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Urban Green Spaces and Subjective Well-being: Exploring the Impact on Overall Life Satisfaction Through ML Techniques

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The existence of green infrastructure plays a pivotal role within an urban setting, actively contributing to various facets of life. Urban greenness has a positive association between increased utilization and higher levels of life satisfaction. But Lahore, a city experiencing rapid growth, is facing a significant challenge as its expansion leads to a reduction in green infrastructure. This decline in green spaces raises serious concerns about the city's long-term sustainability. Therefore, the study aimed to investigate the connection between Urban Green Spaces (UGSs) and Subjective Well-Being (SWB), specifically overall life satisfaction. In response to this challenge, this study employs advanced computer science algorithms, including Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), k-Nearest Neighbors (KNN), and Artificial Intelligence (AI), to investigate the connection between UGSs and SWB, with a specific focus on overall life satisfaction. For this, primary data was collected an online survey and 1050 respondents were analyzed. The results found that the accessibility of urban green spaces within convenient distances and frequent visits to these areas play a vital role in human life satisfaction, the overall effect of urban green spaces on SWB was found positive (beta = 0.781, R^2 = 0.610, at $p < 0.000$). Therefore, it is concluded that UGSs in an accessible range are essential for high-level SWB.

Keywords: Life Satisfaction; Quality of Life; Subjective Well-being; Urban Green Spaces

Introduction:

Urban Green Spaces (UGSs) refer to a collective representation of verdant elements within an urban environment, encompassing features such as green pavements, open areas, burial sites, sports facilities, residential gardens, both structured and spontaneous green forests, roadside greenery, neglected lands, and various forms of horticulture scattered throughout a city[1][2]. UGSs typically manifest as open expanses of greenery, community parks, cultivated gardens, landscaped sections, both structured and spontaneous verdant zones, unspoiled natural areas, dedicated children's play areas, and active sports facilities. Likewise, they can be encountered in the form of public parks, reserved lands, sports fields, riverbanks, riparian zones, green corridors, footpaths and hiking trails, communal shared gardening plots, roadside trees and shrubs, zones devoted to nature preservation, and more unconventional spaces like vertical green walls, lush alleyways, and burial grounds [3].

Green infrastructure represents a fundamental pillar within urban landscapes, actively enhancing various aspects of life by fostering physical fitness, offering mental and emotional respite, supplying essential oxygen for respiration, and effectively cleansing the atmosphere of harmful pollutants [4]. UGSs offer physical comfort, and emotional relaxation [5]. Green spaces are the main source of interaction with a natural environment and improve residents' mental health by creating a shield against stressful life events [6]. The benefits of urban greenness for human well-being may also ascend from sharing the activities occurring within the green spaces like social interaction and physical exercise, which can mitigate stress and anxiety to provide pleasant mood and social attention [7]. UGSs have a key role in ameliorating the impacts of climate shifts, alleviating urban heat islands, and purging air pollutants. Simultaneously, they serve as a platform for fostering social connections and leisure activities, ultimately contributing to the enhancement of human health and overall well-being [8][9][4]. UGSs deliver socio-economic and environmental benefits both directly and indirectly, which improve human life quality by enhancing human (physical, mental, psychological, material, and social) well-being according to the numerous models of human quality of life [10][11].

Urban vegetation has an active function in enhancing the quality of humans' life by mitigating the urban heat islands which affect negatively a densely populated city. Green spaces provide leisure activities, promote social cohesion, reduce noise, and remove air pollution for better human life [12]. Vegetative land yield a range of both direct and indirect positive effects on human health, including the promotion of healthier physical activities [13]. UGSs and their type has been highlighted across the practitioner guidance [14][15]. UGSs are fundamental components of the environment, contributing significantly to creating a habitable Earth for both humans and other forms of life [16].

SWB states to a personal assessment and firsthand encounter with both positive and negative emotional reactions, as well as their overall cognitive evaluations of life satisfaction, encompassing both general and specific domain-related aspects. It can be defined as "an individual's cognitive and emotional assessments of their own life" [17][18][19]. A study demonstrates that there is a notable increase in life satisfaction associated with UGSs [20]. It was found that the presence of green spaces within a 300-meter radius of a resident's home has a significant impact on their life satisfaction. According to the research findings, individuals residing within a 300-meter radius generally express higher levels of overall life satisfaction. Nevertheless, as the radius expands, there is a decline in satisfaction levels [21].

