

[1] Retrofit green roofs are green roofs that are installed on existing buildings rather than being incorporated into the initial design of the building.

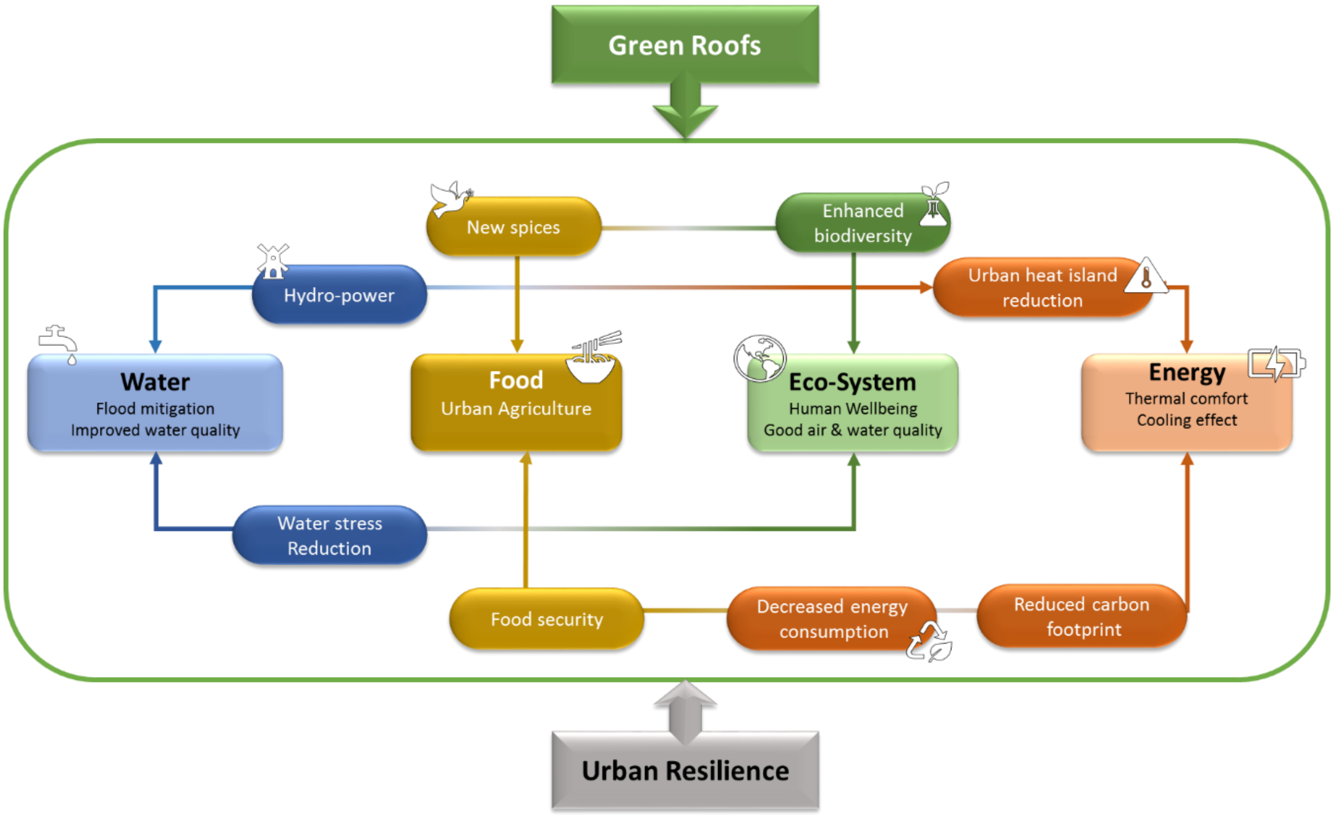


Figure 28. Modified version of implementation framework for urban resilience with green roofs in urban area (Cristiano et al., 2021)

