NUML Journal of Economics (NJE)
Volume 1, Number 1, June 2024, PP. 34-51

Nature-Based Solutions for Urban Climate Change Adaptation in Pakistan

Rabiya Imran[1]

Abstract

Article History:

Received Date: 8th January 2024

Revised Date: 12th April 2024

Accepted Date: 30th May 2024

Published: 10th June 2024

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

This study investigates the readiness of urban residents to adopt nature-based climate adaptation options in three cities of Pakistan. A systematic random sampling approach was employed for survey administration. A proportional sample of respondents was contacted from each sector or zone, based on data from the Census of Pakistan, 2017. The sample size comprised of 1000 respondents, with 250 respondents targeted from each city. Nature-based solutions have significant potential to decrease the vulnerability and enhance the resilience of cities in light of climatic change. Drawing on primary survey and econometric analysis, the study demonstrates a positive correlation between citizens' readiness to adapt and their age, exposure to harsh climates, pessimistic forecasts for the future climate, and perceived danger. Additionally, household composition, respondents' use of recreational and environmental services, and their social collaboration appear to induce their adoption of nature-based climate adaptation options in our study areas.

Keywords: Climate Change, Nature-Based Adaptation, Green Spaces, Water Storage

1. Introduction

Climate change presents significant challenges for cities around the world, impacting various aspects of life and posing threats to both economies and quality of life (Mehryar et al., 2022; WEF, 2019). However, the consequences of climate in emerging nations are more unique because of their poor environmental and socioeconomic circumstances (United Nations, 2021). For instance, Pakistani cities often experience high temperatures, humidity, heat waves, shortage of acute water, and flooding (Ahmed, Padda, Khan, et al., 2023). Usage of water and greater energy along with health and environmental hazards are the result of increased temperature and humidity in the cities of Pakistan, in addition to health and environmental hazards (Kugelman,

[1] Scholar, COMSATS Islamabad, Wah Cantt Campus.
Correspondence: rabyiaimran@gmail.com

2016). Although by 2050, Pakistan's population in cities will exceed half, the influences of weather change on economic and social systems are predicted to be more severe (Haider et al., 2014). In the present context, urban adaptation seems to be a more suitable solution for climate change in Pakistan because of its clear and immediate benefits (Adger et al., 2004). Since climate policies are often designed using top-down approaches (Adger et al. 2013), inhabitants in cities are frequently not completely capable and prepared of responding to the change in climate (Mohanty & Kumar, 2021).

Furthermore, since the explanation of centralized urban adaptation may not be cost-effective and sustainable (Hao et al., 2020), there is a need to deploy locally relevant urban adaptation measures (Ahmed, Padda, & Khan, 2023). In this regard, ecosystem-based adoption such as green places, green walls and roofs, permeable surfaces, vegetation infiltration belts, and urban agriculture (Alves et al., 2020), rain gardens, and sustainable drainage systems are the best options. This study investigates urban residents' readiness for nature-based climate adaptation options in Pakistan. Due to resource constraints, the Pakistani government is unable to allocate adequate resources to build communities' climate resilience. Furthermore, there are problems with technical capacity and timely policy design and implementation. Hence, it is important to promote autonomous and nature-based adaptation solutions to develop urban communities' resilience to climate variability.

Nature-based climate change adaptation offers a comprehensive strategy to lower cities' vulnerability to climate change (Chausson et al., 2020). Understanding urban residents' readiness for Nature-based solutions is important for promoting their adoption and building resilience against climate variability. Previous studies have shown public preferences for nature-based adaptations, including rain gardens, street trees, green roofs, and facades, and found that there is wide support for nature-based adaptations (Woroniecki et al., 2022).

Arshad et al. (2020) and Puppim De Oliveira et al. (2013) conducted studies on urban green spaces as a strategy for climate change adaptation. Their findings suggested that the effectiveness of utilizing green spaces for adaptation purposes depends on local and context-specific factors. On a related note, Frantzeskaki et al. (2019) emphasized the significance of considering various factors such as scale, social, cultural, ecological, and technological contexts for the success of

nature-based solutions. Khan's study (2012) also emphasized the importance of local natural systems, infrastructure, and context-based planning in adaptation efforts.

