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Spatial Distribution of Urban Forest and Its Linkages with Urban Environment in Faisalabad City

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Abstract

Background/Objective: Faisalabad, a major industrial hub in Pakistan, has experienced rapid urbanization and industrial growth, leading to significant environmental challenges, particularly air pollution. The city's urban forests are crucial in mitigating these issues by providing various ecosystem services, including air quality improvement and reducing particulate matter (PM2.5). The main objective of our study was to investigate the spatial distribution of urban forests, spatial mapping of PM 2.5, and the effects of improving urban forests on the overall air and atmosphere of Faisalabad city. **Methodology:** Our study uses field data, satellite imagery, and inverse distance-weighted analysis to highlight the ecological and social benefits, emphasizing the need for sustainable management. **Results:** We found that urban forests provide a wide range of ecosystem services, such as improving air quality by absorbing pollutants and releasing oxygen, reducing the urban heat island effect, and mitigating stormwater runoff, offering recreational spaces for people to engage in physical activities, relax, and connect with nature. The spatial distribution of urban forests plays a crucial role in their effectiveness in reducing PM2.5. Different tree planting distribution plans can significantly affect PM2.5 removal efficiency. The study in Faisalabad found that the spatial distribution of urban forests correlates with the reduction of PM2.5, with higher concentrations of trees leading to greater reductions in particulate matter. Urban forests fostered a sense of community and provided gathering spaces for social interactions, events, and cultural activities. **Conclusion:** The presence of a healthy urban forest can increase property values, attract businesses, and contribute to tourism and local economies as it is essential to manage and preserve urban forests responsibly to maintain these valuable benefits. The key findings suggest that urban forests in Faisalabad City, and urban areas in general, have a significant positive impact on reducing PM2.5 concentrations. The spatial distribution of urban forests is a critical factor that influences their effectiveness. Integrated approaches using remote sensing, machine learning, and spatial analysis can help optimize the placement and management of urban forests to enhance their air quality benefits.

Subject Areas

Environmental Sciences

Keywords

Spatial Distributions, Urban Forest, Planning, Air Quality, Trees

1. Introduction

Faisalabad Forest division was established in 1947 and comprises the revenue jurisdiction of two Districts namely Faisalabad and Toba Tek Singh and consists of compact plantation, roadside, canal side and rail side plantations. The area-wise distribution of the plantation includes 18137.86 acres of compact plantation, 2919.6 K.M of canal side, 447.70 K.M of roadside plantation and 325 K.M of rail side plantation. Faisalabad forest division consists of 4 Number Sub Divisions namely Faisalabad, Toba Tek Singh, Kamalia, Jaranwala and two Forest Ranges namely Gojra & Samundari. 91,630 plants tress divided into two canal systems Rakh Branch and Dijkot Branch situated into Gatwala and Darbar Sufi Barkat Ali sahib [1] [2].

To develop a sustainable urban forestry model, trees are planted and managed along the motorways, highways, streets, municipal parks, gardens and reserves, schools, colleges, universities, hospitals and all other public places where there is some space available for tree planting [3]. It is very difficult to increase forest cover in Pakistan by conventional methods. Additionally, Urban forests offer recreational spaces, enhance biodiversity by providing habitats for wildlife, and help manage stormwater runoff [4]. The presence of green spaces can positively impact the overall well-being of city residents by providing opportunities for relaxation and physical activity. To better understand the spatial distribution and linkages, comprehensive studies are conducted, analyzing factors such as the distribution of green spaces, tree species diversity, proximity to residential areas, and their overall ecological importance in Faisalabad city [5].

Urban forests have an essential influence on the relations between urban populations and nature. However, urban and infrastructural expansion causes dramatic changes in numerous urban landscapes. Urban demand for the construction of roads, railroads and other infrastructure in city development is facing growing pressure on supporting ecological services, especially on biodiversity. The monitoring of global vegetation with the help of SRS (satellite remote-sensing) data is convenient for improving our knowledge concerning spatial distribution and characteristics of vegetation [6]. The study was conducted at the Gatwala Forest Park, a protected/game reserve area located in the heart of Pakistan's third largest city Faisalabad, in the province of Punjab. This park spans over an area of 53 hectares. Floristic data for ground flora was randomly collected at the site. The survey resulted in the identification of 46 species belonging to various plant families. A study on the extent of the establishment of roadside plantations was carried out at Canal Road Faisalabad in 2000 [7]. The study aimed to find possible solutions to degraded conditions of canal roadside plantations through field survey (site survey) and social survey (evaluation of public perception). It was also intended to be helpful in future planning involving plantations in the cities, particularly along roads. It was concluded that for sustainable roadside plantations, future planning should be carried out, taking into account, public perception [8]. Urbanization is the shift of population from rural areas to cities with high population density and built infrastructure. Over half of the human population now lives in cities, and it is estimated that two-thirds of the world's population will be urban by 2050. In Faisalabad, rapid urbanization has led to increased air pollution and habitat losses. Urbanization has led to better access to infrastructure, including various types of technology, transportation, communication, educational and medical facilities, and better jobs [9].

Green Infrastructure (GI), with both its above-and below-ground components, can help cities adapt to climate challenges and contribute to sustainable urban development. Trees and forests in and around cities, which dominate GI, can contribute to climate change mitigation directly by sequestering carbon and indirectly by saving energy and reducing urban heat island effects (e.g., the Chicago Urban Forest Climate Project). Tree planting has been globally embraced as a green solution to solve urban environmental problems (eg, Million Trees NYC, Beijing Tree Planting Campaign) [10]. Likewise, urban soil, as an integral element of GI, is a significant carbon sink and can contribute to adaptation strategies (eg, by controlling flooding and excess heat). However, urban and infrastructural expansion causes dramatic changes in numerous urban landscapes. The monitoring of global vegetation with the help of SRS (satellite remote=sensing) data is convenient for improving our knowledge concerning spatial distribution and characteristics of vegetation [11].

The unplanned development of cities creates several problems, including deterioration of the environment, an unbalanced ecosystem and poor community interrelation, such as the city of Faisalabad. Furthermore, shifting rural communities to urban areas can damage urban forestry by converting natural habitats into concrete heat islands. In this scenario, for the improvement of urban environmental quality, people's perceptions and opinions could be helpful for better implementation of urban management decisions [12]. The objectives of this study were to examine the perception of urban dwellers towards urban trees and to explore the variation in opinion for managing the diverse types of urban spaces. The present study was conducted in 3rd most populous city of Pakistan i.e., Faisalabad. In addition, the current study will explore the spatial distribution of urban forest in Faisalabad, spatial mapping of PM 2.5 in Faisalabad city and linkages between urban forest and air PM 2.5 pollutants in Faisalabad.

