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A Theoretical Framework for Bolstering Human-Nature Connections and Urban Resilience via Green Infrastructure

Jackie Parker [1,2,*] and Greg D. Simpson [1]

[1] Environmental and Conservation Sciences, College of Science, Health, Engineering and Education, Murdoch University, South Street, Perth, WA 6150, Australia; g.simpson@murdoch.edu.au

[2.] Manager of Parks, Leisure and Environment, City of Belmont, 215 Wright Street, Perth, WA 6105, Australia

* Correspondence: Jacqueline.Parker@murdoch.edu.au

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Abstract: Demand for resources and changing structures of human settlements arising from population growth are impacting via the twin crises of anthropogenic climate change and declining human health. Informed by documentary research, this article explores how Urban Resilience Theory (URT) and Human-Nature Connection Theory (HNCT) can inform urban development that leverages urban green infrastructure (UGI) to mitigate and meditate these two crises. The findings of this article are that UGI can be the foundation for action to reduce the severity and impact of those crises and progress inclusive and sustainable community planning and urban development. In summary, the URT promotes improvement in policy and planning frameworks, risk reduction techniques, adaptation strategies, disaster recovery mechanisms, environmentally sustainable alternatives to fossil fuel energy, the building of social capital, and integration of ecologically sustainable UGI. Further, the HNCT advocates pro-environmental behaviors to increase the amount and accessibility of quality remnant and restored UGI to realize the human health benefits provided by nature, while simultaneously enhancing the ecological diversity and health of indigenous ecosystems. The synthesis of this article postulates that realizing the combined potential of URT and HNCT is essential to deliver healthy urban settlements that accommodate projected urban population growth towards the end of the 21st-century.

Keywords: climate change; green infrastructure; human health, human-nature connection theory; urbanization; urban resilience theory

1. Introduction

Over the past two centuries, urbanization has changed the relationship that urban dwellers share with the surrounding environment [1–2]. Resultant are adverse effects, with some proving to be devastating to urban communities and indigenous ecosystems [3–10]. Urban centers are now gripped by two crises, exacerbated by a cascade of factors related to the short term doubling of the global human population, rapid urbanization of humanity, unsustainable lifestyle choices, short-term economically focused development, and the resultant changes in the structure of human settlements [5–10]. Those twin crises are anthropogenic climate change (hereafter referred to simply as climate change) and declining human health in urbanized populations [11–13]. Following a short exploration of those crises in the urban context, this article postulates that the Urban Resilience Theory (URT) and the Human-Nature Connection Theory (HNCT) provide complementary opportunities to mitigate and mediate the drivers and impacts of those two crises.

Informed by the reviews of Parker [14–18] and others [19–20] and the key research over the past decade delivered by Lovell and Taylor [5], Tzoulas et al. [7], Mathey et al. [8], Norton et al. [9], Meerow, Newell and Stults [10], and Burley [12]; a gap is apparent in the existing literature with

respect to applying a complementary combination approach to the implementation of the URT and HNCT in urban centers. The novel approach of integrating the application of those two theories posited in this article addresses this gap in the literary discourse and positively contributes to the refocusing and amendment of the unsustainable development many urban centers are currently pursuing. As such, the conceptual model proffered later in this article postulates that the integration of URT and HNCT to inform the provision of accessible, quality UGI will produce urban centers that can alleviate climate change impacts and declining human health for the betterment of current and future generations.

Explicitly defining the URT and the HNCT is problematic given the breadth of disciplines those theories transect, meaning that definitions are highly contested in current literature [19–22]. Both theories move beyond *Homo sapiens* merely surviving within urban centers, to thriving as humans, communities, and cities in coherence with the surrounds [11]. Recently redefined by Romero-Lankao et al. [11] (p. 2), a combined approach to URT and HNCT seeks to: "develop strategies for environmental protection, economic prosperity, inclusivity, and community wellbeing, while increasing their cities' resilience to both chronic and acute physical, social, and economic challenges."

