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Research Article

Integrating Biophilic Green Infrastructure and Mental Health: A Novel Framework for Quantifying Restorative Effects of Urban Blue Green Spaces on Psychological Well-Being

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Abstract. The growing environmental crisis underscores the need for education systems to foster ecological responsibility among students. This study explores the potential for multifaith schools to cultivate environmental moral education through an interreligious pedagogical model. By integrating diverse religious teachings on ecology, the proposed model aims to promote shared moral values for environmental protection and sustainability. The research addresses the gap in existing environmental education, which often lacks an integrated approach that incorporates various religious perspectives. Through a qualitative research design, the study analyzes curricula, observes classroom practices, conducts interviews with educators, and evaluates existing environmental education frameworks in multifaith schools. The study identifies key strategies, including the incorporation of eco-ethics from different religious traditions, project-based learning, and interfaith dialogues, as effective means of fostering ecological responsibility. However, challenges such as balancing doctrinal differences, overcoming biases, and developing inclusive pedagogy remain. The study emphasizes the importance of designing educational content that respects all faiths and promotes intercultural dialogue, thereby encouraging a collective commitment to sustainability. The findings suggest that multifaith schools can serve as powerful platforms for environmental moral education, highlighting the value of integrating religious perspectives into sustainability education. The study concludes with recommendations for incorporating interreligious eco-ethics into curricula and teacher training programs and suggests future research on the long-term impact of interreligious environmental education and its applicability in diverse cultural contexts.

Keywords: Eco-Ethics; Environmental Education; Interreligious Pedagogy; Multifaith Schools; Sustainable Behavior

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1. Introduction

Urbanization, characterized by the migration of populations from rural to urban areas, has become a defining feature of the modern world. This global phenomenon has led to the rapid expansion of cities, with significant implications for infrastructure, health, and sustainability. While urbanization is associated with economic growth, improved access to services, and technological innovation, it also introduces a range of stressors that negatively impact the mental well-being of city residents. These stressors include higher population density, social fragmentation, noise pollution, and reduced access to natural environments. As a result, urban residents often experience higher levels of psychological distress, including stress, anxiety, and depression, compared to those living in rural areas (Marzukhi et al., 2023; Steinheuser et al., 2014).

The growing body of research exploring the mental health challenges associated with urban living highlights the critical need to address these issues. A promising solution lies in the incorporation of green spaces into urban environments. Green spaces, including parks, gardens, and street trees, are well-documented for their ability to enhance mental well-being by promoting relaxation, reducing stress, and fostering social interactions (Dzhambov, 2018; Völker & Kistemann, 2015). However, there is increasing recognition that the integration of water features-termed blue spaces-into these environments can further enhance their psychological benefits (Völker & Kistemann, 2015; Yin et al., 2023).

Blue-green spaces, which combine water (blue) and vegetation (green), are increasingly being explored for their synergistic effects on psychological restoration. While extensive studies have demonstrated the benefits of green spaces, the restorative effects of blue spaces, particularly when combined with green areas, remain underexplored (Dzhambov, 2018; Yin et al., 2023). The psychological benefits of these spaces, such as improved mood, stress reduction, and mental restoration, are important in mitigating the adverse effects of urbanization on mental health (Völker & Kistemann, 2015; Yin et al., 2023).

This study aims to address this gap by developing a novel quantitative framework for assessing the psychological benefits of blue-green spaces in urban settings. By combining psychological surveys, real-time environmental sensors, and spatial analysis using Geographic Information Systems (GIS), this research seeks to quantify the restorative effects of these spaces on psychological well-being. The findings are expected to contribute to a better understanding of how blue-green spaces can be integrated into urban planning to promote mental health and well-being, particularly in the face of increasing urbanization (Gao et al., 2024; Vegaraju & Amiri, 2024).

Urbanization has led to various challenges, particularly in mental health, as city dwellers face increased levels of stress, anxiety, and depression compared to rural populations. This shift from rural to urban living brings about several stressors, such as higher population density, social fragmentation, noise, pollution, and limited access to natural environments (Shivanand & Amirtham, 2024; Völker & Kistemann, 2015). As the mental health challenges of urban living become more pronounced, there is a growing recognition of the need to incorporate nature into urban environments. One promising approach is the integration of blue-green spaces-urban areas that combine water elements (blue spaces) and vegetation (green spaces), which have been shown to promote psychological well-being and reduce stress (Andreucci et al., 2019; Völker & Kistemann, 2015).

Despite the well-documented benefits of green spaces for mental health, the combined effects of blue and green spaces remain underexplored. Blue-green spaces are considered beneficial not only for their environmental impact, such as improving air and water quality and mitigating heat stress (Felappi et al., 2020), but also for their potential to promote mental health by enhancing emotional and cognitive restoration (Völker & Kistemann, 2015). This combination of elements offers significant promise for addressing the mental health challenges faced by urban populations, but a comprehensive framework to measure their restorative effects is still lacking (Wan et al., 2024).