2. Material and Methods

2.1. Study Area

Faisalabad is the third largest city of Pakistan and the second largest city in Punjab province, according to World atlas it lies in the gratitude (73 - 74˚E, 30 - 31.15˚N) and is located at an elevation of 186 m above sea level. According to a recent survey, it covers an area of 213 km^2 and is occupied by 3.22 million people. It is the most important urban city and is considered a major industrial centre. Due to heavy industries, it lies in the ten most polluted cities in the world, thus it has very poor air quality. It is famous for textile mills, chemical industries, paper printing, marble factories and agriculture equipment, which is the main source of air pollution in this area. Considering the significance this city holds in terms of economic, cultural and industrial growth along with being international access to the world, it is critical to determine the sustainability of the city in terms of infrastructure and the massive population it exists. It is a metropolitan city so a large number of people moving towards here for job and study purposes. Due to the continuously increasing population, its environment is getting worse.

The climate of Faisalabad is considered a semi-arid climate according to the Koppen-Geiger classification with humid and very hot summers and cool dry winters. The temperature of the city rises to as high as 39˚C - 41˚C, in the summer months of May to June, whereas it falls to the average lowest of 4˚C - 6˚C in the winter months of December to January. Faisalabad city is not spread over a large geographical area and does not have topographical features. It lies in plain areas of central Punjab and due to its industrial significance it has a vast road network, so this study will be conducted on land use bases, especially alongside the roads. It is not a planned city so there is no special distribution of lands to colonies, industries, green spaces and roads. Study areas have all kinds of roads primary, secondary and tertiary. Primary roads are those major roads that connect the city to all neighbouring cities, secondary and tertiary roads have no significant importance because all major industries and traffic rush exist in primary roads.

2.2. Area of Faisalabad/Geographical Location

The total area of the Faisalabad is 58.56 square kilometer. It lies between the long direction 73.0 and 74.0 east, latitude 30.0 and 31.50 north at an elevation of 605 feet above sea level. There is no natural boundary between Faisalabad and adjoining districts. River Chenab moves about 30 km in the North West while river Ravi is about 40 km off the Great Town in the Southeast. The earth of Faisalabad is generally fertile. Faisalabad is all around on the north and west by Hafizabad, Jhang and Toba Tek Singh districts separately in the east, it touches Sheikhupura and in the south, it is limited by Ravi river, across which lies Okara. Major crops found in Faisalabad are sugarcane, fodder, wheat, rice, barley, and bajra.

2.3. Faisalabad Air Pollution

Faisalabad is located in Punjab Pakistan, the 3rd most populous city in the country. The city is growing day by day in population so the economic needs also increasing. Faisalabad is the industrial hub of Pakistan. Due to the growing population, the need for transport vehicles also increasing so a lot of road vehicles, as they are public or private produce toxic pollutants in the air, polluting the air of the city. Faisalabad recorded unhealthy air quality, on air quality index currently with 45.8 hg/m^3 PM2.5 value and in 2019 the average value of PM2.5 recorded as 104.6 microgram per cubic meter, which is 4th in worldwide rank and 2nd in the country. Recent data of 6 June 2021 the air pollution in Faisalabad is NO_2 is 2 micrograms per cubic meter, CO 222 micrograms per cubic meter PM2.5 46 micrograms per cubic meter (unhealthy), PM10 88 micrograms per cubic meter (moderate) PM03 95 microgram per cubic meter (good).

2.4. Field Data

The field of small air quality sensors is of growing interest within the scientific community, especially because this new technology is liable to improve air pollutant monitoring as well as be used for personal exposure quantification. In this era of modern technology, a lot of portable devices are present that are used to collect primary data, for example 1405 TEOM Continuous Ambient Air Monitor and TSI Dust Trak Aerosol Monitor these three sensors (AE51, Cairclip and Canarin) were also used to measure the concentration of different particles like O_3, PM, NO_2. Faisalabad is not very advanced in modern technology and equipment to collect atmospheric particulate matter data. This study needs to collect data in the field, so a portable mater TES-5321/5322/5323/5325 PM2.5 Air Quality Monitor was used to collect particulate matter (PM2.5) data on ground level in Faisalabad city. A field survey has been done to collect the data alongside the major roads.

2.5. Data Collection

Data collection is a major task in any research perspective. Data should be accurate to obtain accuracy in results. In this study, both kinds of data were required primary data and secondary data. Primary data can be collected through air quality measuring stations, by using devices, questionnaires and secondary data can be collected and downloaded from different websites and satellites.

2.6. Satellite Data

Current advances in air pollution sensor technologies could provide further information about nearby sources, sustain the siting of regulatory monitoring stations, and advance our knowledge of the finer-scale spatiotemporal variation of ambient air pollutants. Sensors are now being developed that are much smaller and lower cost than customary ambient air monitoring systems and are proficient in being deployed as a network to provide greater coverage of a given area. The distribution of fine particulate matter (PM2.5) in space and time, even far from ground monitoring sites, is an important acquaintance science contribution to epidemiologic analyses of PM2.5 in different aspects. Satellite data sources are considered as secondary data sources. This study also includes a proportion of particulate matter data on a temporal basis and atmospheric particulate matter PM2.5.

2.7. Sampling Sites

Faisalabad is a very large city, and particulate matter PM2.5 data was randomly collected alongside all primary roads of the study area. A random sampling technique was used to collect data from the urban land uses every month. The data was collected by using TES-5321/5322/5323/5325 PM2.5 Air Quality Meter. To obtain the spatial location of these sample points a handheld device global positioning system (GPS) was used to mark the objectives measurement. Geographic Information System (GIS) 10.5 software was used to construct a map of the study area and Google Earth Explorer software was used to locate the sample points' locations (See Figure 1 and Figure 2).

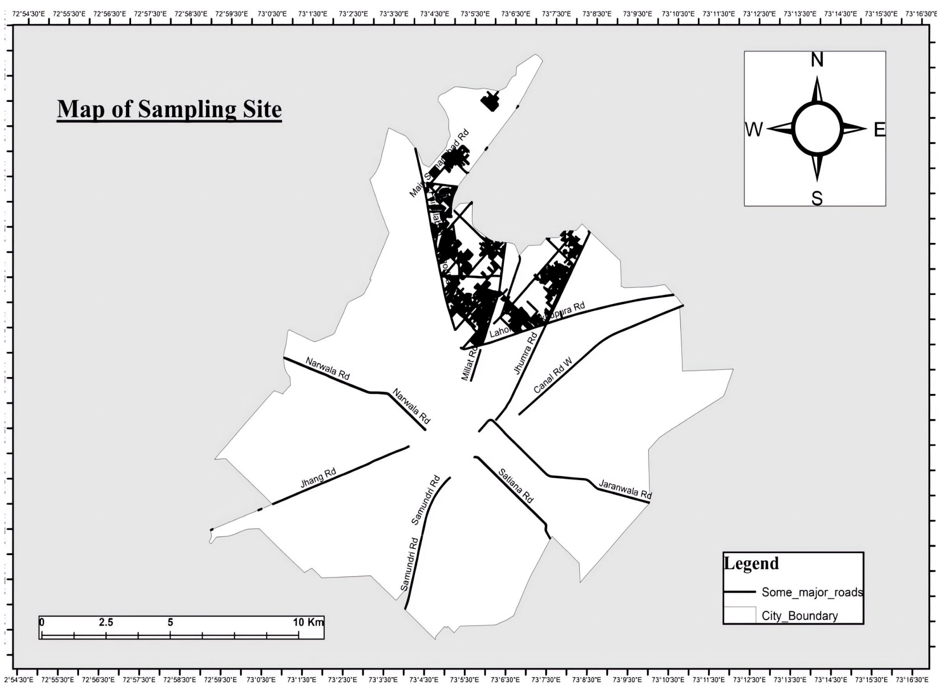

Figure 1. Map of sampling sites.