Green roof retrofitting can lower the surrounding temperature up to 0.4°C during the day and 0.8°C at night. Researchers from Canada investigate the two major barriers of green roofs as overshadowing roof area and orientation (Gagliano et al., 2016). Retrofitting green roofs can be challenging as compared to designing building with green roofs from scratch. However, additional loads and structure failure are the main issues regarding retrofitting green roofs. The study in UK suggests that most buildings can withstand retrofit green roofs in urban centers and it improve the thermal insulation of existing buildings (Castleton et al., 2010). Another argument presented by authors is that retrofit green roofs are cost effective as compared to new buildings. Because old buildings are badly insulated and uses large amount of energy annually (for cooling in summers and heating in winters). Retrofitting green roofs can improve insulation of such buildings and provide multiple economic and environmental benefits. Moreover, the lifespan of retrofit green roofs is expected to be somewhere between 40 and 55 years (Clark et al., 2008; Rosenzweig et al., 2006; Saiz et al., 2006). It is very important factor for life cycle cost assessment of green roofs.

5.2. Green roofs and adaptation planning

Green roofs have become a model solution for adaptation planning, even in the absence of climate change, because it has manifold benefits. One of the major impacts of climate change is heat waves and increasing temperature, and green roofs are doing amazing in tackling the situation ("Climate Action in Megacities 3.0," 2019). These developments aggravated the urban heat island effect, which explains the fact that temperature tends to be a few degrees higher in urban areas as compared to the rural. The reason is very little green spaces, dominance of grey infrastructure, and other heat sources (Donner et al., 2015). On the whole, it affects the city's economy (i.e., high cooling demand & high energy consumption), infrastructure (buildings and streets), water & air quality, biodiversity, health, and wellbeing (Bowler et al., 2010; D'Ippoliti et al., 2010; Feyisa et al., 2014; Schlünzen et al., 2018). Green urban spaces include green roofs & walls, parks, urban forests, street tress, green facades, and private gardens are expected to provide relief to the public.

Moreover, abundance of green structures provides cool surrounding air, shades, insulation of buildings against heat and cold, and also enhances the air quality by captivating pollutants in the air (Demuzere et al., 2014). The facilitation green roofs provide do not end here. Moreover, green roofs support the adaptation of dense areas to frequent and powerful precipitation events. It aids in reducing and delaying the overall amount of rainfall runoff into the sewage system, as well as enhancing the quality of runoff water, by retaining rainwater and allowing it to naturally evaporate (Demuzere et al., 2014). Finally, green roofs have a noticeable contribution in improving the biodiversity and providing home for new species in highly affected areas by severe climate change.

These benefits not only support the technical solutions i.e., green roofs for climate change. There are a few economic and political reasons why green roofs are important for sustainable and climate resilient cities. As compared to other Nature-based solutions, green roofs are comparatively easy to install, inexpensive in the long-run, and cost-efficient (Brink et al., 2016). Lastly, green roofs are politically benevolent because they have a significant amount of public appeal (Sprondel et al., 2016) and provides green spaces without actually occupying any extra land.

5.3. Barriers to green roofs development

Although, green roofs have huge potential in lowering energy consumption, improving indoor temperature, enhancing urban sustainability and biodiversity, and much more. There are certain barriers which must be overcome for smooth and unbothered implementation of green roofs in the context of adaptation planning and urban resilience.

5.3.1. Economic barriers

1) The cost of installing and maintaining a green roof can be high, which can discourage building owners from pursuing this option.
2) Public are not aware of the potential market regarding green roofs.
3) There are limited to non-existing government subsidies and loans to support integrating green roofs on buildings.
4) Involvement of risk factor regarding the performance of green roofs.

5.3.2. Social barriers

1) Many people are not aware of the benefits of green roofs and may not understand how they work. This can make it difficult to persuade building owners to invest in them.
2) Lack of social participation in green roofs development. Public prefer to stick to old energy methods.
3) Designing and installing a green roof requires specialized knowledge and expertise. If there are not enough qualified professionals in a given area, it can be difficult for building owners to find someone to help them with their project.