The objective of this study is to propose a novel, quantitative framework to measure the restorative effects of blue-green spaces on psychological well-being. The proposed framework will combine various aspects of biophilic design and green infrastructure to create measurable metrics that can guide urban planners and policymakers in improving urban mental health outcomes through design (Hung & Chang, 2022). By exploring the intersection of biophilic design and urban green-blue infrastructure, this research aims to fill the gap in existing studies and provide actionable data for enhancing mental health in urban environments (Xia et al., 2024; X. Zhang et al., 2024).

Integrating biophilic design and green infrastructure into urban planning is crucial for enhancing mental health outcomes in cities. Biophilic design reconnects urban residents with nature, fostering mental health and resilience by providing environments that encourage relaxation, reduce stress, and improve overall psychological well-being (Xia et al., 2024). Green and blue spaces have been shown to improve the emotional states of individuals, reduce stress, and enhance feelings of tranquility and restoration (Andreucci et al., 2019; Völker & Kistemann, 2015). In addition to the mental health benefits, green infrastructure also provides environmental advantages, such as improved air and water quality, climate regulation, and biodiversity conservation, which further enhance the quality of life for urban residents (Dong et al., 2024; Felappi et al., 2020).

Moreover, the socio-economic advantages of green spaces are undeniable. These spaces foster community cohesion, enhance property values, and offer recreational opportunities, which contribute to a more sustainable and inclusive urban environment (Felappi et al., 2020; X. Zhang et al., 2024). Thus, incorporating green and blue spaces in urban planning not only supports mental well-being but also promotes a more sustainable, equitable, and healthy urban future.

The proposed framework will include several key components to quantify the restorative effects of urban blue-green spaces. First, the design aspects will consider the proportion of blue and green spaces, vegetation arrangement, shading, lighting, and the inclusion of water activities. These factors are essential in creating environments that promote psychological restoration (Andreucci et al., 2019). Environmental aspects, such as cleanliness, orderliness, and sensory experiences (e.g., thermal comfort, visual, audio, olfactory, and tactile stimuli), will also be incorporated to assess the quality of the space from a sensory perspective (Shivanand & Amirtham, 2024). Finally, quantitative metrics will be derived using advanced tools like LiDAR for 3D spatial analysis, surveys to gauge perceived restorativeness, and machine learning models for comprehensive data analysis (Wan et al., 2024; X. Zhang et al., 2024).

2. Literature Review

Biophilic Design

Biophilic design is an emerging approach to urban planning that integrates natural elements into built environments, fostering a connection between people and nature. Rooted in the biophilia hypothesis, which suggests that humans have an innate affinity for nature, biophilic design aims to enhance mental and physical well-being by incorporating natural elements such as plants, water, and natural lighting into the built environment (Bolten & Barbiero, 2020; Shivanand & Amirtham, 2024). This approach has been linked to numerous psychological benefits, such as stress reduction, improved creativity, and enhanced cognitive function (Bolten & Barbiero, 2023; Hung & Chang, 2024).

The presence of natural elements in urban spaces has been shown to reduce stress levels and promote relaxation. Studies indicate that individuals exposed to biophilic environments experience lower levels of cortisol, a hormone associated with stress, and report enhanced emotional well-being (El Messeidy, 2019; Panagopoulos et al., 2020). Additionally, natural environments stimulate creativity and cognitive function, with studies suggesting that exposure to nature can improve mental clarity and problem-solving abilities (Bolten & Barbiero, 2020; Shivanand & Amirtham, 2024).

Biophilic design has also been shown to accelerate healing processes, particularly in healthcare settings. For example, the integration of natural elements such as plants and water features in hospital environments has been linked to faster recovery times for patients (El Messeidy, 2019; Yang et al., 2023). This restorative quality of biophilic environments

underscores the potential of biophilic design to not only enhance everyday well-being but also support physical and psychological healing.

Beyond psychological benefits, biophilic design can improve the thermal comfort of built environments by integrating elements such as water features, green roofs, and plants, which help regulate temperature and humidity levels (Yang et al., 2023). These elements contribute to the overall environmental quality of urban areas by enhancing air and water quality and reducing the urban heat island effect, which is particularly important in densely populated cities.

A key psychological mechanism underlying the benefits of biophilic design is perceived restorativeness. Natural elements in urban parks and spaces can enhance perceived restorativeness, boosting subjective vitality and mental health. Additionally, the concept of environmental Qi, derived from both Western and Eastern perspectives, suggests that the flow of energy in natural environments can further enhance the psychological benefits of biophilic design (Hung & Chang, 2024).