In practice, urban resilience relates to the ability of an urban center to withstand and recover in the event of a shock such as a natural disaster, terrorist attack, economic failure, or pandemic [19]. With the ability to recover from a city-scale shock being one measure for the level of urban resilience, Hobor [19] reports that urban resilience was closely linked to the economic history of a city, as recovery and adaption requires significant financial and infrastructure resources. More recently, urban resilience, in the context of community planning and urban development, is becoming increasingly integrated with higher considerations of human health and wellbeing [23]. Economic factors, social factors, and the intersecting socio-economic factors, play a larger role in recovery efforts, and therefore the resilience of urban centers.

Human-nature connection is a cognitive, emotional, spiritual, and biophysical attachment or affinity that humans feel for natural places [20–21]. Humans can connect to nature at local, regional, national, or international scales, or connections may be location non-specific (i.e., a connection to water or nature at large). Two grains exist for human-nature connection reported within the literature; fine and coarse. Fine grain connections arise from personal nature experiences, interactions with features within a natural setting, and/or direct interactions with the land, (i.e., gardening or farming) [20]. Coarse grain connections come from cultural significance, cultural landscapes, and broader place attachments [20,22]. Human-nature connections have changed over the past few decades [2,21,24]. The change in this relationship, within the context of declining human mental and physical health of urbanized human populations, has sparked the interest of researchers across many disciplines [14,25–26].

This high-level synthesis opens dialogue around the overlapping contribution that application of those two theories make to urban planning and building urban communities as humanity looks towards the second half of the 21st-century. To that end, the specific purpose of this article is to:

1. Summarize the challenges that the twin crises of climate change and declining health pose for urbanized human populations.
2. Highlight the identified gap in research regarding a combined approach to the implementation of the URT and the HNCT.
3. Set an agenda for future URT and HNCT grounded research that explores how UGI can contribute to inclusive community planning and sustainable urban development as humanity realigns and refocuses on the 21st-century and beyond.

2. Methods and Application

The synthesis presented in this article is informed and inspired by the extensive systemic literature reviews and the UGI research that is reported in several earlier articles by the authors [2,14–18,22,26].In addition, 32 globally focused review articles and 20 geographically specific UGI research articles are directly cited to support the synthesis presented in this article (Tables 1 and 2 below).

Further, a summary of the geographic scope and UGI research focus of the case study, empirical, and documentary research reported in those publications is presented in Appendix A (Tables A1 to A4).

As such, this article is not a systematic. Rather, it is aligned to the "narrative meta-review" of Nieuwenhuijsen [27] (p. 2) that was constructed "around a number of cutting edge and visionary studies on urban…planning and health reported in the literature over the past few years". However, this article goes beyond providing a meta-review to postulate a new conceptual model for the combined application of URT and HCNT in relation to the provision of accessible, high-quality UGI. As highlighted in the introduction, it is the premise of this article that utilization of that combined model of URT and HCNT can provide a UGI-based response to the crises of climate change and declining human health in the face of the rapid urban population growth.

Cognizant of the multifaceted approach that Rist [28] championed for social research undertaken to influence the policy process, the documentary research [29–35] that underpins this article builds on the knowledge reported in the aforementioned literature to scope the key peer reviewed URT and HNCT literature. On the basis of that research, the URT and the HNCT have not previously been connected in other peer reviewed literature.

In addition to summarizing the breadth of research that underpins the proposition of this article that an integrated model of the URT and the HNCT can help urban centers to respond to the challenges of climate change and declining human health, Tables A1 to A3 also provide evidence that supports the global applicability of that proposition. From the outset, this project was structured to avoid a Euro or Western centric filter, which was aided by the scholarship regarding urban centers reporting the globalization of Western approaches to urban development for creating cities to accommodate increasingly urbanized human populations [34–46], (Tables A1 to A3).

3. Challenges for Urban Centers

3.1. The Climate Change Crisis

With most global energy and steel production requiring burning of fossil carbon stores/fuels, the increase in the human population is driving an increase in greenhouse gas emissions [46–47]. As greenhouse gases exceed the natural stable state operating volumes, documented devastating effects of climate change are becoming ever more apparent [46–47]. Tipping-point events currently observable include the accelerated melting of the Arctic Tundra, Greenland Ice Sheet, and Polar Icecaps creating feedback loops that further exacerbate global warming [46–47].