5.3.3. Structural limitations

1) Green roofs can be heavy, so the building must be able to support the weight of the soil and plants. If the structure is not strong enough, retrofitting may be necessary, which can add to the cost.
2) In some cases, additional structural support may be necessary, such as adding more beams or columns to the roof or strengthening the foundation., which adds to the expenses.
3) Unawareness of lightweight growing media, plants that require less water, and modular systems that allow for easy installation and maintenance.

5.3.4. Technological barriers

1) Rely on old and unreliable technology.

2) Green roofs require regular maintenance, including watering, fertilizing, and weeding. Some building owners may be hesitant to take on this responsibility or may not have the resources to do so.
3) Dependent on foreign technical support, which adds to the expenses.

5.3.5. Legal and regulatory barriers

1) In some areas, there may be zoning or building codes that make it difficult to install green roofs. For example, there may be restrictions on the height of vegetation or the amount of soil that can be used.
2) High priority to traditional energy sources and lack of regulations regarding green energy production.
3) More incentives and subsidies are available for energy production using fossil fuels, which increases pollution.

5.4. Benefits of green roofs

5.4.1. Urban heat island

Green roofs can help to mitigate the urban heat island effect, which is a phenomenon in which urban areas tend to be significantly warmer than their surrounding rural areas due to human activities, such as transportation, industry, and buildings. The heat island effect can cause numerous problems, including increased energy consumption, air pollution, and public health concerns.

Green roofs, also known as vegetated roofs or eco-roofs, are roofs covered with vegetation, which can help to reduce the amount of heat absorbed by buildings and cities. The vegetation on green roofs absorbs solar radiation and releases moisture through transpiration and evaporation, which cools the air and reduces the heat stress. Additionally, the soil and vegetation on green roofs act as an insulating layer, reducing the amount of heat transferred into buildings through their roofs.

Green roofs can also help to improve air quality and reduce stormwater runoff in urban areas, which can further contribute to mitigating the urban heat island effect (Cortinovis et al., 2022). With the ability to reduce UHI impact, as well as provide advantages for biodiversity and subjective wellness (Aleksejeva et al., 2022), green roofs have the potential to become a significant component of green infrastructure with favorable implications on urban sustainability and livability.

5.4.2. Flood mitigation

Most publications emphasize the significance of defining the characteristics of different green roofs in order to make them useful planning tools for the creation of climate-change resilient cities. They also explain which two roof systems are most appropriate for cities looking to reduce urban flooding and improve storm water management (Gößner et al., 2021). Green roofs absorb rainfall and release it slowly through evapotranspiration, which reduces the amount of stormwater runoff. The vegetation and soil on green roofs act as a natural sponge, absorbing and retaining water. As a result, less water enters the stormwater system, which reduces the risk of flooding during heavy rainfall events. **Figure 27** shows the perceived benefits of respondents during house hold survey.

