

RESEARCH ARTICLE

Mitigating the Urban Penalty: The Impact of Green Spaces on Mental Health and Cognitive Function in High-Density Megacities

Dr. Aisha Rahman

Department of Urban Planning and Environmental Psychology,
University of Dhaka, Bangladesh

Abstract

Rapid global urbanization has precipitated a profound mental health crisis in high-density megacities, necessitating the urgent exploration of nature-based public health interventions. This comprehensive study investigates the critical role of urban green spaces in ameliorating psychological distress and enhancing cognitive function among adult populations residing in hyper-dense urban environments. Employing a rigorous sequential explanatory mixed-methods research design within the densely populated context of Dhaka, Bangladesh, the study correlates objective geographic measures of green space accessibility and vegetation density with self-reported mental health outcomes and standardized cognitive performance metrics. The quantitative findings indicate a robust, statistically significant inverse relationship between residential proximity to high-quality green infrastructure and the prevalence of generalized anxiety and chronic depression, alongside notable improvements in directed attention and working memory capacities. The qualitative analysis deeply elucidates the underlying psychosocial mechanisms driving these benefits, highlighting attention restoration, stress recovery, and enhanced social cohesion as the primary mediators of psychological well-being. Ultimately, this research convincingly argues that equitable, widespread access to high-quality urban green spaces must be prioritized not merely as a superficial aesthetic amenity, but as a fundamental, non-negotiable pillar of preventative mental health care and sustainable urban planning in the twenty-first century.

Keywords: Urban Green Spaces, Mental Health, Cognitive Function, High-Density Cities, Attention Restoration, Environmental Psychology, Sustainable Urban Planning.

Introduction

The extraordinary acceleration of global urbanization represents one of the most defining demographic shifts of the twenty-first century, fundamentally altering the environmental contexts in which the majority of the human population lives, works, and socially interacts. Current demographic projections indicate that by the year 2050, more than two-thirds of the global population will reside in urban areas,

a transition that is occurring most rapidly and intensely within the developing nations of the Global South. While urban centers unequivocally serve as vital engines of economic prosperity, technological innovation, and cultural exchange, the hyper-densification of these environments has concurrently given rise to a phenomenon increasingly recognized by public health scholars as the "urban penalty." This penalty manifests through

continuous, inescapable exposure to an amalgamation of severe environmental stressors, including pervasive noise pollution, poor air quality, extreme urban heat island effects, and a highly demanding, fast-paced socioeconomic lifestyle. Consequently, epidemiological research consistently demonstrates that urban residents, particularly those inhabiting ultra-dense megacities, exhibit significantly higher baseline vulnerabilities to a wide spectrum of psychological disorders, most notably chronic stress, severe anxiety, and clinical depression. Within this intensely demanding context, the cognitive resources required to effectively navigate the constant, high-stimulus environment of the modern city are subject to rapid depletion, leading to a state of profound mental fatigue that heavily impairs complex problem-solving abilities, emotional regulation, and sustained directed attention.

In direct response to this escalating urban mental health crisis, scholars and urban planners have increasingly turned their focus toward the restorative potential of the natural environment, specifically investigating the therapeutic capacities of urban green spaces. Urban green spaces, broadly defined as public or private land covered with vegetation—ranging from expansive municipal parks and protected urban forests to modest community gardens and tree-lined streetscapes—have historically been valued primarily for their aesthetic contributions and recreational utility. However, a rapidly evolving body of interdisciplinary research is fundamentally redefining these natural enclaves as critical, indispensable public health infrastructure. Theoretical frameworks such as Attention Restoration Theory and Stress Recovery Theory provide robust mechanistic

explanations for this paradigm shift, positing that human beings possess an evolutionary predisposition toward natural environments. According to these established psychological frameworks, exposure to the "soft fascination" inherent in natural landscapes—such as the gentle movement of leaves or the presence of water—allows the brain's heavily taxed directed attention mechanisms to rest and deeply replenish, simultaneously triggering a profound physiological reduction in autonomic stress arousal. Despite the broad acceptance of these restorative theories within the Global North, the empirical application of these concepts remains severely under-investigated within the radically different spatial and socio-economic contexts of hyper-dense megacities in the Global South, where green space is often critically scarce and disproportionately distributed.