While severity in impact is geographically dependent, the rapidly warming climate is: changing global climate patterns of normal and extreme weather events (i.e., rainfall, wind patterns, and storm frequency and tracks); affecting the biophysical and ecological function of agricultural and natural systems; and is causing micro and macros scale displacement and extinction of flora, fauna, and human populations [48–49].

3.2. The Crisis for Declining Health in Urban Populations

Despite predictions from theorists such as Thomas Malthus in 1798 that humanity would double every 25 years [48], this only occurred during a short window in the late 20th and early 21st centuries [48]. Otherwise, human population growth has not been uniform in either a temporal or a geographical context, nor has it always trended in positive direction. World War One (1914–1918), World War Two and the associated Holocaust (1939–1945), and The Great Famine (1959–1961) are examples of periods when the global human population measurably declined [49–52]. The human population reached 800 million during the Industrial Revolution, but took until the early 1800's to reach 100 million and was 1.6 billion at the start of the 20th-century, had grown to 6 billion at the dawn of the 21st century, currently sits at (pre-COVID-19 pandemic projections) 7.8 billion, and is projected to reach 9.5 billion by 2050 [49–52]. Reflecting the slowing trend of global population growth that has been evident since the 1950s, humanity is predicted to only grow by 1 billion people between 2050 and 2100 to start the 22nd Century at 11.2 billion on pre-COVID-19 pandemic projections [49–52].

While populations of some long-established cities are shrinking because of the demographic transition and/or economic migration [49–52], humanity became an increasingly urbanized species during the 20th-century, and that trend is predicted to continue until 2100. Approximately one quarter of the human population (1.95 billion people) lived in urban centers at the start of the 20th-century [51–54]. Further, urban populations are predicted to more than double by the end of the century, with the current level just over 4 billion people (55% of all humans) growing almost 6.5 billion in 2050 (68% of humanity) to reach to 9.5 billion people (85% of the global human population) by 2100 [51–56].

That rapid change in lifestyle has resulted in human disconnection from nature, with little opportunity for adaptation to those changed circumstances [2,14,56–58].As a result, significant adverse health impacts, both physiologically and psychologically, are beginning to emerge [14,17–18]. Physiologically: cardiovascular health has decreased; diabetes has increased; obesity has increased; and biological intolerances have increased [14–15]. Psychologically: depression and anxiety have increased; cognition recovery ability has decreased; and stress related conditions have increased [6–7,12–14]. Human-nature disconnection is likely to have further effects that are not yet apparent, the subject of which is an area of growing interest for researchers and practitioners [14–16].

4. Framing of the Urban Resilience Theory

4.1. Origins and Perspectives of Urban Resilience Theory

Urban Resilience Theory research over the past two decades has been driven by growing environmental, social, and political uncertainty, combined with increased prevalence and severity of risks to urban centers [10]. Tensions arising from the ambiguity and disparity in defining the concept of resilience may go some way in explaining the limited application of the URT principles and teachings by decision makers [10]. To progress the definitional debate and improve wide adoption of the URT propositions, Meerow & Newell [10] (p. 315) proposed the following definition of urban resilience that is appropriate in the context of this article:

> "Urban resilience refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity ".

The URT emerged from the fields of ecology, engineering, and psychology [59–61]. Summaries in the applications of the term resilience in each of those fields appear below. Each perspective provides a unique contribution to the current understanding of URT. Given the multidisciplinary nature of URT, agreement on an explicit definition remains elusive, although all the published formulations share the notion of the ability of a system or urban center to bounce-back from external pressures, stresses, or shocks [11].

Ecological resilience has been defined as the amount of disturbance or pressure that an ecosystem is able to withstand without permanently changing self-organizing processes and structures [59]. The greater the capacity of an ecosystem to recover and adapt to stochastic changes in circumstance, the higher the resilience. An allied ecological theory with relevance to the crises reported in this article is the Alternative Stable State Theory [59–62]. This theory holds that a tipping point may be reached whereby the associated feedback that may not allow the system to recover/return to previous state.

With respect to engineering, the concept of urban resilience arose from the need to respond to new threats within modern society. Concentrating on infrastructure and networks, Bozza et al. [60] defined resilience to be the ability to recover, absorb, and restore equilibrium after a perturbation. From the engineering perspective, the original formulation for resilience was based on the idea that systems and networks need to realize a post-shock equilibrium position [60]. That perspective has evolved, and the current usage of the term resilience has moved towards a performance-based assessment of recovery and is thus seeking those assets and systems perform in the same capacity as

prior to the disturbance or shock [60]. In this context, resilience relates to the recovery of complex systems, which are usually composed of physical subsystems occurring in an urban context [60].