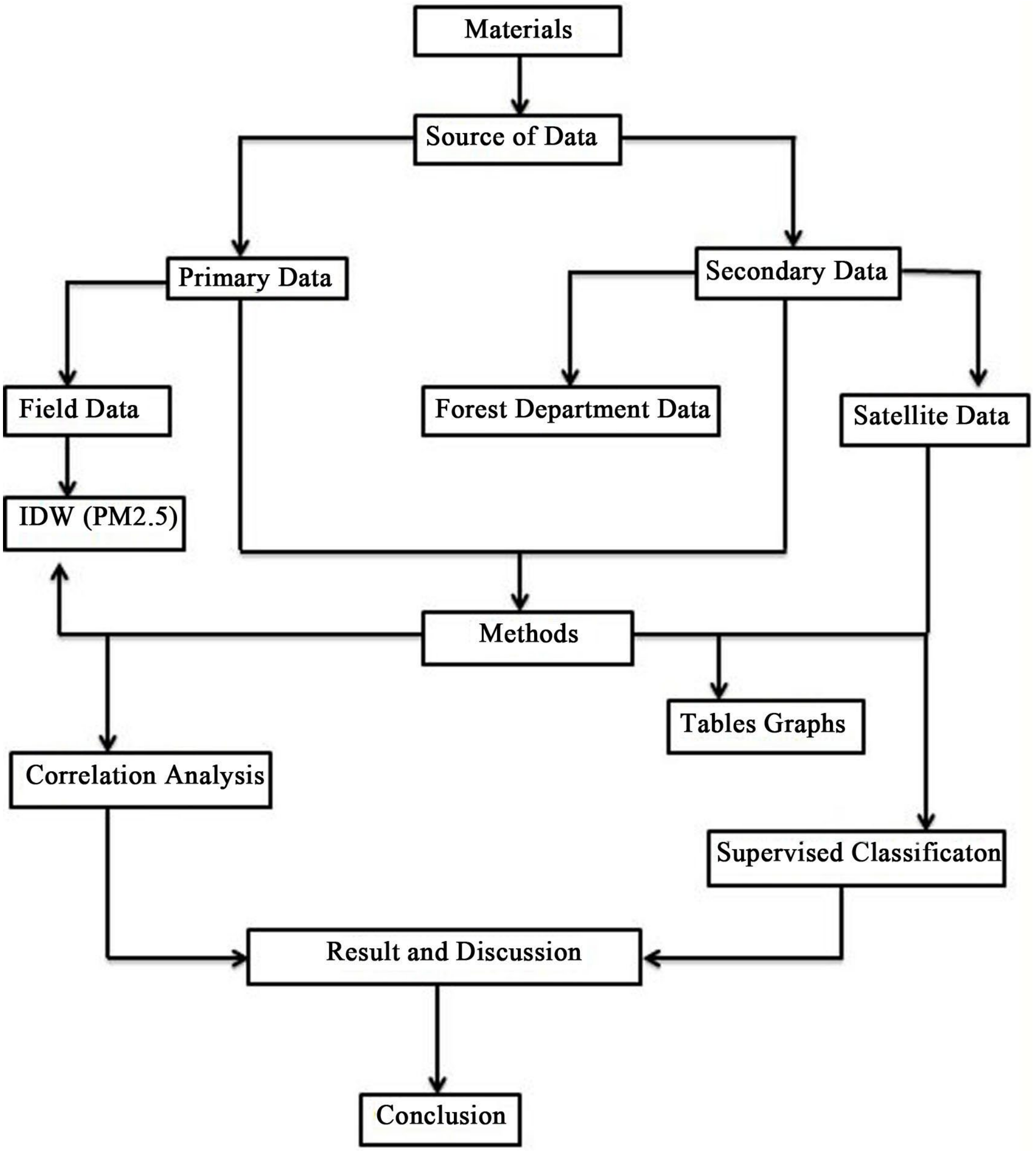

Figure 2. Flow chart.

3. Results and Discussion

3.1. Inverse Distance Weighted (IDW)

In geographical analysis and geostatistics, inverse distance weighted (IDW) analysis is a typical interpolation method. It is a technique for estimating values at unknown locations based on measurements taken at neighbouring locations. The method gives known values weights that are inversely proportionate to their distances from the unknown location, hence the term "Inverse Distance Weighted." IDW is frequently used to estimate values such as pollution levels, temperature, or other geographically distributed data in a variety of domains, including environmental sciences, geography, and remote sensing. The method can aid in the creation of continuous surfaces from scattered data points, allowing for cleaner representations of the underlying spatial patterns (See **Figure 3**).

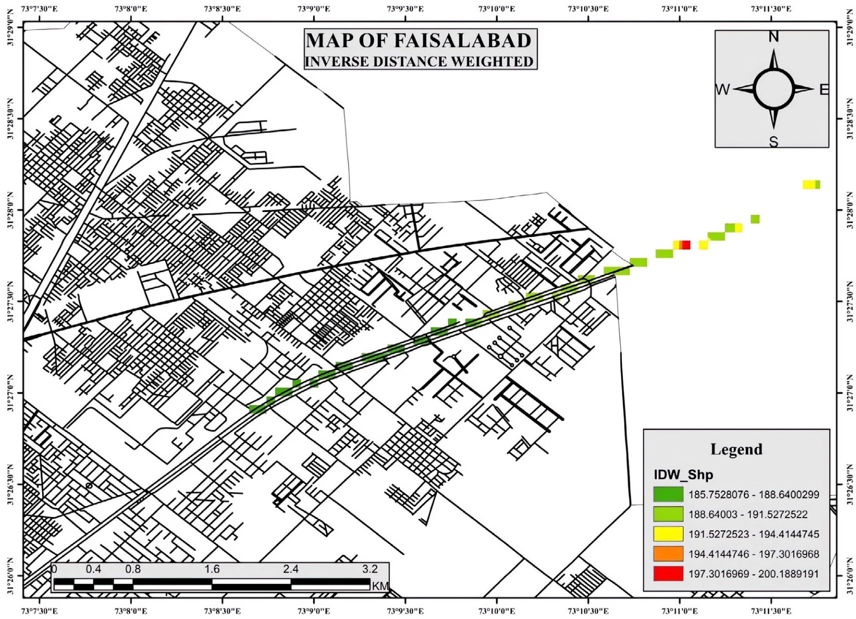

Figure 3. IDW.

In ArcGIS, Inverse Distance Weighted (IDW) interpolation is a widely used geospatial analysis tool with various applications. Here are some common uses of IDW in ArcGIS:

Creating continuous surfaces: IDW can be used to generate continuous surfaces from scattered point data, providing a visual representation of data distribution across the study area.