While Nature-based solution holds great promise for urban climate adaptation, challenges remain in mainstreaming their benefits and securing financing for implementation (Toxopeus and Polzin, 2021). Addressing these challenges requires integrative and trans-disciplinary approaches involving diverse stakeholders and considering socio-environmental conditions to effectively implement nature-based solutions (Matthew et al., 2022). Pakistan can enhance its resilience to climate change and foster sustainable urban development.

1.1. Importance of the Study

Over the past decade, Pakistan has faced unprecedented temperatures and frequent, severe heat waves in its urban areas (Saeed, n.d.). These extreme weather events have resulted in significant human casualties, with approximately 100 deaths reported in a single year due to extreme heat (Sheikh and Tunio, 2013), and over 65,000 people hospitalized in Karachi alone in 2015 due to heat-related illnesses (Haider et al., 2014). Despite these alarming statistics, there has been limited investment in urban climate change adaptation initiatives in Pakistan. While a few studies have addressed climate adaptation in urban contexts (e.g., Rauf et al., 2017; Hussain et al., 2019; Ahmed et al., 2023), the majority of research in Pakistan has focused on the agricultural sector (Abid et al., 2016; Fahad & Wang, 2020; Hasan et al., 2017; F. Saeed et al., 2016).

Nature-based adaptation measures have been particularly overlooked in existing literature. This research aims to address this gap by examining the effectiveness of nature-based adaptation strategies in four major Pakistani cities: Karachi, Lahore, and Twin Cities. The central question of the study is to evaluate the extent to which nature-based adaptation strategies have been successful in mitigating the impacts of climate change in Pakistan.

Research Gap

Cities have a significant role in combating climate change. Previous research has mostly overlooked the range of climate change responses that emerge outside of formal frameworks for decision-making and are spearheaded by entities other than local governments. Furthermore, case studies for the mitigation of climate change in industrialized economies have dominated the body of extant literature. Prior studies have not taken into account the tactics and chances for

daptation that each community in developing nations has to offer. Nature-based adaptation measures have been particularly overlooked in existing literature. This research aims to address this gap by examining the effectiveness of nature-based adaptation strategies in four major Pakistani cities: Karachi, Lahore, Islamabad, and Rawalpindi. The central question of the study is to evaluate the extent to which nature-based adaptation strategies have been successful in mitigating the impacts of climate change in Pakistan.

Study Areas

The research focuses on four specific cities in Pakistan: Karachi, Lahore, Islamabad, and Rawalpindi. Islamabad and Rawalpindi are commonly referred to as twin cities. Islamabad, the capital and economic center of Pakistan, was established in the 1970s and has a population of approximately 1.3 million as per the 2017 census. It attracts migrants from all over the country due to its concentration of government institutions, educational facilities, higher quality of life, and economic opportunities. With an annual population growth rate of approximately 3%, Islamabad has a diverse demographic profile and serves as a hub for rural-to-urban migration.

Rawalpindi, located adjacent to Islamabad, has a population of around 2.5 million according to the 2017 Census of Pakistan. Lahore and Karachi, on the other hand, are densely populated cities in Pakistan, with populations of approximately 14.91 million and 11.13 million respectively.

2. Literature Review

Research on Nature-based solutions for the urban climate in urban climate change adaptation has gained great traction, attracting significant interest from researchers, policymakers, and practitioners worldwide.

The vulnerability structure for social-ecological systems developed by the Intergovernmental Panel on Climate Change (IPPC), serves as a conceptual framework to analyze nature's part in encouraging human adaptation to climate change. This framework emphasizes the importance of limiting exposure to the direct effects of climate change. Nature-based Solutions, when properly applied and encouraged by biodiversity, play a crucial role in reducing the sensitivity of human communities and societies to climate variability.