Psychological resilience is the ability to adapt to stress, significant challenges, or adversities, which may include challenging life events, acute trauma, and/or chronic adversity [61]. Those experiences have the potential to substantially impact on brain function and brain structure [61]. A lack of resilience becomes visible through the development of psychological responses such as anxiety, depression, and/or post-traumatic stress disorder [61]. This perspective strongly adheres to the notion of adaptation in pursuit of ongoing health.

4.2. Converting Theory to Practice

High density urban centers provide access and diversity of services, however also overcrowding, sensory overload, and increased levels of stress [23,62]. Samuelsson et al. [23] posit that greater consideration of resilience principles can improve planning and formation of policy for design and development of urban centers, with respect to densities and provision of services, by assessing opportunities and threats at a city scale.

Building on work by the Organization of Economic and Community Development and other stakeholders and researchers, the 2014 researcher of Kim et al. [63] proposed a new Green Growth model to assess the development and growth of urban centers. Kim et al. [63] recommended twelve indicators of sustainable urban development that include measures such as greenhouse gas emissions, energy use, energy sources, water asset usage, portion of land covered by forest, public transportation opportunities, and more [63].

The Green Growth Model is not dissimilar to the Sustainable Development Goals (SDG's) when looking forward to urban development principles and practices. The recommendations and conclusions within this research show the contributions of URT and HNCT making some way to support the SGD's for achievement by 2030. Examples of this are SDG 3 Good Health and Well-being, SDG 11 Sustainability Development and Communities, and SDG 13 Climate Action.

In line with the Green Growth Model and the SDG's, this new model lends itself to the approach of urban development that provides a socio-ecological focus, in contrast to traditional socio-economic approaches. In that context, URT proposes that greater concentration be placed on [64]:

1. Building and supporting the robustness of cities, systems, and networks;
2. Increasing the efficiency with which the city, system, or network can bounce-back or bounce-forward; and
3. Increasing the ability of practitioners to decentralize, predict opportunities, discontinue redundant practices, and provide transparent and authentic feedback to community and industry stakeholders.

However, potential problems with implementation of URT that are identified in current literature [62] include the:

1. Observed disconnect between researchers and practitioners;
2. Ambiguity surrounding the specific issues being addressed through the URT and the associated ambiguity in the plan to overcome those issues;
3. Broad scope of URT allowing both research and practitioners to use the concept as a buzzword, rather than applying the theory in genuine progression of urban resilience; and
4. Lack in the thorough understanding of resilience characteristics and therefore how to bolster the principles into new policy, strategy, planning, and implementation.

5. Framing of the Human-Nature Connection Theory

5.1. Origins and Perspectives of the Human-Nature Connection Theory

Many models and theories attempt to explain the relationship between humans and nature and the resulting impacts or benefits for human health. Models include the Environment of Health, the Mandala of Health, the Wheel of Foundational Health Need, the Healthy Communities, the One

Health approach, and more [63]. Each of those models attempt to describe the balance and interactions of the biological, social, and spatial influences of human-nature connections.

Through the milestones of urbanization, from ancient city states, through to the 20th-centruy, the connection of humans and nature has been the focus of origin stories and philosophical and scientific writings. Given the ongoing interest in HNCT and similarly the URT, a number of multidisciplinary perspectives inform our current understanding of how exposure to nature influences the health and welfare of human populations. Key perspectives that inform the HNCT are summarized below.

The environmentalism perspective suggests that humans traditionally had a relationship with nature being one of power and dominance, which is embedded in the Judeo-Christian belief systems that shaped Western civilizations [63-65]. That relationship has weakened over the past few decades, anticipated to reflect a natural balancing out between humans and the environment [63].