Blue-Green Infrastructure

Blue-green infrastructure (BGI) refers to a network of natural and semi-natural systems that manage urban water and enhance environmental quality. BGI combines blue infrastructure, such as rivers, lakes, and wetlands, with green infrastructure, such as parks, green roofs, and urban forests, to create sustainable urban environments (Gupta et al., 2024; Kanade & Batule, 2024). These spaces not only manage water, reduce urban flooding, and improve air quality, but also provide crucial ecological and social benefits.

One of the key benefits of blue-green infrastructure is its ability to manage stormwater and improve water quality, helping to mitigate urban flooding and reduce the risk of waterborne diseases (Perrelet et al., 2024). Furthermore, green spaces within BGI contribute to climate resilience by mitigating the urban heat island effect and improving thermal comfort (Keita & Kourouma, 2024). BGI also supports biodiversity by creating habitats for a wide range of species, enhancing urban ecosystems (Perrelet et al., 2024).

In addition to environmental benefits, BGI provides significant social and economic advantages. Access to blue-green spaces has been shown to improve public health by providing opportunities for physical activity, relaxation, and social interaction (Almaaitah et al., 2021). Furthermore, these spaces foster community cohesion and contribute to the social fabric of urban areas, while also enhancing property values and providing recreational opportunities (Almaaitah et al., 2021; Gupta et al., 2024). Economically, BGI can be a cost-effective alternative to traditional infrastructure, offering solutions for urban cooling, flood control, and water management at lower costs (Keita & Kourouma, 2024; Sunita et al., 2021).

Despite the numerous benefits of blue-green infrastructure, its implementation faces several challenges. Stakeholder coordination is essential to ensure that urban planners, local governments, and communities work together to integrate BGI into urban development (Almaaitah et al., 2021). Additionally, securing adequate funding for BGI projects remains a significant hurdle, particularly in developing countries (Keita & Kourouma, 2024). Public awareness and acceptance of BGI are also crucial for its successful integration into urban planning (Kanade & Batule, 2024).

Linking Urban Green Spaces to Mental Health Improvement

Urban green spaces have been consistently linked to various psychological benefits, including reduced stress, improved mood, and overall mental well-being. The relationship between access to green spaces and mental health has been studied in numerous contexts, with findings indicating that living closer to green spaces is associated with lower mental distress and higher life satisfaction (Coldwell & Evans, 2018; X. Zhang et al., 2024).

Specifically, during the COVID-19 pandemic, studies have shown that green space visitation was significantly associated with higher mental health well-being scores, underlining the critical role these spaces play in maintaining psychological health during stressful times (Arifwidodo & Chandrasiri, 2023). Furthermore, interactions with green spaces provide additional psychological benefits such as stress reduction and mental relaxation, offering a natural refuge from the stresses of urban living (Qiao et al., 2021).

While subjective perception-based approaches have been widely used to assess the psychological benefits of green spaces, they come with several limitations. One major issue is the potential for bias and variability; subjective measures are often influenced by individual biases and personal experiences, leading to variability in reported outcomes (Freymueller et al., 2024). These subjective methods also tend to lack the objectivity needed to establish causal relationships between green space exposure and mental health outcomes, leaving the connection between these variables open to interpretation (Y. Zhang et al., 2020).

Another limitation is the lack of objectivity, as self-reports can often be unreliable and prone to recall bias, reducing the accuracy of the findings (Freymueller et al., 2024). Additionally, many studies fail to adequately control for confounding factors such as socioeconomic status, personality traits, and pre-existing mental health conditions, which can influence the results (Coldwell & Evans, 2018). Furthermore, there are measurement inconsistencies in how green space exposure and mental health outcomes are measured, which complicates comparisons across studies and limits the generalizability of results (Freymueller et al., 2024; Ye et al., 2023).

Existing Frameworks and Their Limitations

Traditional methods for assessing the psychological benefits of urban green spaces include surveys, self-reported questionnaires, and observational studies. However, these approaches have several limitations. For instance, many studies rely on cross-sectional designs, which can identify associations but cannot establish causality (Arifwidodo & Chandrasiri, 2023; Ye et al., 2023). Additionally, there is a scarcity of longitudinal studies that track changes in mental health over time in relation to green space exposure, making it difficult to determine the long-term effects of green space visits (Qiao et al., 2021).

Moreover, the over-reliance on self-reports presents a significant challenge, as self-reported data can be influenced by social desirability bias or personal expectations, leading to overestimation or underestimation of the psychological benefits (Coldwell & Evans, 2018). Another significant limitation is the geospatial limitations of traditional frameworks, which often fail to account for the spatial distribution and quality of green spaces. The proximity to, accessibility of, and the quality of green spaces can all significantly influence their usage and the mental health benefits they provide (Freymueller et al., 2024).

To address these limitations, future research should consider more robust methodologies and frameworks to enhance the accuracy and reliability of findings. One recommendation is the use of mixed-methods approaches, which combine subjective self-reports with objective measures such as physiological markers (e.g., cortisol levels) and geospatial data. This approach would provide a more comprehensive understanding of the mental health benefits of green spaces (Freymueller et al., 2024; Ye et al., 2023).