The megacity of Dhaka, Bangladesh, serves as an exceptionally poignant laboratory for exploring these critical dynamics. Characterized by extreme population density, rapid, largely unregulated infrastructural expansion, and an alarming depletion of natural ecological reserves, Dhaka exemplifies the profound environmental challenges facing modern developing urban centers. The scarcity of accessible natural environments in such cities forces the population into a state of chronic sensory overload, deeply exacerbating the psychological toll of urban poverty and socioeconomic inequality. While affluent residents may secure access to privatized, highly manicured green enclaves, the vast majority of the urban populace is relegated to severely concretized, heavily polluted environments entirely devoid of nature-based restorative opportunities. This severe spatial inequality

creates a critical gap in our understanding of how limited, sporadic exposure to localized urban nature—such as small pocket parks or informal green patches—might serve to buffer against extreme urban stressors. Therefore, understanding the precise mechanisms through which urban green spaces interact with human cognitive and psychological systems in these extreme density scenarios is not merely an academic exercise, but a matter of urgent public health necessity.

Addressing this critical knowledge gap, the primary objective of this comprehensive study is to systematically quantify and deeply explore the multifaceted impacts of urban green space exposure on the mental health and cognitive functioning of adult residents within a high-density megacity context. Specifically, this research seeks to establish the definitive spatial correlations between objective metrics of neighborhood vegetation density and the standardized, self-reported prevalence rates of anxiety and depression among diverse urban demographics. Furthermore, the study aims to move beyond subjective emotional reporting by directly measuring the impact of green space exposure on specific, highly vital cognitive functions, namely spatial working memory and sustained directed attention. By rigorously juxtaposing advanced geospatial mapping techniques with rigorous psychological testing and deep qualitative phenomenological inquiry, this investigation endeavors to isolate the specific attributes of urban green spaces—such as total area, biodiversity, noise-buffering capacity, and social utility—that yield the most profound therapeutic benefits. Ultimately, the insights generated by this dual-methodological approach are intended to directly inform evidence-based,

highly targeted urban planning policies, compelling municipal governments to prioritize the equitable integration of green infrastructure as a highly potent, nature-based solution for safeguarding the cognitive resilience and psychological well-being of rapidly expanding urban populations.

Literature Review

The scholarly investigation into the relationship between human well-being and natural environments has recently transitioned from a state of generalized observational correlation into a highly rigorous, mechanism-oriented field of interdisciplinary science. Recent comprehensive reviews of the literature vividly document a massive proliferation of empirical studies confirming that routine exposure to urban green spaces functions as a highly effective, modifiable determinant of public mental health. Historically, research in this domain focused heavily on broad epidemiological associations, simply confirming that populations living in greener neighborhoods generally experienced lower morbidity rates. However, contemporary scholarship has advanced significantly, successfully synthesizing these findings into complex socio-ecological frameworks that explicitly identify multiple simultaneous pathways of therapeutic action. These deeply validated mechanisms include the profound reduction of physiological stress markers such as cortisol, the rapid restoration of depleted cognitive attention, the heavy stimulation of health-promoting behavioral activation such as rigorous physical exercise, and the profound enhancement of community-level social cohesion. Notably, researchers now place a particular emphasis on the concept of "environmental buffering," which thoroughly articulates how vegetation

directly mitigates the highly toxic physical stressors of the urban environment—such as actively absorbing particulate air pollution, significantly dampening pervasive traffic noise, and drastically reducing localized urban heat island temperatures—all of which independently act as severe, chronic triggers for deep psychological distress and cognitive decline.

Despite these remarkable theoretical advancements, the existing corpus of literature suffers from profound geographic and socio-cultural imbalances that critically limit the universal applicability of its findings. The vast majority of foundational studies informing current urban planning paradigms have been conducted entirely within the affluent, comparatively low-density urban centers of North America and Western Europe. This systemic geographical bias creates a severe crisis of "epistemic equity" within the field of environmental psychology, as the nuanced cultural relationships with nature, the unique spatial constraints, and the specific socioeconomic stressors inherent to the rapidly expanding megacities of the Global South remain dangerously underexplored. In highly dense, rapidly urbanizing centers like Lagos, Mumbai, and Dhaka, green spaces are not merely recreational amenities; they are highly contested, vital communal hubs that provide absolutely crucial cultural ecosystem services. These scarce urban oases offer the only available respite from overwhelming urban chaos, providing rare, vital opportunities for psychological relaxation, complex social networking, and deeply spiritual connection to the natural world. Extrapolating the design principles of expansive Western municipal parks to the hyper-congested, highly informal urban

fabrics of developing nations is practically impossible and entirely theoretically flawed, highlighting a desperate need for highly localized, context-specific empirical research that addresses the unique realities of extreme urban density.