From an evolutionary biology perspective, culture-genetic interactions affect our lifestyle choices and thus our health. One example of such an interaction is that humans predominantly gain nutrition derived from food and farming processes [63]. Traditionally, humanity sourced food from farming the land and/or preparing food from natural ingredients that contained varied microflora [63]. For modern human populations living in urban centers, processed and packaged alternatives are now readily available and provide a larger proportion of food intake. Food tolerances and intolerances are suggested to be based largely on food choices, with reduced exposure to microbial activity increasing susceptibility to allergies [63]. An increased incidence of more extreme food-induced allergic reactions is one of the factors contributing to the crisis of declining health in urbanized human populations [63].

The evolutionary psychology perspective is founded on the apparent preference of humans for scenes dominated by nature and natural elements. Emerging only within the past few decades, this perspective suggests that human psychological characteristics are shaped and adapted based on the prevailing ecological and environmental conditions [24–25]. This perspective has delivered concepts that incorporate the inclusions of nature in self, deep ecology, extinction of nature experience, connectedness to nature, and the Biophilic Hypothesis [21,24].

5.2. Converting Theory to Practice

Embracing the HNCT to inform community planning and urban development practices can provide diverse opportunities to improve the security and quality of urban life.

These opportunities include [20–24]:

1. Incorporating nature into design principles and material pallets for commercial buildings, homes, public spaces, and other elements of the built environment [66];
2. Integrating plants, nature, and natural elements into everyday lives, work places/stations, and institutional settings such as hospitals and prisons;
3. Providing opportunities for renaturing and re-connecting with nature through implementation and improvement of the public UGI [66];
4. Restoring and revegetating degraded land and environmental assets such as lakes and riverine zones to assist urban dwellers to engage with nature;
5. Reclaiming abandoned and baron land for the purposes of public enjoyment and recreation as well as increasing biodiversity and other environmental functions; and
6. Advocating for improvements in public accessibility and opportunity for diverse nature experiences via public UGI, nature trails, green walls, green roofs, and more [66].

6. Setting the Scene for Green Infrastructure

The term green infrastructure appeared in the peer-reviewed literature and language of urban planning and management practices during the 1980s [16]. While initially highly contested, the term is now widely accepted in published literature and has generated significant research interest over the past decade [14,16]. The components of UGI encompass a broad range of assets, including green POS, urban trees, urban stormwater management, green roofs and green-walls, and many other

green assets [14,16,67]. A key aspect that distinguishes UGI from other forms of infrastructure (i.e., blue or grey) is the simultaneous delivery of social and environmental services and relief from the hard forms of the built environment [14,16,67].

Urban land managers already rely upon UGI assets, generally in the form of green POS, to deliver opportunities to urban dwellers to connect to nature and mediate the impacts of climate change [14,26]. Arguably the most prominent and widespread occurrence of UGI, green POS, is heavily relied upon to provide public health benefits [14,26]. There is a growing body of published research in which green POS users report and/or have demonstrated improved physiological and psychological health, a better outlook on life, enhanced cognitive recovery, because of the opportunities that quality green POS provides for exercise, recreation, relaxation, and reflection [14–15].

Table 1. Examples of urban green infrastructure offerings that could mitigate and/or meditate impacts arising from the crisis of climate change on urban centers.

Impact	Green Infrastructure Offering	Example References
Ambient temperatures warming faster than urban communities can adapt.	Urban trees, green POS elements, and other porous UGI surfaces reduce reflective and embedded heat, and provide evaporative cooling, which reduces ambient temperatures.	Lovell & Taylor, 2013 [5]; Li et al. 2018 [68]; Roe & Mell, 2013 [69]; Norton et al. 2015 [9]; Mathey et al. 2015 [8].
Increased frequency of extreme weather events	Urban trees act as barriers to extreme events such as wind, hail, and rain. Green POS elements and other porous UGI surfaces absorb rainfall and slow the wind.	Lovell & Taylor, 2013 [5]; Li et al. 2018 [68]; Roe & Mell, 2013 [69]; Norton et al. 2015 [9]; Mathey et al. 2015 [8].
Increased severity and unseasonal timing of storms	Urban tree canopy assists in capturing rain and reducing the velocity of rainfall, which reduces the impact. Green POS elements and other porous UGI surfaces absorb rainfall and slow the wind.	Lovell & Taylor, 2013 [5]; Li et al. 2018 [68]; Roe & Mell, 2013 [69]; Norton et al. 2015 [9]; Mathey et al. 2015 [8].
Flora displacement	Quality green POS and vegetated biofiltration systems can conserve and protect remnant and restored indigenous vegetation.	Lovell & Taylor, 2013 [5]; Cameron et al. 2012 [6]; Tzoulas et al. 2007 [7]; Mathey et al. 2015 [8]; Norton et al. 2015 [9].
Fauna displacement	Urban trees, green POS, green walls, and/or green roofs of remnant/restored indigenous vegetation provide fauna with habitat, food, and refuges.	Cameron et al. 2012 [6]; Tzoulas et al. 2007 [7]; Mathey et al. 2015 [8]; Norton et al. 2015 [9]; Meerow & Newell, 2017 [10].