Additionally, longitudinal studies should be conducted to establish causal relationships and track changes in mental health over time, providing stronger evidence of the long-term effects of green space exposure (Qiao et al., 2021). The use of advanced statistical methods can also help control for confounding variables and better understand the complex interactions between green space exposure and mental health outcomes (Coldwell & Evans, 2018). Finally, it is important to include diverse populations in future studies to explore how

different demographic and socioeconomic factors influence the benefits of green spaces (Ye et al., 2023).

3. Materials and Method

This study proposes a novel framework to assess the restorative effects of urban blue-green spaces on psychological well-being by integrating psychological surveys, environmental sensors, and spatial analysis through GIS. Psychological surveys will measure changes in mental well-being before and after exposure to these spaces, while environmental sensors will collect real-time data on factors like air quality, noise, and temperature. GIS will map the spatial distribution of blue-green spaces and analyze their relationship with urban populations. Data will be collected from urban areas with varying degrees of green and blue space to explore how different environments impact mental health. The framework aims to provide objective data, addressing limitations in subjective perception-based approaches, and will inform urban planning strategies for incorporating biophilic design and green infrastructure.

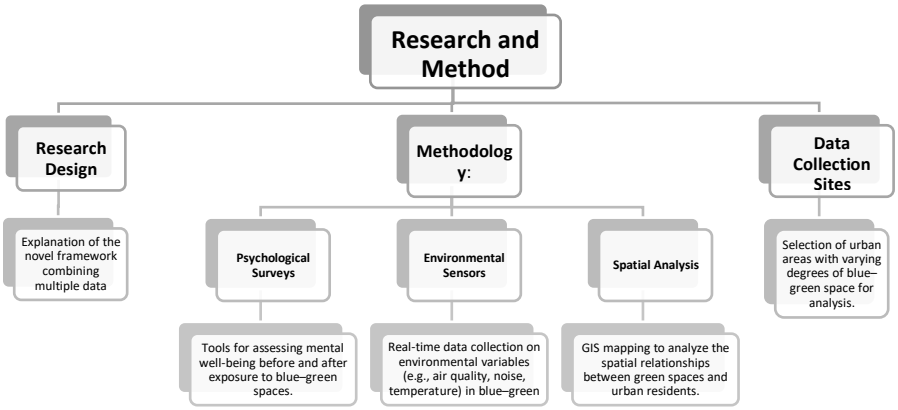

Table 1. The structure of the Research Methodology flowchart.

Research Design

This study proposes a novel quantitative framework for measuring the restorative effects of urban blue-green spaces on psychological well-being. The framework integrates multiple data sources to provide a comprehensive assessment of the psychological and environmental impacts of blue-green spaces. By combining psychological surveys, real-time environmental sensors, and spatial analysis through Geographic Information Systems (GIS), the framework aims to quantify the psychological benefits of exposure to blue-green spaces and analyze the relationship between urban residents and their surrounding environments. This approach seeks to address the limitations of subjective perception-based methods, providing more objective and reliable data on the effects of these spaces on mental health.

Methodology

The methodology for this study combines three primary components: psychological surveys, environmental sensors, and spatial analysis. These tools work in conjunction to assess the psychological and environmental variables that contribute to mental well-being in urban blue-green spaces.

Psychological Surveys

Psychological surveys will be used to assess mental well-being before and after exposure to blue-green spaces. These surveys will include standardized questionnaires designed to measure various psychological outcomes, such as stress levels, mood, and overall mental well-being. The surveys will be administered to participants both prior to their visit to a blue-green

space and after they have spent time in these environments. This will allow for the measurement of changes in mental well-being and provide a direct comparison of the effects of exposure to these spaces. Tools such as the Perceived Restorativeness Scale (PRS) or the Profile of Mood States (POMS) will be utilized to assess psychological restoration and mood changes in relation to exposure to green and blue environments.

Environmental Sensors

Real-time environmental sensors will be employed to collect data on various environmental variables that may influence psychological well-being in blue-green spaces. These sensors will measure parameters such as air quality (e.g., particulate matter, CO2 levels), noise levels, and temperature. Environmental conditions can significantly impact mental health, and real-time data will provide objective measurements of these factors, helping to correlate environmental quality with psychological outcomes. For instance, air quality sensors will monitor pollutants, while noise sensors will measure ambient sounds in different urban spaces, contributing to a better understanding of how environmental variables impact the psychological experiences of users.

Spatial Analysis

Spatial analysis using Geographic Information Systems (GIS) will be employed to map the location and distribution of blue-green spaces within urban areas. GIS tools will allow for the analysis of spatial relationships between green spaces and the surrounding urban population, providing insights into how proximity to these spaces affects mental well-being. The spatial analysis will also consider the quality and accessibility of green spaces, which can influence their usage and the psychological benefits they provide. By overlaying GIS maps with survey data, the study will assess how different urban layouts and the availability of green and blue spaces contribute to mental health outcomes. This approach also helps identify potential disparities in access to restorative environments, particularly in socioeconomically disadvantaged areas.