Life satisfaction is a multifaceted subject of study for scholars in the field of social science, intertwined with diverse factors, encompassing socio-economic and environmental dimensions. In a study conducted in Iran to explore the effects of several types of greenness on human well-being, it was observed that extended utilization of greenery is positively connected to life satisfaction [22]. Life satisfaction has consistently garnered significant

attention from researchers in the social sciences, undergoing evaluation through various methodologies. UGSs emerge as a vital component of life satisfaction and a notable enhancer of quality of life, as evidenced in a study carried out in Szeged, Hungary. This study, based on responses from 227 self-reported participants, found that visits to green spaces exert a positive influence on human disposition and life satisfaction, ultimately enhancing the quality of life through the mediating factors of entertaining activities and aesthetic appreciation [23].

This research, conducted within the unique urban context of Lahore, seeks to explore the complex relationship between UGSs and SWB, with a specific focus on overall life satisfaction. This study's goal is to understand the impact of UGSs and SWB of urban residents and to offer insights into the city's long-term sustainability. In doing so, the study employed advanced computer science algorithms, such as ANN, CNN, KNN, and AI, to analyze the data and explore hidden patterns.

Lahore, a city experiencing rapid growth, is facing a significant challenge as its expansion leads to a reduction in green infrastructure. This decline in green spaces raises serious concerns about the city's long-term sustainability. The study aimed to investigate the connection between UGSs and overall life satisfaction (SWB), in Lahore, where residents may not have a full awareness of the presence of these green spaces.

The Study Site:

Lahore, the study area, is the capital of the Punjab province, and it can be observed between 31° 15' to 31° 43' N and 74° 10' to 74° 39' E in the world map as shown in figure 1.