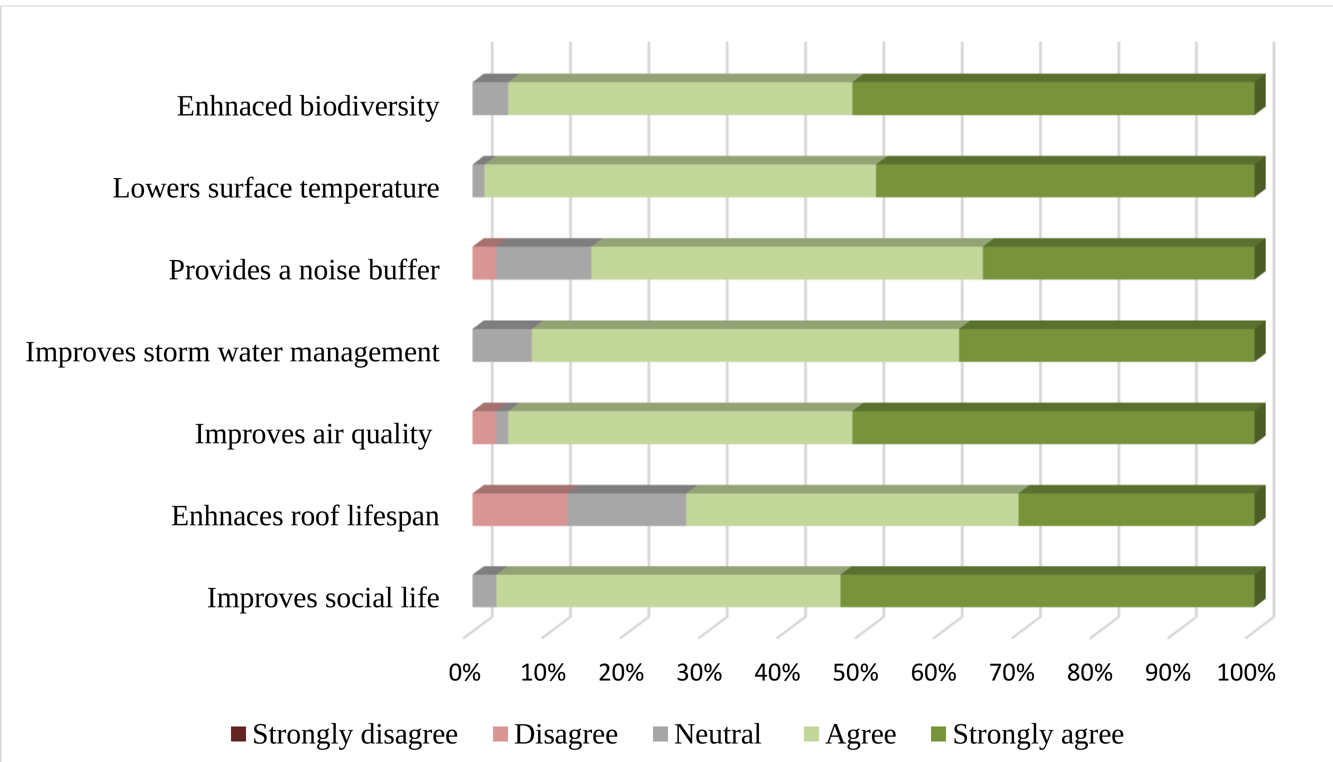


Figure 29. Respondent's perceived benefits of green roofs (Source: Household survey)

If at least 50% of the surrounding region had green roofs, all investigated areas might prevent flooding during moderate rainfall events (irrespective of the type of green roof. In comparison, only a few semi-extensive and extensive green roofs covering 60% to 95% of the surrounding area might prevent floods in the presence of heavy rainfall events (Mora-Melià et al., 2018). Moreover, green roofs can improve the water quality of the runoff that does occur by filtering out pollutants, such as heavy metals and hydrocarbons, that may be present in the stormwater. This can help to protect local waterways and ecosystems from the harmful effects of pollution.

5.4.3. Thermal comfort

Green roofs can improve thermal comfort in buildings by reducing heat gain during the summer and heat loss during the winter. In hot climates, green roofs can reduce the temperature of the roof surface and the air above it, which can help to reduce the cooling load of buildings. The vegetation on roofs absorbs solar radiation and releases moisture through transpiration and evaporation, which cools the air and reduces the need for air conditioning during the summer. A study recommends improving the integration of roof greening strategies within the current policy framework of the government to address the combined challenges of local and global climate change (Peng & Jim, 2015). Due to the significant advantages and cost-effectiveness, more financial incentives might be offered to encourage widespread green-roof installation. The study could be enhanced by gathering more accurate, exact, and pertinent data based on more regional studies in the future.