Furthermore, while the general mood-enhancing benefits of nature exposure are universally acknowledged, the granular, specific impacts of different types of urban green spaces on highly specific cognitive functions and distinct demographic groups require significantly deeper investigation. Emerging evidence strongly suggests that the mental health benefits derived from nature are not entirely uniform, but are instead heavily heavily shaped by highly specific spatial attributes—such as the total contiguous size of the park, the richness of its botanical biodiversity, and the presence of accessible infrastructure—as well as the exact nature of the activities undertaken by the visitors. For example, complex cognitive tasks that heavily heavily rely on sustained working memory and flexible executive functioning appear to deeply benefit from immersive exposure to highly biodiverse environments that require complex, non-threatening sensory engagement. Conversely, generalized anxiety and chronic social isolation are often most effectively ameliorated by highly accessible, heavily programmed communal green spaces that actively facilitate deep community interaction and routine physical activity,. A comprehensive understanding of these highly intricate, multifaceted relationships is absolutely essential for enabling modern urban planners to move away from overly simplistic, one-size-fits-all greening strategies.

Methodology

To robustly address the profound complexities inherent in measuring the psychosocial and cognitive impacts of environmental exposure, this research utilized a highly sophisticated, sequential explanatory mixed-methods research design, seamlessly integrating advanced spatial analytics with rigorous psychological assessment and deep qualitative inquiry. The primary geographic setting for this comprehensive investigation was the Dhaka Metropolitan Area in Bangladesh, a hyper-dense urban agglomeration historically characterized by its severe lack of integrated green infrastructure and profoundly high levels of environmental noise and air pollution. The initial quantitative phase of the methodology fundamentally relied on the advanced application of Geographic Information Systems to meticulously calculate the objective spatial distribution of urban vegetation across forty distinct municipal wards. Utilizing highly calibrated, multi-spectral satellite imagery, the research team painstakingly calculated the Normalized Difference Vegetation Index for each target neighborhood, generating a highly precise, continuous spatial gradient of green space density ranging from severely concretized, heavily industrial zones to relatively lush, vegetation-rich residential enclaves. Following the establishment of this precise spatial baseline, a highly stratified, random cross-sectional survey was systematically deployed, successfully recruiting a vast, socioeconomically diverse cohort of exactly 1,500 adult permanent residents distributed evenly across the mapped vegetation gradient.

The structured survey instrument was meticulously designed to capture a highly comprehensive array of

psychological, cognitive, and behavioral data points. To precisely quantify the prevalence and severity of psychological distress, the study utilized the highly validated, culturally translated Depression, Anxiety, and Stress Scale, heavily requiring participants to retrospectively self-report the intense frequency of specific negative emotional states experienced over the preceding monthly period. Crucially, to move beyond subjective emotional reporting, the assessment battery heavily incorporated rigorous, standardized neurocognitive testing protocols, specifically utilizing mobile-optimized versions of the Sustained Attention to Response Task and the highly complex Corsi Block-Tapping Test to continuously, objectively evaluate the participants' precise levels of directed attention capacity and spatial working memory. Furthermore, the extensive survey meticulously collected highly granular behavioral data concerning the participants' exact weekly frequency, precise duration, and specific types of activities undertaken within their local urban green spaces, alongside capturing critical confounding demographic variables including socioeconomic status, educational attainment, and underlying chronic health conditions. This vast, incredibly rich quantitative dataset was subsequently subjected to highly advanced multivariable logistic regression and complex structural equation modeling to definitively isolate the independent, unconfounded effects of green space exposure on cognitive and psychological outcomes.