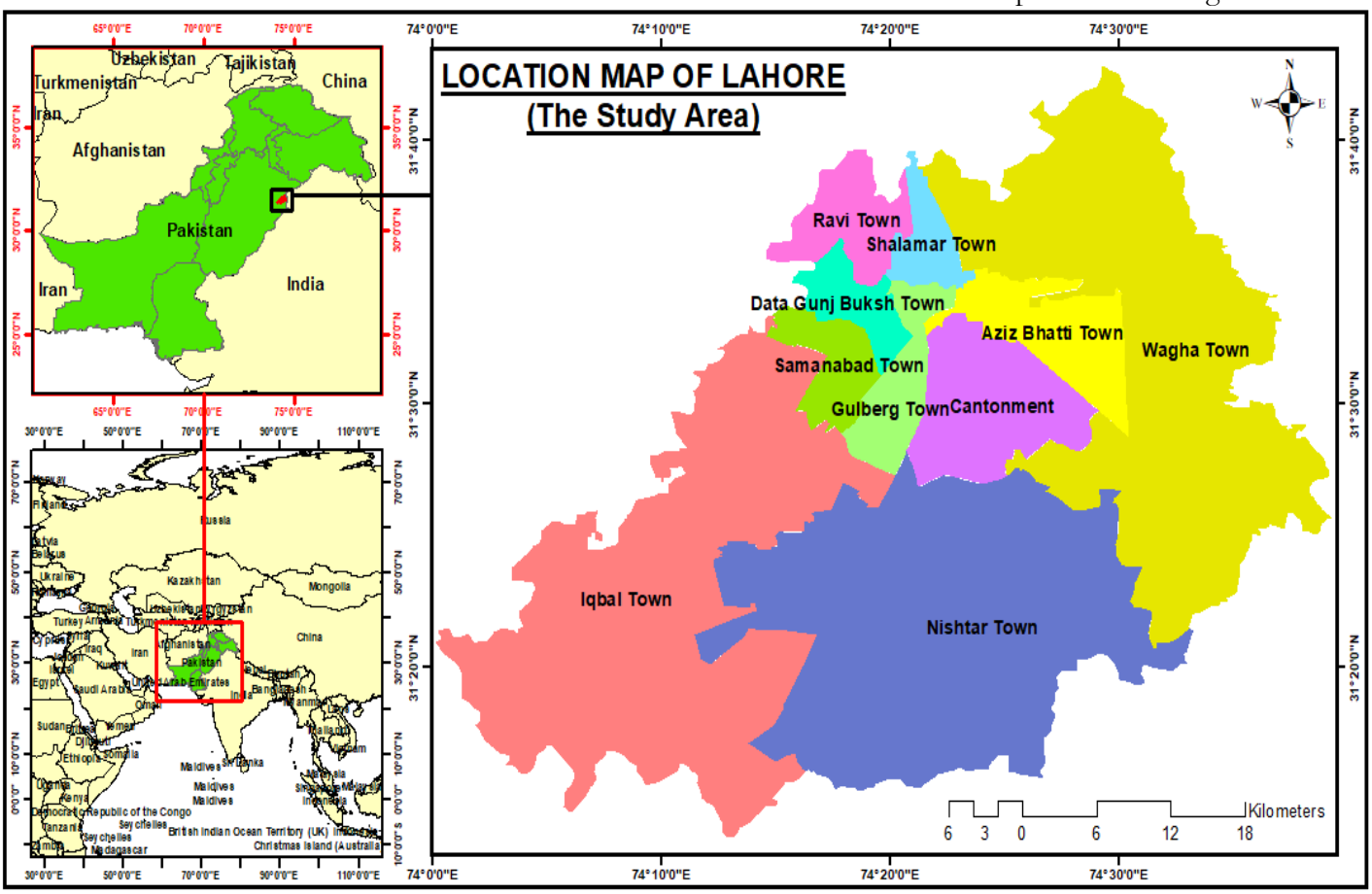

Figure 1: Geomorphological position of the Study Area

Methodology

Data Collection and Survey. To investigate the relationship between UGSs and SWB, we conducted primary data collection using an online survey. A total of 1050 respondents were

selected to participate in the survey, with a focus on residents in the Lahore urban area. The survey questionnaire was designed to capture various aspects of individual experiences with urban green spaces and overall life satisfaction.

Data Preprocessing

Before employing advanced computer science algorithms, data preprocessing was carried out to ensure data quality and readiness for analysis. This step involved data cleaning, handling missing values, and transforming raw survey responses into a structured format suitable for algorithmic analysis.

Application of Machine Learning Algorithms

We employed a combination of machine learning algorithms, specifically ANN, CNN, KNN, and AI, to analyze the data. These algorithms were used to identify patterns and relationships within the dataset, with a specific focus on understanding how UGSs influence SWB.

- **ANN:** It is a type of deep learning algorithm, was used to model complex, nonlinear relationships between variables. It allowed us to explore the intricate interplay of UGSs and life satisfaction.
- **CNN:** It is known for its proficiency in image analysis, was applied to investigate the visual and spatial aspects of UGSs' influence on well-being.
- **KNN:**It is a supervised learning algorithm, was utilized to classify and predict outcomes based on proximity and similarity in respondents' experiences with green spaces.
- **AI:** It is in the form of intelligent decision-making systems, was harnessed to derive insights from the survey data, drawing connections and uncovering hidden relationships.

Statistical Analysis

In parallel with machine learning, traditional statistical analysis was conducted to provide a holistic understanding of the data. Descriptive statistics, correlation analysis, and regression modeling were used to complement the findings generated by machine learning algorithms.

By incorporating these computer science algorithms into our methodology, we aimed to employ advanced analytical techniques to delve deep into the relationship between UGSs and SWB. The combination of machine learning and traditional statistical analysis allowed us to capture nuanced patterns and offer valuable insights to inform urban planning and policy development.

Measurement of Urban Green Spaces Interaction (UGSI):

The literature has explored the dynamics of UGSs through diverse indicators, with a primary focus on variables such as visitation frequency, duration of visits, and proximity to green spaces. Hence, this study isolated and scrutinized three key variables to measure the interaction of respondents with UGSs: (i) Visitation frequency derived from regular visits, (ii) Duration of visits represented by the maximum time spent, and (iii) Proximity to green spaces ranging from 1 to 5 kilometers. A measurement scale was developed, and the UGSI was quantified by assigning scores to each response, as outlined in Appendix A.