Interpolating missing data: When you have missing data points in a dataset, IDW can be used to estimate values at those locations based on the surrounding measured values.

Environmental mapping: IDW is often employed in environmental sciences to map environmental factors like air quality, pollution levels, or soil properties.

Temperature and climate mapping: IDW can be used to create temperature and climate maps, providing a spatial representation of temperature variations across an area. The purpose of Figure 4 is to demonstrate how Inverse Distance Weighting (IDW) can be used to create temperature and climate maps, providing a spatial representation of temperature variations across the study area. This visualization helps in identifying hotter and cooler areas, which is crucial for understanding the urban heat island effect and planning urban green spaces and other mitigation strategies.

Resource management: IDW can help in managing natural resources by estimating values like water quality, mineral deposits, or vegetation cover.

Urban planning: In urban planning, IDW can be used to estimate population density, traffic flow, or noise levels across a city.

Site suitability analysis: IDW can aid in site suitability analysis by interpolating various factors to determine the most suitable locations for specific purposes, such as land use planning or infrastructure development.

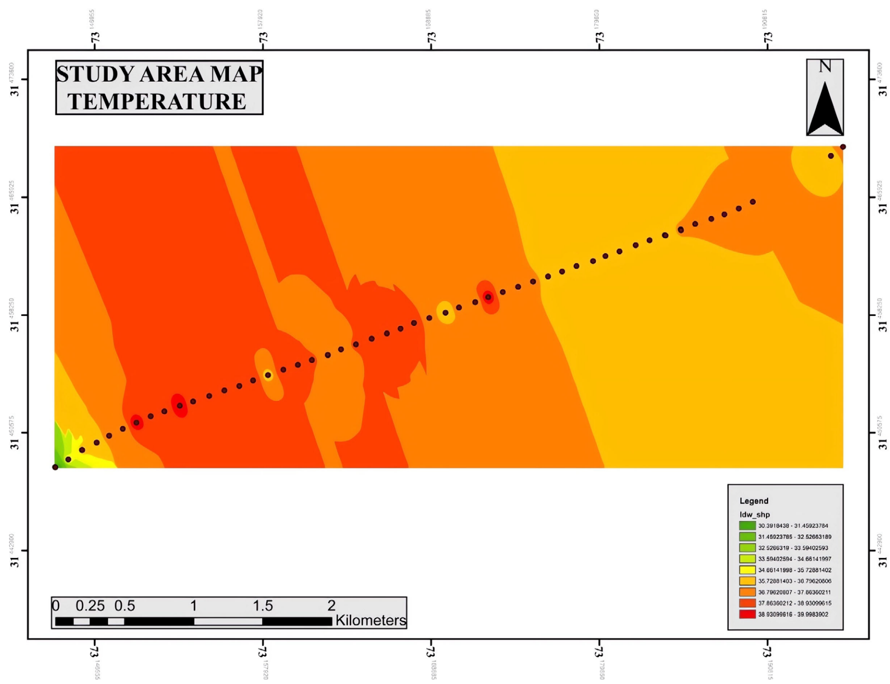

Figure 4. Temperature map in IDW.

Inverse Distance Weighting (IDW) is a spatial interpolation technique used in l fields to estimate values at unmeasured locations based on known values from surrounding points. We use interpolation in IDW because it allows us to estimate the value at an unknown location by considering the distances to nearby points and assigning weights accordingly. The closer the points, the higher the influence they have on the estimated value, and vice versa. This approach is useful when we want to create a continuous surface representation of a variable based on scattered data points.

Interpretation of IDW analysis involves understanding the results and the generated interpolated surface. Here are some key points to consider when interpreting IDW analysis:

Spatial Continuity: IDW creates a continuous surface representation of the variable being interpolated. The interpolated values smoothly transition between known data points, providing a sense of spatial continuity.

Weighted Influence: The influence of each data point on the interpolated value is inversely proportional to its distance from the target location. Closer points have a higher impact, while distant points have less influence.

Outliers and Data Distribution: The distribution of data points affects the interpolated surface. Outliers or data clusters can result in areas of high or low values in the interpolation.

Uncertainty: IDW doesn't account for spatial variation beyond the neighbourhood of data points. Therefore, the reliability of the interpolated values decreases as the distance from the known data points increases.

Parameter Sensitivity: IDW relies on the power parameter (p) to control the influence of distance on the interpolation. Higher values of p give more weight to nearby points, while lower values spread influence to more distant points.

Visualization: Interpolated surfaces can be visualized using contour plots, heat maps, or 3D surfaces. Visualization helps in understanding the spatial patterns and trends of the interpolated variable.

Validation: It's essential to validate the IDW results with independent data or known values. Cross-validation techniques can assess the accuracy of the interpolation.

Resolution: The resolution of the interpolated surface depends on the density of input data points. Areas with sparse data might have lower accuracy compared to areas with denser data coverage.

Overall, the interpretation of IDW analysis involves understanding the underlying assumptions, considering the influence of neighbouring data points, and being aware of the limitations associated with the method. It's important to use IDW in conjunction with other interpolation techniques and domain knowledge to obtain a comprehensive understanding of the spatial distribution of the variable of interest.

3.2. Supervised Classification

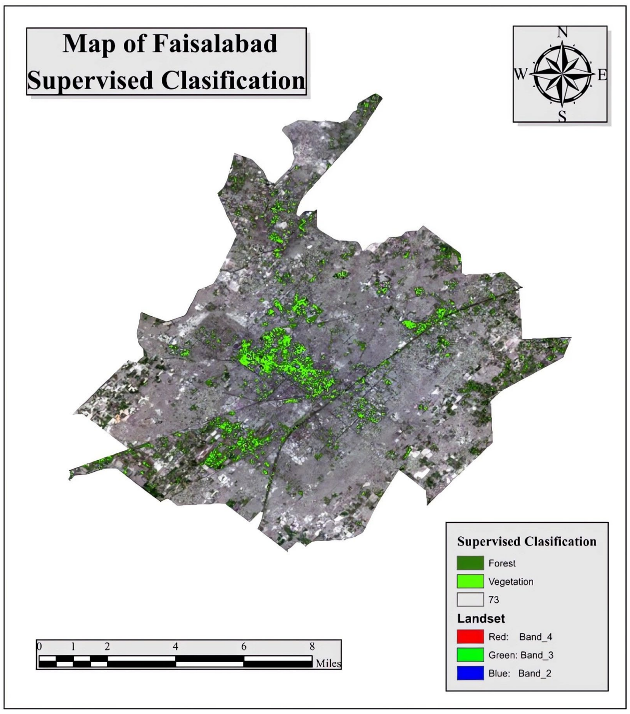

Figure 5. Supervised classification.