The social benefits are greatest when people are least tolerant to hot outdoor air temperatures. Second, the fundamental advantage of having several green roofs is the decrease in heat-related mortality brought on by temperature regulation. Lastly, the study demonstrates that the disruption in the flow of ecosystem-based benefits is anticipated to be bigger in climates where the observed temperatures are closer to threshold temperatures due to their nonlinear interactions with the climatic dynamics (Foudi et al., 2017). The owners and occupants of buildings, town planners, and landscape architects could encourage the installation and use of green roofs for citizens to appreciate the mitigation of thermal conditions. Future studies might look into the ways to regulate or repel evapotranspiration-generated moisture in order to improve thermal comfort by roof greening (Lee & Jim, 2019). Moreover, the usefulness of green roof depends on analyzing physical (spatial and geographic) and non-physical (social and economic) factors. A reliable algorithm and national GIS analysis tool could help in expansion of green roofs and improve ecosystem in urban areas.

5.4.4. Enhanced biodiversity

The variability in the potential of green roofs to provide different urban sustainability benefits depending on the benefit category and the location in the urban fabric. There is very little actual implementation of green roofs to provide sustainability in real world. The strategy used in (Aleksejeva et al., 2022) can be applied practically in decision-making at the government level, such as targeted mandates for green interventions. Before submitting any applications regarding green roofs, careful planning is necessary to ensure the strategy's success (Salih et al., 2021). With the right conditions and a proper design strategy, green roofs can support a thriving and biodiverse environment in urban areas; design strategies are essential for the creation of a rich ecological area.

5.4.5. Carbon footprint reduction

The use of green roofs is a viable alternative for tropical cities to improve the natural environment with significant potential to reduce carbon footprint over the course of a building; the study's authors therefore hope that it will encourage the efficient and long-lasting usage of green roofs (Nadeeshani et al., 2021). To encourage the further adoption of green roofs, it is advised that future studies be conducted to evaluate the carbon footprint of other types of green roofs and to address the impact of carbon absorption in green roofing. It is also anticipated that this will contribute to a wider body of knowledge, resulting in increased use of green roofs in local as well as global contexts.

Due to their public and individual benefits, green roof applications have been found to be suitable for industrial areas as well as individual homes. Supporting green roof applications by taking the public's interest into account will be a very beneficial strategy for a sustainable environment and lowering carbon emissions (Catalbas et al., 2021). Due to their public and individual benefits, green roof applications have been found to be suitable for industrial areas as well as individual homes (Catalbas et al., 2021). Supporting green roof applications by taking the public's interest into account will be a very beneficial strategy for a sustainable environment and lowering carbon emissions.

5.4.6. Evapotranspiration

In order to make green roofs useful planning tools for the creation of climate change-resistant cities, the findings in emphasize the significance of defining the characteristics of each type of green roof. It was also revealed that green roof systems are best suited for cities that want to reduce the impact of air pollution and improves the quality of water (Gößner et al., 2021). Urban planners won't be able to finish the decision-making procedures and put in place a blue—green infrastructures that is optimal for heat mitigation. storm water management, and improve air quality until correct data are available. The findings also demonstrated that green roof maintenance components are insufficient and unsuitable for Asian tropical climate; existing green roof maintenance is restricted to a basic horticultural and landscaping management strategy (Zaid et al., 2022). Policymakers and building stakeholders will be able to create useful green roof maintenance guidelines according to the finding.

5.4.7. Ecological support

Residents who grew up in cities were inclined to adopt urban green space initiatives in the context of ecological benefits. Additionally, they possess better self-rated health status and understanding of green roofs in residential urban areas (F. Liu et al., 2021). Moreover, the perceptions of various socioeconomic groups and different types of urban green spaces deserve to be investigated. The study may help policy-makers better understand residents' hidden outlooks and expectations regarding the numerous benefits of green roofs. They also interpret the strategy used to refine incentive programmes to encourage green roofs integration. A more complex typology could be used to assess the health status, childhood, and current living situations (F. Liu et al., 2021). Green infrastructure offers a path for how to accomplish a goal by establishing justifications for prerequisites. It may be a practical way to address many impacts of climate change and encourage the attainment of the United Nations Sustainable Development Goals (SDGs).