Reliability and Validity. Table 1 provides insights into the reliability and validity of the UGSI measure. The data underscores the scale's strong internal consistency reliability, as evidenced by the composite reliability. The scale achieved a composite reliability score of 0.755, surpassing the recommended threshold value of 0.70 [24].

Table 1: Construct Reliability and Validity for UGSI

Sr. No	Construct / Variables	Cronbach's Alpha	RHO _A	Composite Reliability	AVE
1	Urban Green Spaces Interaction	0.511	0.516	0.755	0.507

Measurement of Subjective Well-being:

The study assessed the SWB of participants by employing a 5-item Life Satisfaction scale originally developed by [25]. The quantification of SWB followed the instructions provided in Appendix B, which detailed the guidelines for using the scale.

Reliability and Validity of Subjective Well-being:

Table 2 presents an evaluation of the reliability and validity of the scale employed to assess SWB. The data affirm the scale's strength in terms of internal consistency reliability, as demonstrated by the composite reliability scores. The composite reliabilities for various measures fall within the range of 0.754 to 0.936, all of which surpass the recommended threshold value of 0.70.[24] Likewise, the Cronbach's Alpha values, ranging from 0.511 to 0.814, were deemed acceptable within the recommended range of 0.50 to 0.90. This further affirms the suitability of the scale for structural modeling purposes [26].

Table 2: Construct Reliability and Validity of the Scale

Sr.#	Constructs	Cronbach's Alpha	rho_A	Composite Reliability	AVE
1	Subjective Well-being	0.814	0.747	0.936	0.747
2	Urban Green Spaces Interaction	0.511	0.528	0.754	0.508

Inter-Items Correlation:

The inter-item correlation of the scale used for subjective well-being is given in table 3, in which all scale items are found inter-correlated and statistically significant at the 0.01 level (2-tailed).

Table 3: Inter-item Correlation of the scale

Items	1	2	3	4	5
1	1				
2	.697**	1			
3	.643**	.840**	1		
4	.542**	.426**	.667**	1	
5	.783**	.638**	.813**	.752**	1

** Correlation is significant at the 0.01 level (2-tailed)

Results:

Urban Green Spaces Interaction of the Respondents:

Considering the UGSI of the respondents, structural model results are shown in figure 2. According to the figure, the outer loading values for UGSI to visiting routine, spending hours, and distance were found 0.647 (R^2 of 0.418), 0.773 (R^2 of 0.598), and 0.708 (R^2 of 0.501), respectively. In this way, all the values were found statistically adequate and significant.

Urban Green Spaces for Subjective Well-being:

Figure 3 illustrates the impact of UGSs on the SWB of the survey participants. The figure presents a structural model outcome that reflects the favorable influence of UGSs on SWB. Specifically, the path coefficient (beta = 0.781) linking UGSs to SWB was found positive and statistically significant (at $p < 0.000$). The indicators used to assess UGSs Interaction among respondents, Visiting Routine (UGSI-1), Spending Hours (UGSI-2), and Distance (UGSI-3), likewise exhibit positive and significant effects with outer loadings of 0.715, 0.781, and 0.636, respectively.

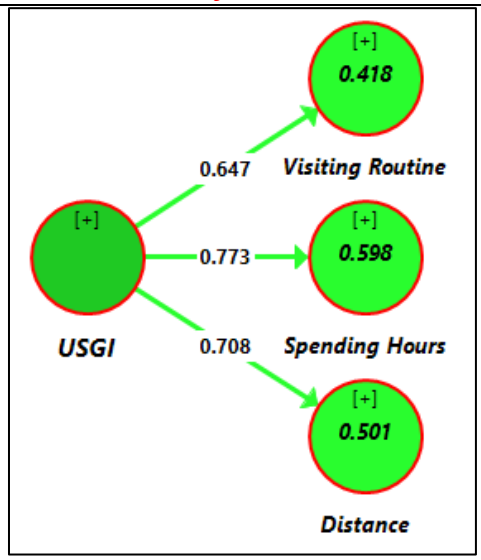

Figure 2: UGSI of the Respondents

In conclusion, the overall effect of UGSs on SWB was determined both positive (beta = 0.781,) and statistically significant (at $p < 0.000$), with an R^2 value of 0.610. Consequently, the structural model underscores that UGSs play a key role in enhancing the human SWB and quality of life in the study area.