In summary, the opportunities offered by UGI are becoming increasingly significant assets that support healthy communities and enhance liveability in urban centers. In addition, UGI has relevance in migrating and mediating the twin crises of climate change (Table 1) and declining human health (Table 2).

Table 2. Examples of urban green infrastructure offerings that could mitigate and/or meditate impacts arising from the crisis of declining human health in urban centers.

Declining Health Impacts	Green Infrastructure Offerings	Example References
Increase in anxiety disorders.	Contact with and experiences within quality remnant and restored nature spaces shown to reduce anxiety.	Burley, 2018 [12]; Suppakittpaisarn et al. 2017 [13]; Parker & Simpson 2018 [14]; Parker, 2017 [15]; Cameron et al. 2012 [6]; Mekala et al. 2014 [70]; Tzoulas et al. 2007 [7]; Mathey et al. 2015 [8]; Heckert & Rosan, 2018 [71]
Increase in depression.	Contact with and experiences within quality nature spaces shown to reduce depression. Quality public open spaces (POS) also provide opportunities for recreation and socialization, which is known to reduce depression.	Burley, 2018 [12]; Suppakittpaisarn et al. 2017 [32]; Parker & Simpson 2018 [14]; Parker, 2017 [15]; Cameron et al. 2012 [6]; Mekala et al. 2014 [70]; Tzoulas et al. 2007 [7]; Mathey et al. 2015 [8]; Heckert & Rosan, 2018 [71]
Increase in stress related illness	Contact with and experiences within quality remnant and restored nature spaces shown to reduce stress and therefore reduce stress related illness. Quality POS also provide opportunities for recreation and socialization, which is known to reduce stress.	Suppakittpaisarn et al. 2017 [12]; Cameron et al. 2012 [6]; Tzoulas et al. 2007 [7]; Sammuelsson et al. 2019 [23];
Decrease in cardiovascular health	Quality POS provide opportunities for formal and informal recreation and exercise, which is known to improve cardiovascular health.	Suppakittpaisarn et al. 2017 [13]; Cameron et al. 2012 [6]; Mekala et al. 2014 [70]; Tzoulas et al. 2007 [7]; Mathey et al. 2015 [8]; Heckert & Rosan, 2018 [71].
Increase in diabetes	Quality POS provide opportunities for formal and informal recreation and exercise, which is known to assist in the avoidance and/or management of diabetes.	Urakami, 2017 [72]; Fang, 2018 [73].
Increase in heat related hospitalizations	Urban trees, green POS elements, and other porous UGI surfaces reduce reflective and embedded heat, and provide evaporative cooling, which reduces ambient temperatures.	Knowlton et al. 2009 [74]; Sun et al. 2019 [75]; Heaviside et al. 2016 [76].

7. Concurrent Application of URT and HNCT

This section consolidates the information presented above to summarize how the equitable provision of easily accessible quality UGI aligns to both the Urban Resilience and Human-Nature Connection theories. This section provides responses that help mediate and mitigate the impacts from the twin crises of climate change and declining levels of human health within urban centers. Building from this content, Section 9 presents a conceptual model (Figure 1) that shows how the unified application of URT and HCNT can inform community planning and urban development that is preadapted to mitigate and mediate impacts from both climate change and declining human health in this century and beyond.

7.1. Urban Resilience Theory

As previously mentioned, URT can contribute to the mediation and mitigation of climate change [77]. In summary, URT provides teachings and direction for practitioners and decision makers that can: improve traditional policy and planning frameworks, stimulate new systems and measures that aim to reduce greenhouse gas emissions, provide tools for climate change adaptation programs, promote capacity building through inter-governmental cooperation, and direct recovery planning for identified crises and emerging challenges.