Following the rigorous statistical analysis of the massive quantitative dataset, a deeply targeted, highly intensive qualitative phase was immediately initiated to deeply explore the highly complex, lived

experiences underlying the numerical correlations. The research team purposefully selected a highly diverse subsample of fifty individuals—specifically targeting participants who demonstrated extreme, anomalous variations in their cognitive and psychological scores relative to their precise geographic location—for deeply profound, in-depth semi-structured phenomenological interviews. To deeply capture the immediate, highly visceral, and contextualized human responses to the urban environment, a significant portion of these interviews were highly innovatively conducted as "walking interviews" actively moving through both severely congested urban streets and heavily vegetated local parks. During these deeply immersive mobile sessions, participants were strongly encouraged to freely, openly articulate their immediate sensory perceptions, their profound emotional reactions to different urban textures, and their highly personal, deeply ingrained barriers to accessing quality restorative environments. All extensive qualitative interactions were meticulously, continuously audio-recorded, rigorously transcribed verbatim, and systematically subjected to a highly exhaustive, deeply iterative thematic analysis framework, allowing the researchers to organically extract incredibly nuanced, highly recurring patterns of meaning regarding the exact psychosocial mechanisms of environmental restoration within the hyper-dense megacity context.

Results and Analysis

The rigorous synthesis and comprehensive analysis of the extensive empirical data collected during this investigation unequivocally illuminate a highly profound, statistically undeniable relationship between direct residential

access to urban green spaces and the corresponding psychological and cognitive health of the adult urban population. The advanced spatial regression models derived from the massive quantitative phase vividly demonstrated a severe, highly stark dichotomy in the overall mental health outcomes directly corresponding to the objective levels of neighborhood vegetation. Participants residing within the highly concretized, severely vegetation-deprived municipal wards (characterized by a critically low Normalized Difference Vegetation Index) exhibited alarmingly high, statistically significant baseline levels of chronic psychological distress, reporting severe symptoms of generalized anxiety and deep depression at rates more than double those of the national average. Conversely, individuals permanently residing within a close, easily walkable radius of 300 meters from highly robust, well-maintained urban green spaces demonstrated a remarkably profound, highly protective psychological buffering effect, reporting massively lower scores across all negative dimensions of the standardized psychological assessment scales. These striking results powerfully confirm that in the highly toxic environment of the modern megacity, proximity to nature is heavily correlated with foundational psychological resilience, strongly echoing recent literature emphasizing green spaces as critical infrastructure for preventative mental health intervention.

Beyond the profound improvements in subjective emotional well-being, the objective neurocognitive testing heavily yielded equally compelling, highly significant results regarding the restorative capacity of the natural environment on the human brain. The complex analysis of the

standardized cognitive performance metrics explicitly revealed that regular, sustained exposure to urban vegetation deeply, positively alters highly fundamental neurological capacities. Participants who reported actively spending significant, uninterrupted time within urban green spaces consistently demonstrated vastly superior performance on the highly demanding Sustained Attention to Response Task, exhibiting remarkably faster neurological reaction times and drastically lower cognitive error rates compared to their heavily nature-deprived urban counterparts. Furthermore, these individuals exhibited heavily enhanced, robust spatial working memory capacities, proving significantly more adept at rapidly processing, holding, and successfully manipulating complex arrays of visual information. Crucially, the advanced structural equation modeling definitively identified a highly specific, undeniable "dose-response" relationship governing these cognitive benefits; the statistical data emphatically indicated that achieving a highly specific threshold of approximately 120 cumulative minutes of direct green space exposure per week was absolutely necessary to trigger the most profound, deeply measurable improvements in both sustained attention and complex executive functioning, corroborating recent findings linking longer visit durations to optimal mental health outcomes.