5.4.8. Urban sustainability

Integrating green roofs in urban planning will need to specifically target city policymakers. The choice to install green roofs can be greatly influenced by the presence or absence of appropriate regulations and policies. According to current incentives, owners of green roofs face the majority of the risk while the general public benefits as a whole. Therefore, it is logical to assume that decisions made at the policy level will have a significant impact on how quickly green roofs and other green infrastructure will be adopted in the future (Brudermann & Sangkakool, 2017b). The analysis appears to establish a connection between distinct types of green roofs and particular policy tools.

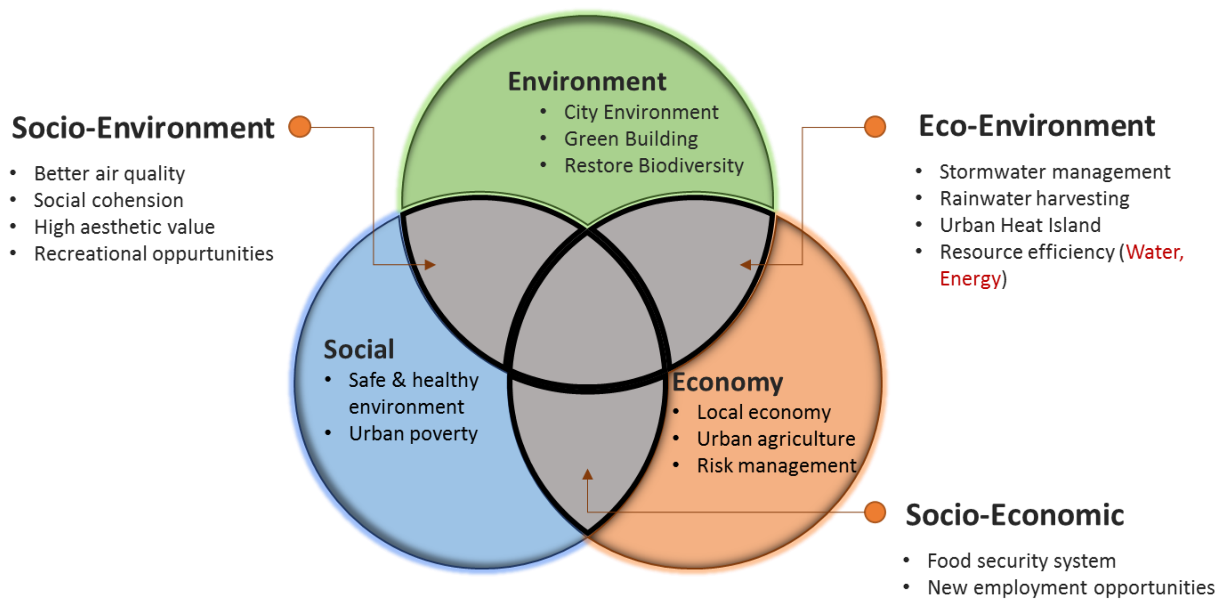


Figure 30. Modified conceptual understanding of urban sustainability via green roofs (Al-Zu bi & Mansour, 2017)

With all necessary caution, it is possible to make recommendations for local governments: cities looking for advice on how to promote green roofs in urban planning (Roggero, 2020). These studies and incentives also help to decide the size of roof needed and adoption of certain policy instrument.

6. Conclusion

Future studies in the context of green roofs and climate change have higher chances of achieving modeling accuracy, as modern technical support will become major part of such green initiatives. Moreover, spatial and temporal scales are going to get improve that will give public access to find suitable green roof according to their needs and space available. This inclusion would allow decision-makers and urban planners to run sensitivity tests while taking into account different combination of input variables, such as plant types, public water availability, irrigation assets, types of blinds, and other factors. It also maximizes the human wellbeing and environment co-benefits the public knowledge, urban capacities, and resources available for green roofs implications suitable for urban, peri-urban, and suburban areas. They will serve as the foundation for regional urban planning and the design of urban spaces. The study's output is to develop a universal model that depicts how the city's climate might change if green roofs are installed on as many housing estates as possible.