Over the past three decades, natural disasters that impact urban centers have quadrupled [77]. Further, climate change place many urban centers at risk and increases the susceptibility of cities also impacted by natural disasters [77]. Cities were once considered a place of refuge for inhabitants. Urban centers are, however, increasingly seen as hotspots of climate hazards and climate risks [77]. Climate hazards comprise floods, windstorms, droughts, fires, large temperature fluctuations, sea level rise, and landslides [77]. Climate risks represent the likelihood of climate hazards occurring, as well as the likelihood of adverse impacts to human health, green and grey infrastructure assets, and environmental and urban services or even loss of human life [77]. Implementing climate change mediation and mitigation measures informed by the URT, can avoid (mediate) climate hazards or reduce (mitigate) climate risks to: reduce the susceptibility of the affected locations and increase the ability of those locations to withstand imminent hazards, and improve in post-disaster response and post-disaster recovery. Specifically, URT contributes to overcoming climate change hazards and climate change risks in the following ways [77]:

- Informs risk reduction programs at a city (and wider) scale;
- Informs measures to modify current work practices to reduce the likelihood of passively (unintentionally) increasing risk;
- Informs modifications to current management practices, policy, legislation, working structures, and tools to reduce risk and increase the ability for adaptation;
- Informs the modifications of internal organizational level policies to reduce risk for individual organizations;
- Promotes cooperation between government agencies and the public to optimize risk reduction, disaster response, and disaster recovery; and
- Supports a conceptual shift in the philosophy that drives professional and public education.

For the above strategies to be effective, industry change makers, policy advisors, practitioners, and decision makers need to ensure the following [76]:

- Actions, changes, and programs do not unintentionally increase the risk to urban centers;
- Institutionalize the idea of risk reduction for the implementation of all public works and policy;
- Ensure high level commitment to disaster recovery and climate change to aid acceptance;
- Cooperate with government agencies, industry partners, and competitors to create multi-level systems to manage risk; and
- Promote and support professional development and education on risk reduction in support of urban resilience principles.

The application of the URT for mediating and mitigating climate change is strengthened by the scope of the theory and strategic planning of policy creation, infrastructure investment, building and construction, resource extraction and utilization, and environmental asset management.

Declining human health in urbanized populations manifests as physiological conditions such as declining cardiovascular health and/or increasing diabetes and obesity and through psychological afflictions such as increases in stress related illness and the associated increase in anxiety and depression [12–15]. The teachings and direction of URT offers three key responses to declining human health among urban dwellers and supports several additional opportunities to stabilize and improve human health within urbanized human populations.

Firstly, in addition to other measures, URT advocates and provides frameworks to ensure that urban dwellers have fair and equitable access to the environmental services and benefits provided by UGI assets. In this frame of reference, the UGI may constitute or be incorporated into urban POS that supports exercise and recreation, safe urban spaces suitable for engagement and connection with other urban dwellers, frameworks for engagement and deeper involvement of individuals with their local community in order to build social capital and social resilience, and the fair and equitable access to health related services that support and provide care for individuals whose health is compromised [10,65].

Secondly, URT supports and advocates for changes in common practice and approach to the consumption of resources that support modern urban life [10,65]. This is particularly evident in the space of energy production. Application of the teachings and direction of URT in this context supports the implementation of renewable energy sources in conjunction with new technology that proves successful in reducing emissions. Carbon emissions, a large proportion of the waste from traditional energy production, negatively impacts human health in urban centers in directly through the effects of climate change and directly through exposure to atmospheric contaminants [44–45]. Regarding the direct exposure to atmospheric contaminants, energy related emissions reducing air quality precipitates an estimated 3.4 million pre-mature deaths, globally, each year [78] from disease mechanisms linked to adverse respiratory health conditions and cancers [46–47]. Adoption of renewable energy sources and other new technologies aligned to increased urban resilience can significantly reduce emissions and therefore reduce the health risk among urban populations. Further, several policy and legislative changes that can, and already do, contribute to improving public health are aligned to URT principles [78].