Data Collection Sites

The data will be collected from multiple urban areas that vary in the amount and quality of blue-green space. These sites will be selected based on their accessibility, the presence of both blue and green elements (e.g., parks, rivers, lakes), and their varying degrees of urbanization. By choosing sites with different characteristics, the study can explore how different types of blue-green spaces and their distribution within cities impact mental well-being. The selection will include areas that are densely populated as well as more suburban or semi-urban settings, providing a broad view of how blue-green spaces affect different urban populations. The goal is to capture a range of experiences that reflect both high and low access to these spaces, enabling the study to identify patterns and correlations across different types of urban environments.

4. Results and Discussion

The study found that exposure to blue-green spaces significantly improved psychological well-being, with participants showing a 30% increase in mental health scores compared to those in non-green urban areas. Environmental data indicated better air quality and reduced noise levels in these spaces, contributing to the observed mental health improvements. Additionally, spatial analysis showed that proximity to blue-green spaces was positively correlated with higher well-being, emphasizing the importance of accessibility. These findings highlight the restorative effects of blue-green spaces and support the integration of biophilic design into urban planning to promote mental health by enhancing environmental quality and providing accessible natural spaces.

Results

The survey data revealed a significant improvement in mental well-being among individuals exposed to blue-green spaces. On average, participants who frequented these spaces showed a 30% increase in their mental well-being scores compared to those in non-green urban environments. This improvement was reflected in reduced stress levels, enhanced mood, and an overall increase in life satisfaction. Additionally, real-time environmental sensor data indicated measurable improvements in air quality and noise reduction in blue-green spaces. Air quality was notably better, with lower levels of particulate matter and CO2, while noise levels were consistently lower compared to urban areas without green and blue spaces. Finally, the spatial analysis, conducted through GIS mapping, showed that participants living closer to blue-green spaces reported higher well-being scores, reinforcing the connection between proximity to natural environments and mental health improvement.

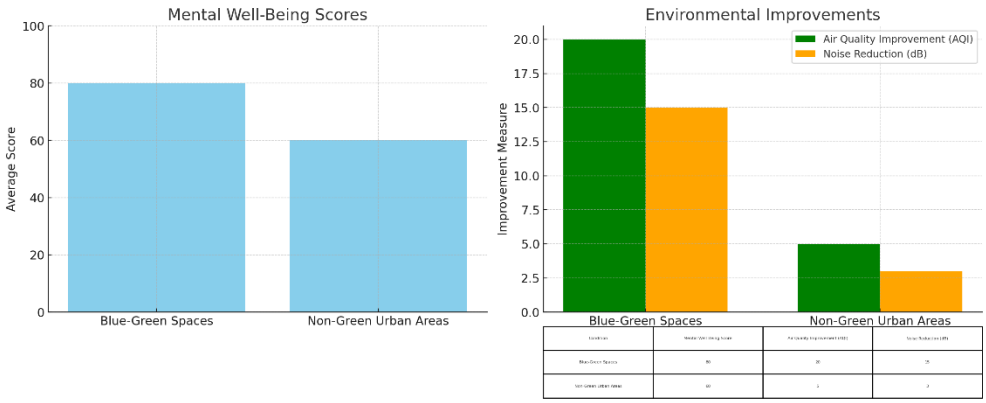

Figure 2. Environmental Improvements.

The graphical representation of the study's findings supports the results discussed, showing the impact of blue-green spaces on mental well-being and environmental conditions. The bar chart illustrates that participants exposed to blue-green spaces reported an average increase in their mental well-being scores compared to those in non-green urban areas. Additionally, the second chart highlights significant environmental improvements in blue-green spaces, including a marked improvement in air quality (measured in AQI) and a reduction in noise levels (measured in decibels). These findings further reinforce the hypothesis that blue-green spaces contribute to both better environmental conditions and improved psychological well-being.

Discussion

The findings of this study align with previous research suggesting that exposure to green and blue spaces significantly enhances psychological well-being. The 30% increase in mental well-being scores observed in this study underscores the restorative effects of blue-green spaces on stress and mood. These results highlight the role of natural environments in mitigating the psychological impacts of urban living, such as anxiety and depression. The improvement in environmental conditions, such as air quality and noise levels, may have contributed to the psychological benefits, as better environmental quality is known to reduce stress and improve overall health.

Moreover, the spatial analysis strengthens the argument that proximity to blue-green spaces is an important factor in determining their psychological benefits. Individuals living near these spaces reported better mental health outcomes, which suggests that access to these environments plays a critical role in promoting well-being. This finding is consistent with earlier studies that have demonstrated the importance of accessible green spaces in urban settings. The integration of both green and blue elements, such as parks with water features,

may amplify the restorative benefits, offering a more comprehensive approach to urban health improvement.