By providing a range of benefits in the context of adaptation planning and urban resilience. They have become an increasingly popular option for architects, developers, and urban planners seeking to create sustainable, resilient, and livable urban environments. However, to fully realize the potential of green roofs, it is important to ensure that they are integrated into wider urban planning and design strategies, and that they are supported by policy frameworks and incentives that encourage their adoption and maintenance over the long term.

7. Recommendations

Therefore, from the review we can comprehensively understand that green roofs are efficient and practical tool to combat climate change. They have wide range of benefits interlinked with other themes of urban planning in the context of sustainability, adaptation, and resilience. Many studies on green roofs have been conducted over short time periods, typically last four to five years. Future research could focus on longer-term monitoring of green roofs to better understand how they perform over time and how they interact with changing weather patterns and urban environments. However, there is a concerning knowledge gap that hinders green roof acceptability in public. Green roofs have the potential to increase biodiversity in urban areas, but more research is needed to understand how different types of green roofs affect local wildlife populations. Future research perspectives could focus on the types of plants and animals that thrive on green roofs, and how to design green roofs that maximize biodiversity. Concerning biodiversity, no in-depth research efforts were made to augment green roofs into urban planning.

Green roofs have been shown to reduce building energy use by providing insulation and shade, but more research is needed to understand how to optimize green roof design for energy efficiency. Future studies could focus on how to design green roofs to minimize heat loss during winter months and reduce cooling needs during summer months. The components of green roofs are selected on the basis of structural limitations and aesthetic profits. These components influenced the benefits like improve air and water quality, and noise insulation, which were not much researched. While green roofs can be expensive to install, they can provide long-term economic benefits such as increased property values and reduced maintenance costs over time. Researchers could focus on quantifying the economic benefits of green roofs and identifying the most cost-effective designs and maintenance practices.

Moreover, it was noticed that green roofs studies are restricted to a few countries. Although, every country is facing climate change and are working towards adaptation, but level of complexity is different. So, research on local level is extremely necessary for successful integration of green roofs in urban planning for adaptation and urban resilience. Public perception of green roofs can influence their adoption and success in urban areas. Future research could focus on understanding how different segments of the public view green roofs, and how to design green roofs that are visually appealing and socially acceptable. It is important to make the green roof material available at local level and its accessibility should be checked at each potential geographical location. It will help policy makers to take wise decisions for urban sustainability. Policy makers could step-forward in providing incentives and robust legislation regarding green roofs.

This research also points at the need of scientific investigation for integration of green roofs. Continued research on green roofs is essential to understand their potential benefits and limitations, and to develop best practices for their design, installation, and maintenance. Few years from now, we can expect green roofs at every geographical location around the world.

Annexures

Annexure-A: Questionnaire for household survey

Sr. Number: ____________

Nust Institute of Civil Engineering (Nice) – Urban and Regional Planning

<u>Assessing the role of green roofs as Nature-based</u>

<u>solutions for adaptation planning and urban resilience – Islamabad, Pakistan</u>

<u>Household survey</u>

(Note: Data collected will only be used for educational purposes.)

<u>Demographic Characteristics:</u>

Age: Family Size:

Gender: Male; Female Household income:

Educational level: House ownership status:

Occupation: Green spaces in house:

<u>Theory of planned behavior determinants</u>		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
1	You would be interested in saving money through using energy efficient techniques in your household					
2	You would be interested in adding value to your home with the addition of energy saving techniques					

3	You might have seen any traditional practices regarding green spaces in your neighborhood					
4	You might have observed any community participation in making your surroundings green (parks)					
5	How much do you trust your government for such initiatives?					
6	People have positive attitude considering improving urban environment through green spaces					
7	How much do your family & friends supports your pro-environment behavior?					
<u>Subjective perceptions on green roofs</u>		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
8	You have enough knowledge of green roofs					
9	How likely would you consider green roofs as an option for saving energy in your home?					
10	How likely would you consider green roofs as an option for increasing value in your home?					
11	If green roofs were an option in new development of tract housing, how likely would you consider buying?					
12	How likely are you willing to pay for green roofs?					