Nature-based solutions have emerged as a promising approach that secures and improves the delivery of an ecosystem that supports livelihood and welfare, as well as provides different

sources of income that may aid the communities to accommodate climate change or other environmental disasters. Several studies have contributed to our understanding of NBS and its effects. Girardin et al. (2021) highlighted the cooling potential of NBS and emphasized the importance of timely intervention in mitigating climate change impacts. Seddon et al. (2021), focused on the communication aspect of NBS, emphasizing the importance of clear and accurate messaging to enhance understanding and adoption of NBS. Moreover, in a comprehensive assessment of cities, settlements, and key infrastructure, Dodman et al. (2022), explored the role of NBS in the context of climate change impacts, adaptation, and vulnerability. Their contribution to the Sixth Assessment Report of the IPCC, provided valuable insights into the potential of NbS to enhance the resilience of urban residents in the face of climate change.

Ahmed (2023), highlighted the critical need for proactive urban planning in Rawalpindi, Pakistan, amidst rapid urbanization and the looming threats of climate change and pandemics. The findings underscore the pronounced vulnerability of densely populated areas such as Dhok Ratta, UC-2, to the combined effects of climate change and pandemics due to factors such as high population density, inadequate healthcare infrastructure, and socio-economic disparities. Moreover, the study identifies areas with comparatively lower vulnerability rankings, such as New Katarian-II, Dhaman, and MC Stadium B Block, suggesting the potential efficacy of targeted interventions and urban planning strategies in mitigating vulnerability.

Nature-based Solutions are increasingly promoted by various stakeholders, including governments, financial institutions, and international governmental organizations, due to their ability to potentially address interconnected challenges related to climate change, biodiversity, and social issues. This integrated approach is often referred to as the climate-biodiversity-society (CBS) nexus. Seddon et al. (2020) highlighted the potential of NBS in addressing various global changes beyond climate change alone. Similarly, Pörtner et al. (2021), provided scientific insights sponsored by IPBES and IPCC, shedding light on the intersection of biodiversity and climate change. Meanwhile, Pascaul et al. (2022), discussed the governance strategies for facilitating transformative change across the climate-biodiversity-society nexus

Stakeholder preferences and perceptions regarding NbS are crucial in adaptation planning. Hoang & Fenner (2016) explored stakeholders' priorities, preferences, and perceptions regarding nature-based solutions, emphasizing the importance of stakeholder involvement for successful

interventions and coherent policies. Several studies have examined factors influencing preferences and usage of different adaptation measures in urban areas (Batool et al., 2018; Kumar & Brewster, 2022; Okonya et al., 2013). Mohanty & Kumar (2021) and Patel & Arputham (2008) found that citizens' preferences for urban adaptation measures are largely influenced by their intentions, behavior, and observations of climate change rather than the actual biophysical climatic changes. Moreover, climate change risk perceptions have been shown to influence support and intentions for urban adaptation (Abid et al., 2016; Lee, 2018), whereas Kusenbach et al. (2010) demonstrated that experiences of climate change shape behavior and perceptions to engage in suitable actions.

The study conducted by Ahmed and Luqman (2024) shed light on the adaptation strategies adopted by urbanities in Rawalpindi, Pakistan. By surveying 450 residents and employing Heckman's treatment effect model, the study identified education and income as significant factors positively influencing the adoption of adaptation strategies.

Despite the growing recognition and multifaceted benefits of Nature-based Solutions, their implementation poses many challenges. Goodwin et al. (2023), assessed NBS methods for climate change adaptation around 130 cities globally and 216 urban projects and revealed limitations in addressing CBS problems, especially by taking into consideration the diverse forms of climate changes, social justice, the capability of cooperation between public and private sectors, and different mutual advantages. The data indicates that knowledge and practices are geared more toward the Global North, with critical CBS concerns in the Global South, specifically related to climate risks and urban ecosystems.

Similarly, a study assessing 97 NBS for climate change adaptation in the European Alps, found that the NBS location is not associated with the existing current supply-flow-demand indicators of most NCP, nor to the degree of danger. Nonetheless, NBS tackles droughts and floods in places where the risk is more to these hazards but fails to match higher values for NCP indicators. On the contrary, NBS targeting to produce wood and providing a protective role for landslides are in places with high levels of NCP, regardless of the severity of the dangers. In conclusion, these findings show that hazards and NCP indicators are not the key factors of NBS implementation (Dubo et al., 2022).