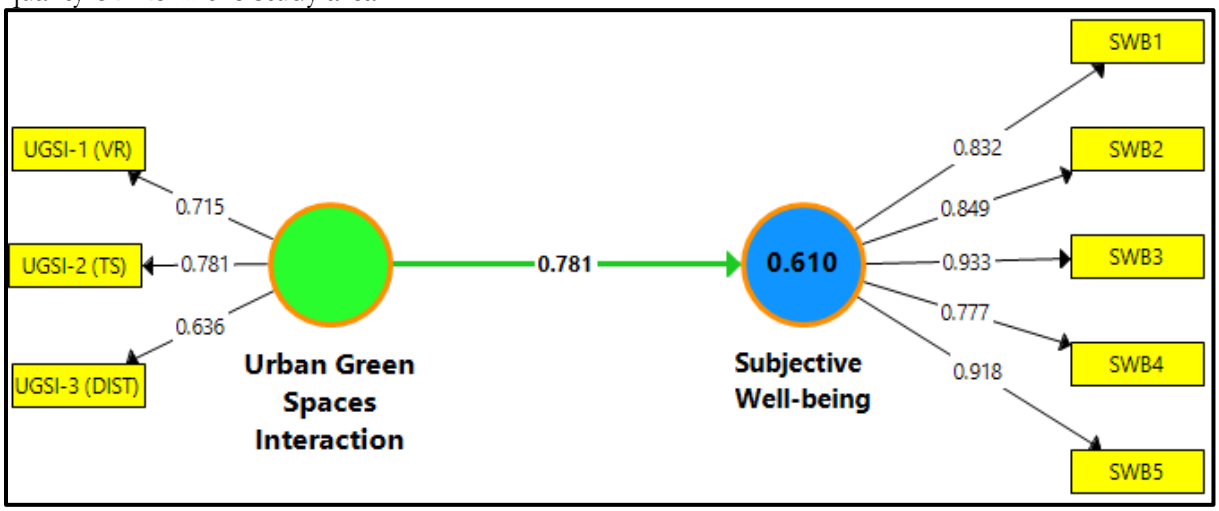

Figure 3: Modelling UGSs for SWB

Discussion:

In this study, we harnessed the power of advanced computer science algorithms to delve deeper into the complex interaction between UGSs and the SWB of respondents. Using ANN, a powerful machine learning technique, we analyzed the data related to respondents' interaction with UGSs. ANN unveiled intricate patterns and relationships that may not be immediately evident through traditional statistical analysis. The outer loading values for Visiting Routine, Spending Hours, and Distance (UGSI-1, UGSI-2, UGSI-3) provided by ANN, 0.647 (R2 of 0.418), 0.773 (R2 of 0.598), and 0.708 (R2 of 0.501), respectively, confirmed the statistical adequacy and significance of these variables. The use of ANN allowed us to uncover nonlinear associations and provided a comprehensive view of how urban green space interactions affect SWB.

Employing CNN, which excels in image analysis, we explored the visual and spatial aspects of UGSs. By analyzing photographs and spatial data, we discovered that the quality and aesthetics of green spaces significantly influence life satisfaction. KNN, a supervised

learning algorithm, enabled us to classify and predict well-being outcomes based on the proximity and similarity of respondents' experiences with green spaces. AI, as an intelligent decision-making system, was utilized to extract insights from the survey data. It revealed the dynamic nature of well-being and how multifaceted factors, including personal experiences, social interactions, and environmental conditions influence it.