13	How likely do you face obstacles regarding investment for green roofs?					
14	How likely would you be to consider purchasing a house with a green roof in a new housing development?					
15	How likely would you be to consider an addition of a green roof to your existing home if it saved you money in the long-term?					
16	If an incentive program was available to convert your roof to a green roof, would you take part in one?					
<u>Climate change risk perception</u>		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
17	How much do you believe in climate change?					
18	How likely have you experienced a disaster in the past?					
19	What kind of disaster have your experienced?	Flood / Heatwave				
20	You aware of health risks regarding floods and heatwaves					
21	You are aware of any evacuation routes in case of flooding					
22	You are aware of health precautions regarding heat waves					

23	How likely do you worry regarding floods & Heatwaves reaching your neighborhood?					
24	Rate your self-assessed levels of personal preparedness in case of disaster (heatwave and flood)					
25	You are aware of any early warning systems in case of any disaster					
26	How likely would you use any coping methods for heatwave/floods?					
<u>Benefits of Green roofs in urban areas</u>		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
27	Social life improves from green spaces					
28	Green roofs enhance leisure values					
29	Green roofs enhance roof life					
30	Green roofs improve air quality					
31	Green roofs provide noise buffer/insulation					
32	Green roofs lower surface temperature and keep interior cool					
33	Green roofs reduce heat sickness from heat waves and heat stroke					

34	Green roofs provide home for birds (enhances biodiversity)					
<u>Challenges in accepting green roofs</u>		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
35	Lack of green roofs effects on quality of life					
36	Awareness of green roofs by Government					
37	No incentives from government for green roofs					
38	Lack of technology for implementing green roofs					
39	Special provision in building regulation about green roof					
40	Sustainable environment awareness promotes green roofs					
41	Cost is a major hindrance in the adaptation of green roofs					
42	Govt. should subsidize green roof material					
43	Resident with green roofs should have incentives in water supply and sewerage charges					

<u>Suggestions:</u>

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Annexure-B: Questionnaire for expert's interviews

Sr. Number: _____________

NUST INSTITUTE OF CIVIL ENGINEERING (NICE) – URBAN AND REGIONAI PLANNING

Assessing the role of green roofs as nature base solutions for adaptation planning and urban resilience - Islamabad

Expert's interview

(Note: Data collected will only be used for educational purposes.)

Demographic Characteristics:

Age:

Gender:

Education:

Profession:

Statutory and Policy Response		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
1	There is development going on for promoting and implementing green roofs					
2	How much evaluation is currently going on concerning green roof technologies?					

3	There are robust policy/rules/standards for green roofs in residential areas					
4	How much the implementation of policy is effective					
5	How much obstacles faced during submission of initial payment/investment in green roofs					
6	Govt. offered any incentives to motivate green roof installments					

Economical Dimension of Green roofs		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
7	Govt. is giving incentives for green roofs installation					
8	Green roofs are real estate asset					
9	Green roofs fulfill traditional user-end energy demand					

Internal factors (Strengths)		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
10	Green roofs provide environmental benefits					
11	Green roofs improve life quality & aesthetics					
12	Ability to provide thermal comfort					
13	Ability to reduce flood risks					
14	Saves energy as compared to expensive electricity production options					
Internal factors (Weaknesses)		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
15	Has structural and static challenges					
16	Has higher implementation and maintenance costs					
17	High chance of possible damage to building					
External factors (Opportunities)		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
18	Climate change adaptation and mitigation					
19	Chance of public acceptance & environmental awareness					

20	A step towards green policies in cities					
<u>Internal factors (Threats)</u>		**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
21	Comes with legal & political constraints					
22	We lack knowledge					
23	Uncertainty of potential adopters					

<u>Other Challenges:</u>

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The questionnaire ends here. Thank you for your time.

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