Supervised classification is a machine learning technique where the algorithm is trained on a labelled dataset. The training data consists of input-output pairs, where the inputs are the features of the data, and the outputs are the corresponding labels or classes. The goal is to learn a mapping between the inputs and the labels, so the algorithm can predict the labels for new, unseen data. The process involves selecting a suitable model, feeding it the labelled training data, and adjusting its parameters to minimize the prediction error. Common algorithms for supervised classification include decision trees, support vector machines (SVM), k-nearest neighbours (KNN), and deep learning methods like neural networks. Once the model is trained, it can be used to predict the labels of new data points based on their features. Supervised classification is widely used in various fields, such as image recognition, spam detection, sentiment analysis, and medical diagnosis (Figure 5).

Supervised classification with forest and vegetation at Canal Road would involve using a labelled dataset of satellite or aerial imagery that includes regions of the Canal Road area. The classification task would aim to differentiate between forested areas and other types of vegetation along the road.

To perform the classification, the steps would generally involve:

Data Collection: Obtain high-resolution satellite or aerial imagery covering the Canal Road area.

Data Preprocessing: Preprocess the imagery to remove noise, correct any distortions, and prepare it for analysis.

Data Labeling: Manually label areas in the imagery as "forest" or "vegetation" based on ground truth information or expert knowledge.

Feature Extraction: Extract relevant features from the imagery, such as spectral information (e.g., red, green, blue bands), texture, and vegetation indices such as NDVI (Normalized Difference Vegetation Index).

Model Selection: Choose a suitable supervised classification algorithm for the task, such as Random Forest, Support Vector Machines (SVM), or Deep Learning-based models.

Model Training: Use the labelled data to train the selected model, allowing it to learn patterns and characteristics of forested and vegetated areas.

Model Evaluation: Assess the performance of the trained model using validation data to ensure it generalizes well to new, unseen data.

Classification: Apply the trained model to the entire Canal Road area to classify regions as forested or vegetated.

The use of supervised classification in ArcGIS includes:

Land Cover Mapping: Supervised classification helps create land cover maps by classifying pixels in satellite or aerial imagery into different land cover classes, such as vegetation, water bodies, urban areas, and forests. This information is valuable for environmental monitoring, urban planning, and natural resource management.

Change Detection: By classifying different periods of satellite imagery using the same land cover classes, supervised classification enables the detection of changes over time. This can be useful in studying land use changes, deforestation, urban expansion, etc.

Environmental Analysis: Supervised classification can be applied to satellite imagery to identify and monitor various environmental features like wetlands, coral reefs, and agricultural fields.

Disaster Assessment and Management: In the aftermath of natural disasters, supervised classification can be used to identify affected areas, assess the damage extent, and aid in disaster response and recovery efforts.

Habitat Mapping: It helps in mapping and monitoring habitats for wildlife and conservation purposes, crucial for understanding biodiversity and implementing conservation strategies.

Agricultural Monitoring: Supervised classification can be used to monitor agricultural land, and crop types, and assess crop health, helping farmers make informed decisions.

Infrastructure Planning: It can assist in identifying and mapping urban infrastructure like roads, buildings, and utilities, supporting urban planning and development. ArcGIS provides various tools and algorithms for supervised classification, such as Maximum Likelihood Classification, Random Trees, and Support Vector Machines. The accuracy of the classification heavily depends on the quality of training data and the choice of classification algorithm, as well as proper preprocessing and validation techniques.

3.3. Spatial Auto Correlation

Spatial autocorrelation analysis is a method used in spatial statistics to assess the degree of similarity or dissimilarity between the values of a variable at different locations on a map video. It helps identify patterns of spatial clustering or dispersion. Common techniques include Moran's I and Geary's C, which measure the spatial dependence between neighbouring locations. This analysis is valuable in various fields, such as geography, ecology, and urban planning, to understand spatial relationships and patterns in data (See Tables 1 - 4, Figure 6 and Figure 7).

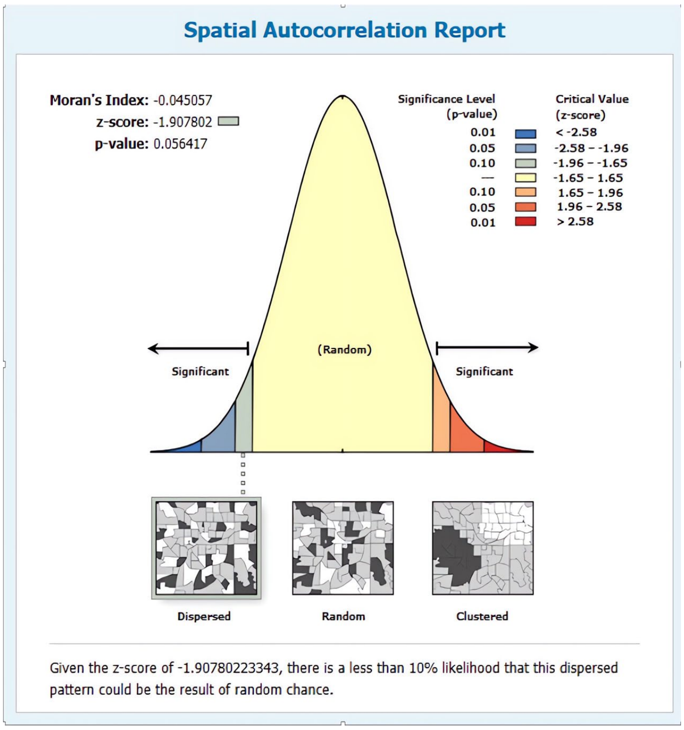

Figure 6. Spatial autocorrelation report.

Table 1. Global Moran's I summary.

Moran's Index:	−0.120778
Expected Index:	−0.015873
Variance:	0.038325
z-score:	−0.535866
p-value:	0.592051

Table 2. Dataset information.

Input Feature Class:	11 Jun.
Input Field:	PM2_5
Conceptualization:	INVERSE_DISTANCE
Distance Method:	EUCLIDEAN
Row Standardization:	False
Distance Threshold:	101.9206 Meters
Weights Matrix File:	None
Selection Set:	False

Table 3. Table of temperature in canal road.

	Low Temperature	High Temperature
Yasrab Colony	35.1	36.8
Abdullah Pur	33.1	39.7
Mansoorabad	36.3	38.9
Saeed Colony	36.2	39.1
Zia Colony	35.5	39.9
Malik Pur	35.7	37.8
Canal Gardan	36.7	39.2
Amir Town	36.7	38.8
Chack No. 199	35.7	37.3
Paradise Valley	34.4	34.4

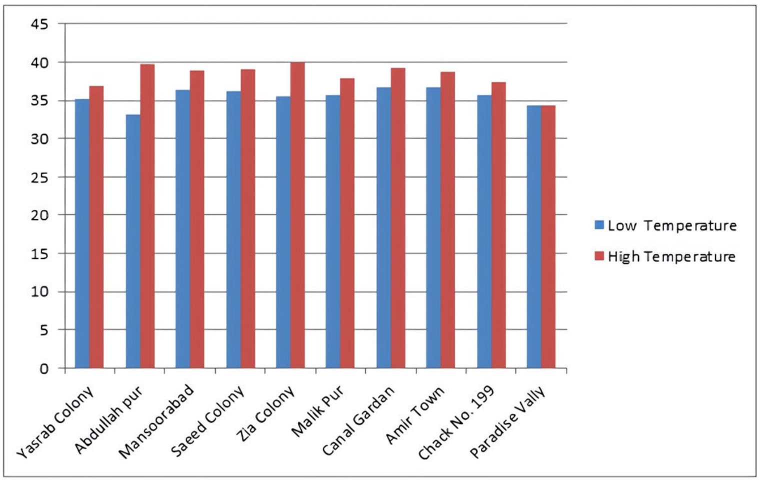

Figure 7. Low humidity data and high humidity data to show Yasrab colony low 40.4, high 45.8 Abdullah pur low 36, high 45.6 Mansoorabad low 36, high 42.1 saeed colony low 36.2, high 40.7 Zia colony low 36.6, high 42.7 Malik pur low 41.6 high 57.1 canal garden low 49.1, high 58.7 Amir Town low 46.1, high 54.7 chak no. 199 low 55.1 high 58.6 Paradise Valley low 56.6 high 59.7.