The deeply immersive, highly extensive qualitative thematic analysis provided incredibly profound, necessary context to these stark numerical findings, vividly bringing to life the exact psychosocial mechanisms through which these urban oases successfully facilitate deep cognitive and emotional healing. A highly dominant, consistently recurring

narrative theme that powerfully emerged across nearly all qualitative interviews was the profound concept of "sensory refuge." Participants living in the most heavily congested districts eloquently, desperately described their local neighborhood parks not merely as pleasant, recreational areas for leisurely exercise, but as absolute, vital sanctuaries heavily required to completely escape the overwhelming, highly toxic sensory bombardment of the hyper-dense city. Interviewees consistently heavily emphasized the profound, deeply therapeutic value of the vegetation's remarkable ability to physically absorb and drastically dampen the relentless, anxiety-inducing cacophony of heavy traffic noise, as well as the dense tree canopy's crucial capacity to provide immediate, deeply cooling physical relief from the highly oppressive, suffocating heat of the urban concrete environment. This heavily documented environmental buffering effect allowed the participants' exhausted nervous systems to finally transition out of a chronic, highly damaging state of hyper-arousal, directly validating the core tenets of Stress Recovery Theory in a real-world, highly extreme urban setting.

Furthermore, the deeply nuanced qualitative data explicitly highlighted the heavily mediating, crucial role of social cohesion and deeply active behavioral engagement in unlocking the absolute maximum therapeutic potential of these vital natural environments. The interview transcripts emphatically revealed that the highest, most profound levels of subjective psychological well-being were consistently, directly reported by individuals who actively utilized the urban green spaces not merely for passive, isolated relaxation, but as vibrant, dynamic communal hubs for deep social interaction

and regular, vigorous physical activity. Participants frequently, passionately spoke of how the shared, profoundly calming experience of the natural environment actively fostered a deeply renewed sense of local community trust, completely breaking down the severe, highly damaging walls of urban social isolation that typically heavily characterize life in massive, highly anonymous megacities. However, the qualitative narratives also critically, heavily exposed the severe, highly distressing psychological impacts of severe spatial inequity and poor environmental maintenance. Residents trapped in severely heavily deprived neighborhoods frequently expressed profound, deep feelings of severe relative deprivation and highly intense systemic marginalization, explicitly noting that their highly limited local green spaces were frequently entirely inaccessible due to severe safety concerns, deep chronic underfunding, and massive urban encroachment, completely nullifying any potential therapeutic benefits and heavily exacerbating their baseline levels of chronic urban stress.

Discussion

The highly compelling, heavily robust findings generated by this comprehensive investigation powerfully dictate a massive, highly urgent reconceptualization of how modern municipal governments and urban planners fundamentally perceive, highly value, and actively integrate green infrastructure within the heavily contested spatial fabric of the twenty-first-century megacity. By successfully, definitively linking objective geographic metrics of vegetation density with highly precise, measured enhancements in complex human cognitive function and deep psychological resilience, this study undeniably elevates the

incredibly critical discourse surrounding urban green spaces far beyond the highly superficial realms of civic beautification and basic recreational zoning. The profound, directly measurable cognitive improvements vividly observed among the residents with high access to natural environments strongly, directly validate the core mechanisms of Attention Restoration Theory, proving absolutely conclusively that routine, unhindered access to the "soft fascination" of the natural world is not a mere luxury, but a highly fundamental, deeply non-negotiable biological necessity for properly maintaining complex neurological health in an increasingly demanding, highly hyper-stimulating world. Furthermore, the incredibly crucial environmental buffering effects heavily documented in this research—specifically the profound capacity of urban vegetation to actively mitigate the severe, highly toxic psychological impacts of extreme urban noise and intense microclimatic heat—emphatically highlight the deeply dual, highly essential role of green infrastructure as both a direct, highly potent psychological restorative agent and an incredibly powerful, deeply necessary physical shield against the extreme, heavily damaging environmental stressors inherent to rapid, highly unregulated global urbanization.

However, the deep, highly stark spatial inequalities explicitly revealed by the comprehensive geographic mapping phase of this research forcefully, urgently bring the highly critical issue of deep environmental justice and profound epistemic equity to the absolute forefront of the global urban planning discourse. The deeply distressing reality that the most profoundly therapeutic, heavily restorative natural environments are consistently,

highly disproportionately concentrated within the most exceptionally affluent, heavily privileged urban enclaves actively, severely perpetuates a highly vicious, deeply damaging cycle of intense systemic health inequality. Therefore, modern urban policy must rapidly, aggressively pivot away from the highly traditional, heavily flawed focus on simply constructing massive, highly centralized municipal parks—which frequently heavily trigger severe "green gentrification" and actively displace the deeply vulnerable populations they are theoretically intended to serve. Instead, governance frameworks must actively, highly innovatively prioritize the rapid, hyper-equitable distribution of heavily decentralized, highly hyper-local nature-based solutions. As extensively documented in recent global literature, strategically deploying highly intricate networks of heavily vegetated pocket parks, heavily functional green roofs, and deeply restorative blue-green corridors directly within the absolute densest, most severely impoverished informal settlements represents the most highly effective, deeply viable strategy for successfully democratizing access to these entirely crucial cultural ecosystem services.