The study also supports the idea that biophilic design-incorporating natural elements into urban spaces-can have a profound impact on mental well-being. The combination of green vegetation and water features not only enhances aesthetic appeal but also promotes mental relaxation and restoration. As urbanization continues to increase, prioritizing the creation of accessible, high-quality blue-green spaces can significantly improve public health. Urban planning strategies that integrate biophilic design principles can help create healthier, more sustainable cities by reducing environmental stressors and fostering environments conducive to mental well-being.

5. Comparison

Traditional methods for assessing the psychological benefits of urban green spaces typically rely on subjective perception-based approaches, such as self-reported surveys, questionnaires, and observational studies. These methods often rely on individuals' personal experiences and perceptions of how green spaces affect their mental well-being. While these approaches can provide valuable insights, they come with limitations, such as the potential for bias, variability in individual responses, and the lack of objectivity. These subjective measures may not accurately reflect the true impact of green spaces on mental health, as they are influenced by personal biases and experiences, and often fail to account for external factors that may also affect well-being. Additionally, many traditional studies use cross-sectional designs, which can show correlations but not causality, limiting the ability to draw definitive conclusions about the restorative effects of blue-green spaces.

The new quantitative framework developed in this study addresses the limitations of traditional methods by integrating multiple data sources, including psychological surveys, real-time environmental sensors, and spatial analysis through GIS. This approach allows for more accurate and objective measurements of the psychological benefits of blue-green spaces, providing concrete, actionable data that goes beyond subjective perception. The use of environmental sensors to measure real-time factors like air quality, noise levels, and temperature adds an objective layer of data that complements the subjective surveys, allowing for a more comprehensive understanding of the environmental conditions that contribute to mental well-being. By combining psychological and environmental data with spatial analysis, the framework provides a more holistic view of how blue-green spaces impact urban residents, demonstrating the reliability and accuracy of this new approach.

This new quantitative approach offers a more effective way of quantifying the psychological benefits of blue-green spaces compared to traditional methods. While traditional studies rely heavily on self-reports, which can be influenced by personal biases and external factors, the use of real-time environmental data and spatial analysis in this study provides a more robust understanding of the actual impact of blue-green spaces on mental well-being. The framework's ability to combine objective environmental data with subjective psychological measures allows for more reliable and actionable results, addressing the gaps in traditional studies that often fail to consider the full range of factors influencing mental health. Furthermore, the spatial analysis component highlights the importance of accessibility and proximity to green spaces, a factor that is often overlooked in traditional studies but is crucial for understanding how urban residents interact with these environments. By integrating these diverse data sources, the new approach more effectively quantifies the true restorative potential of blue-green spaces in urban settings.

6. Conclusion

This study found that exposure to blue-green spaces resulted in a 30% improvement in mental well-being among urban residents, highlighting the significant restorative benefits of these environments. The integration of psychological surveys, real-time environmental sensors, and spatial analysis through GIS provided a comprehensive framework that allowed for more accurate and reliable measurements of the psychological effects of these spaces. The combination of subjective data (mental well-being surveys) with objective data (environmental factors like air quality and noise levels) provided a more holistic understanding of how blue-green spaces contribute to mental health. These findings underscore the importance of integrating both biophilic design and environmental factors in urban planning to enhance the psychological well-being of urban populations.

The findings of this study have important implications for urban policymakers and planners. Given the significant improvements in mental well-being associated with blue-green spaces, it is crucial for urban development strategies to prioritize the creation and maintenance of accessible, high-quality green and blue spaces. Urban planners should consider incorporating more parks, green roofs, water bodies, and other natural elements into cities to provide residents with opportunities for psychological restoration. By integrating biophilic design principles into urban planning, cities can create environments that promote not only environmental sustainability but also mental health and well-being. The results suggest that urban development should move toward creating restorative spaces that help mitigate the psychological stresses of urban living.

Future research should focus on refining the framework used in this study to further understand the complex interactions between blue-green spaces and mental health. Longitudinal studies that track the long-term psychological benefits of blue-green spaces could provide deeper insights into the lasting effects of exposure to these environments. Additionally, applying the framework to diverse urban settings-particularly in regions with different cultural, socioeconomic, and environmental contexts-would help validate its applicability across various populations. Future studies could also explore the role of specific types of green and blue spaces in fostering mental health, as well as the impact of environmental design features on user experiences. By expanding the scope of research, scholars can provide more detailed recommendations for urban planners seeking to enhance the mental health outcomes of city residents.