Castelo et al. (2022), critically examined the various challenges and opportunities associated with the adoption of NBS and sought to provide insights into how these solutions can be effectively utilized, emphasizing the importance of tailored implementation strategies and structure. Moreover, an expert-based analysis of barriers and strategies for the implementation of NBS conducted a survey including 80 participants and identified key barriers specific to 35 pre-defined NBS. The most significant barriers were related to technological complexity, lack of skilled staff and training programs, and the general lack of awareness regarding NbS. The research further provided potential strategies for the successful implementation of NPS.

Overall, the literature emphasizes the importance of Nature-based solutions (NbS) in urban climate change adaptations and highlights key areas for future research and policy intervention.

3. Methodology

This research employs a quantitative approach, primarily relying on quantitative analysis through regression techniques. The selection of nature-based adaptation options in the study areas was informed through focused group discussions with citizens and existing literature. Household-level adaptation options were identified, drawing insights from previous studies such as Ferreira et al. (2022) and Arnberger et al. (2017) on urban green spaces, Teotónio et al. (2020) on green walls and roofs, Lorencová et al. (2021) on green gardens, roofs, and water storage, and Asmuni et al. (2016) and Gill et al. (2007) on rain gardens. These options are believed to mitigate temperature extremes, conserve water and energy, and provide various benefits in terms of green economy, improved health, and well-being (Kabisch et al., 2016; and Hafeez and Ahmad (2002).

However, the selection of the most suitable adaptation measures for the local context in Pakistan required discussions with citizens and relevant departments in the study areas. As a result, four nature-based adaptation options were chosen for study areas, including rain gardens, green alleys, roof insulation, and green spaces. Table 1 presents list of variables.

The current study employs both econometric and descriptive methods to explore residents' readiness for adaptation. Descriptive methods are used to present sample characteristics, adaptability to climate change, and summary statistics of variables through graphs and tables. To investigate the factors influencing residents' willingness to implement household-level climate change adaptations, econometric research is conducted using the Probit model technique. The

Probit model helps identify key factors influencing respondents' willingness and probability of accepting adaptation alternatives, considering locally relevant factors. The specification of the basic econometric model is presented below, following the approach outlined by Zhang et al. (2020).

$$Yi=(P/X)=\beta 0+\beta i\sum Xi+\varepsilon$$

Whereas 0 = otherwise and 1 = in the case of adopting an adaptation option, Yi is a dichotomous dependent variable. The constant term is denoted by $\beta 0$, the estimated coefficients by βi, and the collection of explanatory variables by Xi. The explanatory variable that increases the likelihood of adopting a certain climate change adaptation measure is represented by the positive sign, while the opposite effect is shown by the negative sign. The error term is represented by εi (Bender & Grouven, 1998).

Table 1: Variables and Measurements

Independent Variables	Measurement	Dependent Variables	Measurements
Age	Continuous Variable	Rain gardens	0 = Yes, 1=No
Gender	0 = male, 1 = female	Green roofs	0 = Yes, 1=No
Education	1= household head is literate, 0 = otherwise	Water storage	0 = Yes, 1=No
Education	In years	Green urban spaces	0 = Yes, 1=No
Household Monthly income	Continuous variable		
Household size	Continuous variable measured in numbers of household members		

3.1. Data Collection

The current study relies on primary data collected from residents of Karachi, Lahore, and twin cities. Before the survey, the questionnaire underwent a pilot test to ensure its effectiveness. Trained enumerators were responsible for administering the surveys. The questionnaire covered various aspects, including demographic information such as age, household size, and assets

owned, as well as respondents' perceptions of local weather and climate change, and their readiness to adapt.

A systematic random sampling approach was employed for survey administration. The study areas were divided into sectors and zones, corresponding to urban administrative divisions in the twin cities. A proportional sample of respondents was then contacted from each sector or zone, based on data from the 2017 Census of Pakistan. Respondents were provided with information about the purpose of data collection before participation. The intended sample size was 1000 respondents, with 250 respondents targeted from each city. However, due to financial constraints associated with self-funded research, limitations were encountered during fieldwork implementation.