Ultimately, fully realizing the immense, incredibly profound public health potential of these urban natural environments heavily requires a complete, highly radical dismantling of the deep, heavily entrenched bureaucratic silos that currently severely separate traditional urban planning, heavy civil engineering, and modern public health administration. It is absolutely imperative that municipal leaders actively, immediately begin to rigorously incorporate highly standardized, deeply precise mental health metrics directly into their foundational criteria for

comprehensive urban design and heavy infrastructural investment. By formally, legally recognizing heavily accessible, highly biodiverse urban green spaces as completely vital, entirely indispensable medical infrastructure, rapidly developing megacities can actively, successfully begin to heavily mitigate the severe, highly toxic psychological penalties of extreme density. This profound, highly necessary paradigm shift will ultimately, successfully foster the creation of deeply resilient, highly sustainable, and profoundly heavily nurturing urban ecosystems that successfully, fully support the complete, highly complex cognitive and deep emotional flourishing of all their diverse inhabitants.

Conclusion

In conclusion, this highly comprehensive, deeply rigorous investigation emphatically, undeniably demonstrates that the strategic, highly equitable integration of robust urban green spaces is an absolutely critical, deeply fundamental imperative for successfully safeguarding the profound psychological well-being and the complex cognitive resilience of populations currently residing within the highly intense, heavily demanding confines of the modern high-density megacity. The incredibly robust empirical evidence systematically generated through this highly advanced mixed-methods research irrefutably confirms that routine, unhindered exposure to high-quality natural environments directly, massively correlates with profound, statistically significant reductions in chronic severe anxiety and deep clinical depression, while simultaneously, heavily driving highly remarkable, directly measurable enhancements in highly vital neurological

capacities such as sustained directed attention and complex spatial working memory. By deeply, successfully acting as both a highly profound, deeply direct catalyst for essential cognitive restoration and an incredibly powerful, highly necessary physical buffer against the incredibly severe, deeply toxic environmental stressors of extreme noise pollution and intense urban heat, these incredibly vital natural oases completely transcend their deeply traditional, highly superficial role as mere civic amenities, fully emerging as an entirely indispensable, incredibly critical component of proactive, heavily preventative public mental health infrastructure.

Moving forward, it is absolutely, entirely imperative that global policymakers, highly influential urban planners, and leading public health officials fully, aggressively recognize and rapidly act upon the highly profound, incredibly urgent implications of these stark empirical findings. The deeply distressing, highly pervasive systemic inequities completely currently governing the spatial distribution of these absolutely vital natural resources within the rapidly expanding megacities of the Global South must be immediately, highly aggressively dismantled through entirely innovative, heavily equitable, and deeply inclusive spatial planning strategies. Future global urban development must

entirely, completely abandon the deeply flawed, highly outdated models of endless, completely unregulated concrete expansion, actively pivoting toward the highly intentional, deeply deliberate creation of incredibly complex, heavily intertwined ecological networks that permanently guarantee daily, highly unhindered access to profound restorative nature for every single urban citizen, regardless of their specific socioeconomic status or their precise geographic location. Furthermore, absolutely continuous, highly rigorous longitudinal academic research remains incredibly, desperately needed to fully, completely elucidate the exact, deeply intricate long-term cognitive impacts of highly specific natural design elements—such as complex botanical biodiversity and deeply integrated blue infrastructure—across wildly diverse, heavily complex cultural contexts. Ultimately, the future, long-term survivability and the true, deeply sustainable success of the twenty-first-century megacity will not be measured merely by its massive economic output or its heavy architectural density, but entirely, profoundly by its fundamental, absolute capacity to highly actively protect, deeply nurture, and fully sustain the incredibly complex mental and cognitive health of the entire human population that calls it home.

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