Table 4. pm value in various areas of Faisalabad city.

	PM 2.5 (μg/m³) Minimum	PM 2.5 (μg/m³) Maximum
Yasrab Colony	73	93
Abdullah pur	69	83
Mansoorabad	70	82
Saeed Colony	70	79
Zia Colony	68	86
Malik Pur	65	78
Canal Gardan	70	89
Amir Town	71	80
Chack No.199	69	82
ParadiseValley	62	68

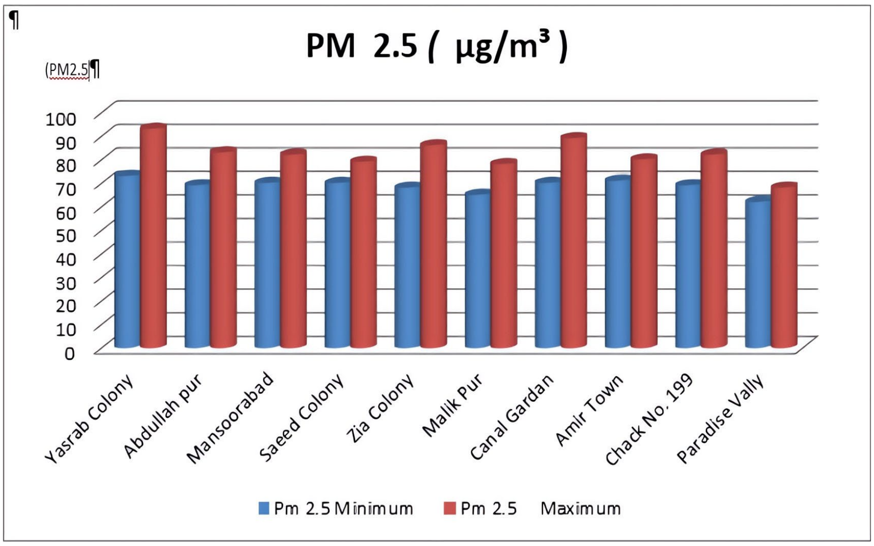

Figure 8. Graph of PM. (μg/m³)

PM2.5 **(μg/m³)** minimum and maximum of Dust particles having Air from canal Road Yasrab colony has 73 minimum and 93 maximum Dust particles, Abdullah pur has 69 minimum and 83 maximum, Saeed colony 70 minimum and 82 maximum, Mansoorabad has also 70 minimum and 79 maximum, Zia colony 68 minimum and 68 maximum, Malik pur 65 minimum and 78 Maximum, Canal Garden 70 per cent minimum and 89 maximum, Amir Town 71 minimum and 80 maximum, Chack no.199 has 69 minimum and 82 maximum Paradise valley 62 minimum and 68 per cent maximum dust particles in air (See Figure 8).

3.4. Humidity in West Canal Road Faisalabad

Humidity is West Canal Road Faisalabad in Low humidity data and high humidity data to show Yasrab colony low 40.4, high 45.8 Abdullah pur low 36, high 45.6 Mansoorabad low 36, high 42.1 Saeed colony low 36.2, high 40.7 Zia colonies low 36.6, high 42.7 Malik pur low 41.6 high 57.1 canal garden low 49.1, high 58.7 Amir Town low 46.1, high 54.7 Chak no. 199 low 55.1 high 58.6 paradise valley low 56.6 high 59.7 (See Figure 9).

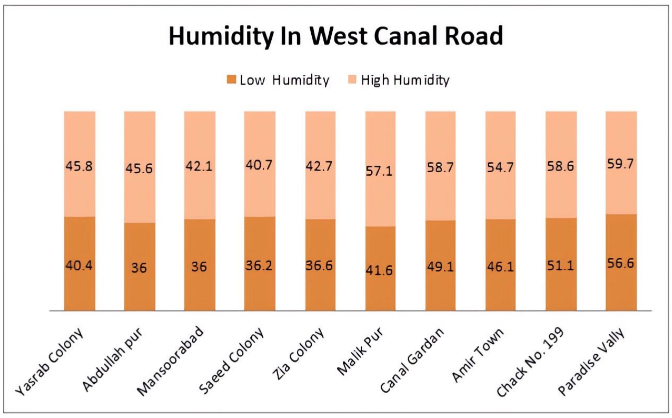

Figure 9. Graph of humidity in west of canal road.

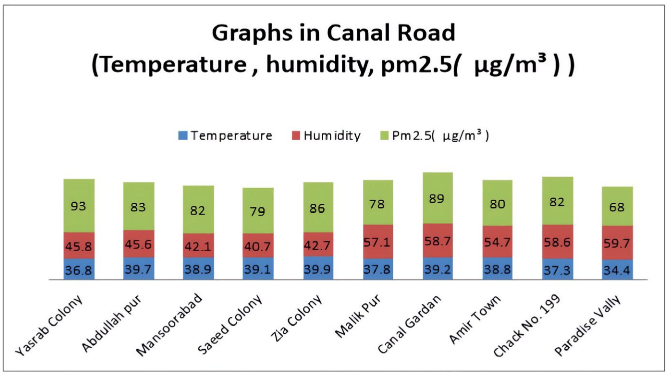

Figure 10. Graphs in canal road (Temperature, Humidity, PM 2.5. (µg/m^3)).

Canal road temperature and humidity data minimum and maximum. Yasrab colony contains temperature 36.8, humidity 45.8 and pm 2.5, 93. Abdullah pur temperature 39.7, humidity 45.6 and pm2.5, 83. Mansoorabad temperature 38.9, humidity 42.1 and pm 2.5, 82. Saeed colony temperature 39.1, humidity 40.7 PM2.5, 79. Zia colony temperature 39.9, humidity 42.7 and PM2.5, 86. Canal Garden temperature 39.2, humidity 58.7 and PM2.5 80, Amir Town temperature 38.8, humidity 54.7 and PM2.5, 80. Chak No. 199 temperature 37.3, humidity 58.6 and PM2.5, 82. Paradise Valley temperature 34.4, humidity 59.7 and PM2.5, 68. All these values are temperature and humidity (See **Figure 10** and **Figure 11**).