4. Results and Discussion

This section presents the findings of the study, including the socioeconomic characteristics of the sample, descriptive analysis, and regression results.

1. Descriptive Statistics

Table 2 presents the socioeconomic characteristics of the survey participants. The average age of respondents is 38, with considerable variability observed in the age range. Male respondents constitute approximately 55% of the sample, reflecting the gender distribution in the local culture. On average, respondents have completed 12 years of education, indicating a predominance of college-educated individuals. The average monthly family income reported is 51,000 Pakistani rupees (PKRs). However, the range and standard deviation of reported household income indicate a diverse range of income levels within the sample. The average household size of six aligns with data from the 2017 Population Census for the study areas.

The current research in Pakistan examines the preparedness of citizens in three densely populated cities—Karachi, Lahore and the twin cities—to adapt to climate change. The study focuses on citizens' readiness for four nature-based adaptation options: rain gardens, green alleys, green roofs, and green spaces and infrastructure. While green spaces, green roofs, and green alleys are aimed at addressing rising temperatures, rain gardens are specifically designed to tackle water scarcity resulting from prolonged droughts in the study areas. These adaptation

options were selected following consultations with urban climate change specialists and a thorough review of existing research.

Table 2: Descriptive Statistics of Sample Respondents

Variables	N	Mean	St. Dev.	Min.	Max.
Age (years)	836	38	9.42	18	73
Gender	836	0.51	0.46	0	1
Education (years)	836	12	2.59	0	20
Household monthly income (PKRs)	836	51000	64000	22000	150,000
Household size	836	7	3	1	15

This section presents the findings of a Probit model that investigates the factors influencing citizens' readiness to adopt nature-based adaptation options.

Rain gardens, as a response to water scarcity induced by climate change, are identified as a natural solution. Despite their limited adoption in the research areas, rain gardens have been widely utilized in other contexts. The results indicate a statistically significant positive correlation between age distribution and the likelihood of using rain gardens for climate change adaptation. This finding aligns with previous studies by Ehsan et al. (2022), Nakano et al. (2016), and Ahmed et al. (2023), which suggest that older individuals tend to favor climate change policies. However, it contrasts with the observation made by McCright et al. (2016), who suggest that older individuals generally hold negative views toward pro-climate change initiatives. Results of probit model are given in Table 3.

As anticipated, the variable indicating an unfavorable future climate is found to be significant for rain gardens, suggesting that respondents who perceive a worsening future climate are more likely to utilize rain gardens as an adaptation measure. The margins indicate that respondents with such a perception have a 9% higher likelihood of employing rain gardens for adaptation purposes.

Table 3: Probit Model Estimates of Sample Respondents

Variables	Rain Gardens	Green Roofs	Water Storage	Green Urban Spaces
Gender	-0.263	-7.851*	-0.004	-3.880**
	(0.207)	(0.4.210)	(0.161)	(-2.392)
Age	8.864**	0.134***	0.150***	-0.003
	(4.233)	(4.665)	(5.287)	(0.009)
Education	0.059	-0.048	0.040	0.553***
	(0.043)	(0.030)	(0.033)	(3.475)
Household size	-0.173***	0.019	-0.038	0.157**
	(0.0570)	(0.037)	(0.043)	(2.057)
Homeownership	0.026	-0.101	0.284**	-0.331**
	(0.197)	(0.138)	(0.148)	(0.137)
vehicle in a household	0.145	0.212	0.142***	0.069
	(0.257)	(0.170)	(2.806)	(0.176)
Social network	0.213	-0.016	0.376**	-0.324*
LR chi-square	65.36	46.61	130.55	78.61
Log-likelihood	-373.767	-639.693	-582.442	-624.869
Pseudo- R2	0.08	0.04	0.10	0.059
N	836	836	836	836

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The research findings reveal that households with children are less inclined to establish rain gardens, with families having children being 2% less likely to adopt this adaptation strategy. This reluctance can be attributed to the priority given by families with children to their children's health and education, making it challenging for them to invest in rain garden technology. However, it is worth noting that other studies, such as Viti et al. (2023), have found no discernible impact of having children on individuals' preferences for urban modifications.