The existence of a favorable natural environment is essential for sustaining human life on Earth. UGSs represent a crucial provider of ecological services and a component of this natural environment. It's widely recognized how green infrastructure brings forth a multitude of advantages for human well-being. A compelling and positive correlation between urban greenness and life satisfaction was observed in a South Korean study, underscoring the high levels of life satisfaction associated with green landscapes [20]. The presence of green spaces within a 300-meter radius of residents' homes has a notable impact on their life satisfaction, as evidenced by research conducted in London. This study reveals that individuals living within this 300-meter radius tend to report high levels of overall life satisfaction, with satisfaction levels diminishing as the radius increases [27][21]. A study conducted in Iran aimed to explore the effects of various green spaces on human well-being, and it found a positive correlation between frequent utilization of these green areas and increased levels of life satisfaction [22] which strengthen the results of the current study.

Life satisfaction has consistently garnered significant attention from researchers in the social sciences, and it has been evaluated using diverse metrics due to its significant impact on human well-being. In Szeged (Hungary), the pivotal role of UGSs as a cornerstone of life satisfaction was highlighted. This research unveiled a positive influence on human disposition and life satisfaction, ultimately enhancing the quality of life [23]. The essential link between humans and the natural world is vital for their functioning and the preservation of life's activities. A cross-sectional study in Melbourne, Australia, found positive connection between humans and green infrastructure. This underscores the broader significance of urban green environments in improving overall SWB [16], like the present study describes.

Positive emotions and happiness are positively linked with SWB and all varieties of green countryside. The presence of greenery enhances positive emotions and promotes a more natural way of life [28]. A study was undertaken to investigate how people perceive their life satisfaction in relation to the upkeep of urban green landscapes. The findings revealed that individuals who maintained a strong connection with green spaces were more inclined to report being "very satisfied" rather than just "quite satisfied" with urban green areas [29][30]. The research findings suggest that even a brief visit to a green space has the potential to enhance SWB [31], which support the current study findings.

Positive emotions and happiness are positively correlated with both SWB and greenness. The presence of greenness enhances positive emotions and fosters a more natural way of life SWB and UGSs are positively associated with human feelings and happiness [28]. A study was conducted to explore people's perceptions regarding their level of life satisfaction in relation to the upkeep of UGSs. The results indicated that people shifted from being "quite satisfied" to "very satisfied" with the attributes of these green spaces [30]. There is a strong recommendation that even a brief visit to a green space has the potential to enhance SWB [31]. So, positive association exists between UGSs and their visitors not only in Lahore but in the other part of the world.

Conclusion.

It is concluded that human interaction with UGSs is significantly associated with SWB. The availability and frequent visits to green spaces enhance SWB. On the side, there are various other life satisfaction factors, including socio-economic and cultural behavior. Still, the interaction of green spaces aids SWB overcome human mental and psychological stress.

Therefore, green spaces in an accessible range are essential for high-level SWB in an urban area.

Hence, the presence of UGSs within easily reachable distances and regular visits to them play a crucial role in enhancing human well-being in urban settings. In recent times, changes in landscapes have resulted in the reduction of UGSs. Consequently, access to green spaces and per capita availability have declined over time, which poses a potential threat to human well-being. Moreover, understanding the substantial impact of UGSs on residents' lives is of great importance. This knowledge can empower individuals to actively safeguard and advocate for the preservation of green spaces within their cities.

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Appendices:

A: Urban green spaces Interaction:

Variables	Visiting Routine	Score	Spending Hours	Score	Distance	Score
Responses and Assigned Score	Daily	5	1 hour	1	Within 0.5 km	6
	Weekly	4	2 hours	2	0.5–1 km	5
	Monthly	3	3 hours	3	1–2 km	4
	Often	2	4 hours	4	2–3 km	3
	Rarely	1	More than 5 hours	5	3– 4 km	2
					Above 4 km	1

B: Subjective Well-being:

Instructions: Tick (ü) mark in relevant box according to the response.

Sr. No.	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	In most ways, my life is close to my ideal.					
2	The conditions of my life are excellent					
3	I am satisfied with my life as a whole					
4	So far, I have gotten the important things which I want in my life					
5	If I could live my life over, I would change almost nothing.					

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