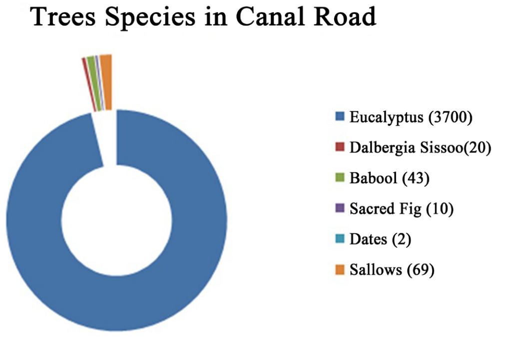

Figure 11. Graph of tree species of west canal road Faisalabad.

On Canal Road are different kinds of trees in which 2 trees of dates are located, sacred figs are 10 in number, Dalbergia Sisso are 20 in number, Babool trees are 43 in number, Sallows are 69 in number and Eucalyptus are 3700 in number.

4. Conclusions

Urban forests are critical to improving the quality of life in cities. They are vital ecosystems that provide several benefits to both the environment and the residents. These lush pockets of nature assist in decreasing the urban heat island effect, reduce air pollution, and trap carbon dioxide, thereby addressing climate change problems [4]. Furthermore, urban forests provide wildlife habitat, encourage biodiversity, and provide recreational activities for city people, promoting physical and emotional well-being [13]. They also help to improve water quality and reduce stormwater runoff, making cities more resilient to natural calamities. To fully reap the benefits of urban forests, towns must invest in their preservation, expansion, and upkeep. Recognizing the significance of these green [14] [15].

The spatial distribution of urban forests in Faisalabad is uneven, with a higher concentration in certain areas compared to others. For instance, the city's central and eastern parts have more green spaces, while the western and southern areas are more built-up [16]. The results showed that urban trees, particularly those in high-traffic areas, significantly reduce PM levels. Specifically, the total PM2.5 retention was highest in urban areas, indicating the effectiveness of urban forests in capturing airborne pollutants [17]. Another case study in Faisalabad focused on the integration of green spaces within industrial zones. The implementation of green belts and the planting of trees along major roads have been shown to reduce PM2.5 concentrations by up to 20% [18]. These green spaces not only improve air quality but also enhance the aesthetic appeal and psychological well-being of the residents. Moreover, the Pakistan Clean Air Program has initiated several projects to increase urban forest cover in Faisalabad [17] [19]. One such project involved the planting of over 50,000 trees in key areas of the city, including parks, streets, and industrial zones. Monitoring data from these areas have shown a notable decrease in PM2.5 levels, demonstrating the tangible benefits of urban forest initiatives. The size and distribution of urban parks vary significantly, with some areas lacking adequate green spaces [20]. Various historical and urban planning decisions have played a significant role in the current distribution of urban forests. For example, the establishment of colonial infrastructure like Motorway City and FDA City has influenced the spatial layout [21]. Furthermore, economic and social factors also contribute to the uneven distribution, with wealthier neighbourhoods often having more green spaces. Our study has revealed that urban forests in Faisalabad help mitigate the urban heat island effect by providing shade and evaporative cooling. This is particularly important given the city's relatively flat terrain and high temperatures [21]. They improve air quality by filtering airborne particulate matter and absorbing pollutants. Studies have shown that evergreen plants, especially, play a crucial role in dust retention and air purification. Urban forests enhance the mental well-being of residents by providing recreational spaces and reducing stress [18]. The presence of green spaces is linked to higher happiness scores and better emotional health and promotes physical activity, which is essential for maintaining good health [22]. Moreover, green spaces can increase property values and attract investments, contributing to the city's economic development. They reduce energy costs by lowering the need for air conditioning in buildings, which is beneficial for both residents and businesses [23] [24].

The linkage of the urban environment refers to the interconnectedness and relationships between various components within a city or urban area [25]. This includes the physical infrastructure, such as roads, buildings, and utilities, as well as social, economic, and ecological aspects. Understanding these linkages is crucial for urban planning, sustainability, and addressing issues like transportation, housing, pollution, and community development [26] [27].

The interconnection and linkages between various components inside a city or urban region are referred to as urban environment linkage [28]. This covers both physical infrastructure, such as roads and buildings, as well as social, economic, and environmental factors. Understanding these connections is critical for urban planning, sustainability, and dealing with concerns such as transportation, housing, pollution, and community development [29].

5. Recommendation

Efforts should be made to ensure a more equitable distribution of urban forests across the city, particularly in underserved areas. Community involvement and participation in urban forest planning can help identify areas with the greatest need for green spaces. In addition, integrated spatial planning that considers the ecological, social, and economic aspects of urban forests is essential. Regular monitoring and maintenance of existing green spaces are necessary to ensure their long-term sustainability. Implementing policies that mandate the inclusion of green spaces in new developments can help increase the overall coverage of urban forests and reduce the level of PM2.5. To sum up, collaboration between local government, private sectors, and community organizations can facilitate the creation and maintenance of urban forests. Embracing the potential of urban forests and prioritizing their linkage in urban planning will play a pivotal role in shaping resilient and sustainable cities for generations to come.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Abbas, M.W., Gillani, A. and Hussain, S. (2020) Plan under Thal Development Authority in the Desert in Punjab, Pakistan. *Dilemas Contemporáneos: Educación, Política y Valores*, 7.

https://www.researchgate.net/publication/343713734_Plan_under_Thal_Development_Authority_in_the_desert_in_Punjab_Pakistan

[2] Khan, H.A., Majeed, W., Mustafa, S. and Shabbir, S. (2023) Trees as the Roosts of Rose Ringed Parakeet in Central Punjab Pakistan. *The Journal of Animal and Plant Sciences*, **33**, 1133-1147. https://doi.org/10.36899/japs.2023.5.0707

[3] Mo, F., Selman, P. and Woudstra, J. (2021) The Origins of the Modern Park System of the International Settlement in Shanghai (1899-1929). *Landscape Research*, **46**, 435-449. https://doi.org/10.1080/01426397.2020.1867975

[4] O'Brien, L.E., Urbanek, R.E. and Gregory, J.D. (2022) Ecological Functions and Human Benefits of Urban Forests. *Urban Forestry & Urban Greening*, **75**, Article ID: 127707. https://doi.org/10.1016/j.ufug.2022.127707

[5] da Schio, N., Phillips, A., Fransen, K., Wolff, M., Haase, D., Ostoić, S.K., *et al.* (2021) The Impact of the COVID-19 Pandemic on the Use of and Attitudes Towards Urban Forests and Green Spaces: Exploring the Instigators of Change in Belgium. *Urban Forestry & Urban Greening*, **65**, Article ID: 127305. https://doi.org/10.1016/j.ufug.2021.127305

[6] Lv, T., Zhou, X., Tao, Z., Sun, X., Wang, J., Li, R., *et al.* (2021) Remote Sensing-Guided Spatial Sampling Strategy over Heterogeneous Surface Ground for Validation of Vegetation Indices Products with Medium and High Spatial Resolution. *Remote Sensing*, **13**, Article No. 2674. https://doi.org/10.3390/rs13142674

[7] Sabir, M.A., *et al.* (2021) Opinion of Urban Dwellers Varies to Manage the Urban Spaces for Urban Forestry: A Case Study of Faisalabad City. *Pakistan Journal of Agricultural Sciences*, **58**, 105-113.