Green alleys, which mitigate the effects of extreme temperatures caused by climate change, serve as another nature-based response to environmental shifts. These alleys also offer aesthetic value,

enhancing natural beauty in urban settings. The positive and statistically significant relationship between age distribution and the likelihood of using green alleys as a climate change adaptation suggests that older respondents are more inclined to adopt this measure. Additionally, physically active individuals, such as those who engage in frequent walking, show a higher likelihood of investing in green alleys. This can be attributed to their appreciation for vegetation and its overall environmental benefits, as well as the positive impact of regular physical activity on citizen well-being, as noted by Toselli et al. (2022).

Physically active individuals demonstrate approximately a 10% higher likelihood of investing in green alleys, representing the highest marginal impact in this model. Furthermore, the variable indicating an unfavorable future climate is positively associated with respondents' interest in implementing green alleys as a climate change adaptation measure. A respondent who perceives a worsening future climate has roughly a 6% higher chance of establishing a green alley, indicating that perceived climate risk plays a significant role in driving climate adaptation efforts in the study areas. Although the coefficients for the presence of cars in households and future temperature increase variables are insignificant, their marginal impacts remain significant. The adoption of green alleyways as an adaptation strategy is influenced by the presence of a car in the household and the perception of future temperature rise by nearly 5%.

It presents the binary logistic estimates concerning the factors influencing citizens' readiness to adapt, focusing on green roofs as an adaptation option. Similar to green alleys, green roofs aim to mitigate the impacts of extreme temperatures brought on by climate change. The findings illustrate the potential of green roofs as a climate change adaptation strategy.

As anticipated, home ownership is positively associated with the likelihood of investing in green roofs. This implies that homeowners are more inclined to invest in environmentally friendly solutions compared to tenants, who may face restrictions in making modifications to their properties. Specifically, homeowners are approximately 6% more likely to invest in green roofs, according to the marginal impact analysis. These results align with Teotónio et al.'s (2022) research, which suggests that homeowners exhibit a greater willingness to pay for environmentally friendly solutions in their homes compared to tenants.

Moreover, the presence of cars in households significantly influences the adoption of green roofs, indicating that households with cars are more likely to invest in this adaptation measure.

This variable contributes significantly, with a 15% marginal impact on the probability of utilizing green roofs as an adaptation strategy in the study areas.

5. Conclusion and Policy Implications

Pakistan is highly vulnerable to the impacts of climate change, with various regions and communities experiencing adverse effects. This study delves into the readiness of the population in four major Pakistani cities—Karachi, Rawalpindi, Islamabad, and Rawalpindi—to adapt to climate change through nature-based adaptation options. Specifically, the study examines the factors influencing individuals' decisions to invest in and implement nature-based urban climate change adaptation measures. Utilizing data from a primary survey and employing the binomial logistic regression technique, the study draws key conclusions and discusses their policy implications.

The findings suggest that older respondents are more inclined to adopt rain gardens as a climate change adaptation measure. Similarly, individuals are more likely to embrace rain gardens if they anticipate a decrease in future rainfall. Furthermore, the willingness to install green roofs is higher among those who perceive a reduction in rainfall. These results underscore the importance of citizens' experiences with changing weather patterns, their outlook on future climate conditions, and their perceptions of risk in influencing the adoption of rain gardens. From a policy perspective, these insights highlight the potential for specific socio-demographic groups to spearhead climate change adaptation efforts.

Moreover, the study reveals that households with children exhibit a positive inclination towards deploying green spaces but display reluctance towards adopting rain gardens as an adaptation strategy. While it may seem that households with children are hesitant to adopt, a nuanced interpretation suggests that these households are willing to embrace adaptation measures, albeit opting for less costly modifications. This underscores the significance of household size and composition in shaping the adoption of climate adaptation technologies, emphasizing the need to consider these factors when formulating policies.

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