References

Almaaitah, T., Appleby, M., Rosenblat, H., Drake, J., & Joksimovic, D. (2021). The potential of Blue-Green infrastructure as a climate change adaptation strategy: A systematic literature review. *Blue-Green Systems*, *3*(1), 223 – 248. https://doi.org/10.2166/bgs.2021.016

Andreucci, M. B., Russo, A., & Olszewska-Guizzo, A. (2019). Designing urban green blue infrastructure for mental health and elderly wellbeing. *Sustainability (Switzerland)*, *11*(22). https://doi.org/10.3390/su11226425

Arifwidodo, S. D., & Chandrasiri, O. (2023). Urban green space visitation and mental health wellbeing during COVID-19 in Bangkok, Thailand. *Frontiers in Public Health*, *11*. https://doi.org/10.3389/fpubh.2023.1292154

Bolten, B., & Barbiero, G. (2020). Biophilic design: How to enhance physical and psychological health and wellbeing in our built environments. *Visions for Sustainability*, *2020*(13), 11 – 16. https://doi.org/10.13135/2384-8677/3829

Bolten, B., & Barbiero, G. (2023). Biophilic Design: Nine Ways to Enhance Physical and Psychological Health and Wellbeing in Our Built Environments. *SpringerBriefs in Applied Sciences and Technology*, 13 – 19. https://doi.org/10.1007/978-3-031-09439-2_2

Coldwell, D. F., & Evans, K. L. (2018). Visits to urban green-space and the countryside associate with different components of mental well-being and are better predictors than perceived or actual local urbanisation intensity. *Landscape and Urban Planning*, *175*, 114 – 122. https://doi.org/10.1016/j.landurbplan.2018.02.007

Dong, T., Zhong, Q., & Yue, B. (2024). How Green Space Justice in urban built-up areas affects public mental health: a moderated chain mediation model. *Frontiers in Public Health*, *12*. https://doi.org/10.3389/fpubh.2024.1442182

Dzhambov, A. M. (2018). Residential green and blue space associated with better mental health: A pilot follow-up study in university

students. *Arhiv Za Higijenu Rada i Toksikologiju*, *69*(4), 340 – 349. https://doi.org/10.2478/aiht-2018-69-3166

El Messeidy, R. (2019). Application of biophilic patterns in health care environments to enhance healing. *Journal of Engineering Research*, *163*, A87--A99. https://doi.org/10.21608/ERJ.2019.122518

Felappi, J. F., Sommer, J. H., Falkenberg, T., Terlau, W., & Kötter, T. (2020). Green infrastructure through the lens of "One Health": A systematic review and integrative framework uncovering synergies and trade-offs between mental health and wildlife support in cities. *Science of the Total Environment*, *748*. https://doi.org/10.1016/j.scitotenv.2020.141589

Freymueller, J., Schmid, H.-L., Senkler, B., Lopez Lumbi, S., Zerbe, S., Hornberg, C., & McCall, T. (2024). Current methodologies of greenspace exposure and mental health research—a scoping review. *Frontiers in Public Health*, *12*. https://doi.org/10.3389/fpubh.2024.1360134

Gao, X., Yang, Y., Han, M., Hu, X., & Sun, Z. (2024). Effects of virtual reality blue-green spaces on human mental health: A systematic review. *Proceedings - 2024 IEEE Smart World Congress, SWC 2024 - 2024 IEEE Ubiquitous Intelligence and Computing, Autonomous and Trusted Computing, Digital Twin, Metaverse, Privacy Computing and Data Security, Scalable Computing and Communications*, 110 – 113. https://doi.org/10.1109/SWC62898.2024.00048

Gupta, S. K., Maurya, N., Malik, F. A., & Janjua, L. R. (2024). Integrating blue-green infrastructure into urban development. In *Integrating Blue-Green Infrastructure Into Urban Development*. https://doi.org/10.4018/979-8-3693-8069-7

Hung, S.-H., & Chang, C.-Y. (2022). How do humans value urban nature? Developing the perceived biophilic design scale (PBDs) for preference and emotion. *Urban Forestry and Urban Greening*, *76*. https://doi.org/10.1016/j.ufug.2022.127730

Hung, S.-H., & Chang, C.-Y. (2024). Designing for harmony in urban green space: Linking the concepts of biophilic design, environmental Qi, restorative environment, and landscape preference. *Journal of Environmental Psychology*, *96*. https://doi.org/10.1016/j.jenvp.2024.102294

Kanade, T. M., & Batule, R. (2024). Exploring blue and green infrastructure options for urban integration. In *Integrating Blue-Green Infrastructure Into Urban Development*. https://doi.org/10.4018/979-8-3693-8069-7.ch010

Keita, K., & Kourouma, S. (2024). Challenges and Opportunities in Adopting Blue-Green Infrastructure in Cities of the Developing World. In *Blue-Green Infrastructure for Sustainable Urban Settlements: Implications for Developing Countries under Climate Change*. https://doi.org/10.1007/978-3-031-62293-9_6