[8] Mácová, K., Szórádová, A. and Kolařík, J. (2022) Are Trees Planted along the Roads Sustainable? A Large-Scale Study in the Czech Republic. *Sustainability*, **14**, Article No. 5026. https://doi.org/10.3390/su14095026

[9] Arif, G.M., Sadiq, M., Sathar, Z., Jiang, L. and Hussain, S. (2022) Has Urbanization Slowed down in Pakistan? *Asian Population Studies*, **19**, 311-335. https://doi.org/10.1080/17441730.2022.2156508

[10] Pereira, C., Flores-Colen, I. and Mendes, M.P. (2023) Guidelines to Reduce the Effects of Urban Heat in a Changing Climate: Green Infrastructures and Design Measures. *Sustainable Development*, **32**, 57-83. https://doi.org/10.1002/sd.2646

[11] Tian, P., Li, J., Cao, L., Pu, R., Wang, Z., Zhang, H., *et al.* (2021) Assessing Spatiotemporal Characteristics of Urban Heat Islands from the Perspective of an Urban Expansion and Green Infrastructure. *Sustainable Cities and Society*, **74**, Article ID: 103208. https://doi.org/10.1016/j.scs.2021.103208

[12] Rahaman, M.A., Kalam, A. and Al-Mamun, M. (2023) Unplanned Urbanization and Health Risks of Dhaka City in Bangladesh: Uncovering the Associations between Urban Environment and Public Health. *Frontiers in Public Health*, **11**, Article ID: 1269362. https://doi.org/10.3389/fpubh.2023.1269362

[13] Wang, D., Xu, P., An, B. and Guo, Q. (2024) Urban Green Infrastructure: Bridging Biodiversity Conservation and Sustainable Urban Development through Adaptive Management Approach. *Frontiers in Ecology and Evolution*, **12**, Article ID: 1440477. https://doi.org/10.3389/fevo.2024.1440477

[14] Mamajonova, N., *et al.* (2024) The Role of Green Spaces in Urban Planning Enhancing Sustainability and Quality of Life. *Holders of Reason*, **2**, 346-358.

[15] Cameron, R.W.F., Brindley, P., Mears, M., McEwan, K., Ferguson, F., Sheffield, D., *et al.* (2020) Where the Wild Things Are! Do Urban Green Spaces with Greater Avian

Biodiversity Promote More Positive Emotions in Humans? *Urban Ecosystems*, **23**, 301-317. https://doi.org/10.1007/s11252-020-00929-z

[16] Quddoos, A., Muhmood, K., Naz, I., Aslam, R.W. and Usman, S.Y. (2024) Geospatial Insights into Groundwater Contamination from Urban and Industrial Effluents in Faisalabad. *Discover Water*, **4**, Article No. 50. https://doi.org/10.1007/s43832-024-00110-z

[17] Sabir, M.A., Nawaz, M.F., Khan, T.H., Zulfiqar, U., Haider, F.U., Rehman, A., *et al.* (2024) Investigating Seasonal Air Quality Variations Consequent to the Urban Vegetation in the Metropolis of Faisalabad, Pakistan. *Scientific Reports*, **14**, Article No. 452. https://doi.org/10.1038/s41598-023-47512-y

[18] Sabir, M.A., *et al.* (2023) Exploring the Impact of Urban Vegetation on Particulate Matter Levels and Urban Environment Enhancement. *Plant and Environment*, **4**, 35-44.

[19] Ahmad, M., Bangash, S.A., Shah, S.S., Chemingui, H. and Abubakar, M. (2024) Revolutionizing Healthcare in the Metaverse: The Power of Blockchain. In: Nijalingappa, P., *et al.*, Eds., *Examining the Metaverse in Healthcare*: *Opportunities*, *Challenges*, *and Future Directions*, IGI Global, 51-76. https://doi.org/10.4018/979-8-3693-1515-6.ch003

[20] Riaz, A., *et al.* (2002) Green Areas: A Source of Healthy Environment for People and Value Addition to Property. *Labour*, **37**, 41.

[21] Ahmed, S., Huifang, W., Akhtar, S., Imran, S., Hassan, G. and Wang, C. (2021) An Analysis of Urban Sprawl in Pakistan: Consequences, Challenges, and the Way Forward. *International Journal of Agricultural Extension*, **8**, 257-278. https://doi.org/10.33687/008.03.3438

[22] Farooq, M.S., Feroze, N., Cheng, T. and Feroze, F. (2024) Pakistan's Green Urbanization in the Perspective of Ecological Civilization. *Chinese Journal of Urban and Environmental Studies*, **12**, Article ID: 2450017. https://doi.org/10.1142/s2345748124500179

[23] Tarish, M., Ali, R.T., Shan, M., Amjad, Z., Rui, Q., Akher, S.A., *et al.* (2024) Plant Tissues as Biomonitoring Tools for Environmental Contaminants. *International Journal of Plant Biology*, **15**, 375-396. https://doi.org/10.3390/ijpb15020030

[24] Younis, A., *et al.* (2002) Development and Management of Green Spaces on Samundri Road, Faisalabad: A Case Study. *Pakistan Journal of Agricultural Sciences*, **39**, 292-296.

[25] Zeng, X., Yu, Y., Yang, S., Lv, Y. and Sarker, M.N.I. (2022) Urban Resilience for Urban Sustainability: Concepts, Dimensions, and Perspectives. *Sustainability*, **14**, Article No. 2481. https://doi.org/10.3390/su14052481

[26] Mohebbi, S., Zhang, Q., Christian Wells, E., Zhao, T., Nguyen, H., Li, M., *et al.* (2020) Cyber-Physical-Social Interdependencies and Organizational Resilience: A Review of Water, Transportation, and Cyber Infrastructure Systems and Processes. *Sustainable Cities and Society*, **62**, Article ID: 102327. https://doi.org/10.1016/j.scs.2020.102327

[27] Tonne, C., Adair, L., Adlakha, D., Anguelovski, I., Belesova, K., Berger, M., *et al.* (2021) Defining Pathways to Healthy Sustainable Urban Development. *Environment International*, **146**, Article ID: 106236. https://doi.org/10.1016/j.envint.2020.106236

[28] Luo, D., Liang, L.W., *et al.* (2021) Exploration of Coupling Effects in the Economy-Society-Environment System in Urban Areas: Case Study of the Yangtze River Delta Urban Agglomeration. *Ecological Indicators*, **128**, Article ID: 107858. https://doi.org/10.1016/j.ecolind.2021.107858

[29] Mouratidis, K. (2021) Urban Planning and Quality of Life: A Review of Pathways Linking the Built Environment to Subjective Well-Being. *Cities*, **115**, Article ID: 103229. https://doi.org/10.1016/j.cities.2021.103229