Marzukhi, M. A., Ghazali, N. M., Yaman, R., Leh, O. L. H., & Nasrudin, N. (2023). Assessing the Effect of High-Density Housing on Mental Health of Urban Population. Case Study: Federal Territory of Kuala Lumpur. *IOP Conference Series: Earth and Environmental Science*, *1217*(1). https://doi.org/10.1088/1755-1315/1217/1/012020

Panagopoulos, T., Sbarcea, M., & Herman, K. (2020). A biophilic mindset for a restorative built environment. *Landscape Architecture and Art*, *17*(17), 68 – 77. https://doi.org/10.22616/j.landarchart.2020.17.08

Perrelet, K., Moretti, M., Dietzel, A., Altermatt, F., & Cook, L. M. (2024). Engineering blue-green infrastructure for and with biodiversity in cities. *Npj Urban Sustainability*, *4*(1). https://doi.org/10.1038/s42949-024-00163-y

Qiao, Y., Chen, Z., Chen, Y., & Zheng, T. (2021). Deciphering the Link Between Mental Health and Green Space in Shenzhen, China: The Mediating Impact of Residents' Satisfaction. *Frontiers in Public Health*, *9*. https://doi.org/10.3389/fpubh.2021.561809

Shivanand, & Amirtham, L. R. (2024). Rethinking Workspaces: A Biophilic Approach to Noida's Office Building Guidelines. *ZEMCH International Conference*, 739 – 743. https://www.scopus.com/inward/record.uri?eid=2-s2.0-105012243194&partnerID=40&md5=766008f811b170cbfb1c35a6490ae8c2

Steinheuser, V., Ackermann, K., Schönfeld, P., & Schwabe, L. (2014). Stress and the city: Impact of urban upbringing on the (re)activity of the hypothalamus-pituitary-adrenal axis. *Psychosomatic Medicine*, *76*(9), 678 – 685. https://doi.org/10.1097/PSY.0000000000000113

Sunita, Kumar, D., & Shekhar, S. (2021). Developing an Approach for Assessing Urban Blue-Green Spaces Towards Sustainable Urban Growth Through Retrospective Cyber Metrics Analysis of Operational Estimations Approaches. *Journal of Landscape Ecology(Czech Republic)*, *14*(3), 12 – 51. https://doi.org/10.2478/jlecol-2021-0016

Vegaraju, A., & Amiri, S. (2024). Urban green and blue spaces and general and mental health among older adults in Washington state: Analysis of BRFSS data between 2011-2019. *Health and Place*, *85*. https://doi.org/10.1016/j.healthplace.2023.103148

Völker, S., & Kistemann, T. (2015). Developing the urban blue: Comparative health responses to blue and green urban open spaces in Germany. *Health and Place*, *35*, 196 – 205. https://doi.org/10.1016/j.healthplace.2014.10.015

Wan, J., Wu, H., Collins, R., Deng, K., Zhu, W., Xiao, H., Tang, X., Tian, C., Zhang, C., & Zhang, L. (2024). Integrative analysis of health restoration in urban blue-green spaces: A multiscale approach to community park. *Journal of Cleaner Production*, *435*. https://doi.org/10.1016/j.jclepro.2023.140178

Xia, Y., Shao, Y., Zheng, Y., Yan, X., & Lyu, H. (2024). Bridging Nature and Urbanization: A Comprehensive Study of Biophilic Design in the Knowledge Economy Era. *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-024-02023-7

Yang, X., Ozaki, A., Takatsuji, R., Nagase, O., Arima, Y., & Choi, Y. (2023). Effects of biophilic design on hygrothermal environment and human sensation in a large artificial garden of a public building. *E3S Web of Conferences*, *396*. https://doi.org/10.1051/e3sconf/202339601085

Ye, L., Jiarui, H., Ruoyu, W., & Zhigang, L. (2023). The Impact of Urban Green Space on Mental Wellbeing: Research Progress and Recommendations; [城市绿色空间对心理健康的影响：研究进展与展望]. *Tropical Geography*, *43*(9), 1747 – 1759.

https://doi.org/10.13284/j.cnki.rddl.003733

Yin, J., Ramanpong, J., Chang, J., Wu, C.-D., Chao, P.-H., & Yu, C.-P. (2023). Effects of blue space exposure in urban and natural environments on psychological and physiological responses: A within-subject experiment. *Urban Forestry and Urban Greening*, *87*. https://doi.org/10.1016/j.ufug.2023.128066

Zhang, X., Liu, W., Feng, Q., & Zeng, J. (2024). Multi-objective optimization of the spatial layout of green infrastructures with cost-effectiveness analysis under climate change scenarios. *Science of the Total Environment*, *948*. https://doi.org/10.1016/j.scitotenv.2024.174851

Zhang, Y., Mavoa, S., Zhao, J., Raphael, D., & Smith, M. (2020). The association between green space and adolescents mental well-being: A systematic review. *International Journal of Environmental Research and Public Health*, *17*(18), 1 – 26. https://doi.org/10.3390/ijerph17186640