Thirdly, briefly returning to the climate change crisis, URT offers frameworks and strategies to support human populations in adapting to the threats and challenges of climate change. This may be in the form of employable technology (i.e., improved heating/cooling, off the grid power back-ups), behavior change (i.e., reduction in waste, reduction in electricity dependence), UGI support (i.e., urban trees, urban POS, revegetation) and implementation, and building and construction changes (i.e., solar passive design, new materials) [10,65]. Those adaptations, informed by the URT, can reduce negative health outcomes, which can manifest in premature death, caused by climate hazards such as extended heatwaves and/or flooding and landslides associated with more frequent extreme weather events [10,65].

7.2. Human-Nature Connection Theory

The HNCT provides multiple practical opportunities for modern cities to respond to climate change by cultivating and increasing pro-environmental behaviors, advocating for the creation and implementation more UGI assets, improving practices and approaches to current community planning and urban development regimes, and advocating for the renaturing of urban communities [20–23]. The level of human-nature connection is seen to be a reliable predictor for pro-environmental behavior [20]. Pro-environmental behavior is defined as individuals that display behaviors that contribute to environmental sustainability, such behaviors including limiting waste, limiting energy consumption, improving recycling habits, and more [77]. Pro-environmental behavior represents ground level action in reducing the anthropogenic drivers of climate change. Therefore, the higher the level of human-nature connection, the higher the level of pro-environmental behaviors and the resultant decline in behaviors that contribute to climate change [20–25]. Human-nature connections, in this context, show human-influenced measures of environmental protection and conservation.

Urban green infrastructure is at the core of HNCT (and Biophilic Design) principles as it contributes to mediating and mitigating climate change. As highlighted above, the HNCT advocates for increased rates of implementation for UGI assets such as green POS, green walls, green roofs, urban trees, and more. These UGI assets significantly increase the area of spongy surfaces in the built environment. Those spongy surfaces reduce the urban heat island effect by absorbing and reducing reflective heat, providing shade that allows for human and fauna refuge, absorbing rainfall and stormwater to help reduce local-scale flooding and erosion, and increasing the amount of biodiversity, all of which increases urban resilience in relation to climate hazards [20–25].

Community planning and urban development strategies play a significant role in shaping how cities are designed and constructed. Improvements to community planning and urban development policies and frameworks greatly influence how humans cohabitate with the environment and each other in urban centers. Planning and development designed around people, and their deep seeded desire to be within and around nature and natural elements can also provide answers to climate change. Urban centers can contribute to the mediation and mitigation of climate through means such as solar passive heating and cooling design principles, providing focus on natural light and natural air flow to reduce the reliance on electricity, employing sustainable building materials to reduce the need for resource extraction, and more [20–25]. Therefore, approaches that align with the HNCT and Biophilic Design principles prove to be essential in addressing the climate change crisis.

Similarly, HNCT offers some unique contributions to address the crisis of declining human health amongst urban populations. As highlighted by this article, these contributions include the teachings from the ecological health perspective, the direct physiological and psychological benefits available from engaging with nature, the contributions that the presence of quality urban nature make to communities and social capital that supports of public health, and a reduction in vulnerability to adverse health conditions [20–25,46–47].

For the past 50 years, as humans have become an ever more urbanized species, the interrelationships between people and the environment around them, and how these relationships affect human health, have been a growing focus for research [14,78,79]. Dating back to the 1980s, the Mandala of Health model was advanced to explain the complexities and holistic influences, systems, and relationships of human interactions with nature. Similarly, Wilson [24] proposed his Biophilic Hypothesis in the 1990s. These anthropocentric models, like others before and after, focus on the benefits that interacting with quality nature spaces provides for mind, body, and spirit of individuals. The Mandala of Health also incorporated the interactions and entanglements at the family level that arise from personal behavior from psycho-social, economic, and environmental factors; from the physical environment, and from human biology [63]. The third layer proposed by Hancock [63] is the human-made environment (community) and fourth an all-encompassing layer of the Mandala is the biosphere (culture). The Mandala of Health proposes that each of these layers affect human health and wellbeing and need cognition to all factors to find the equilibrium required for peak health performance and outcomes. Research over the past few decades has built on ecologic health models, however the notion remains much the same. To achieve good health and wellbeing outcomes, balance must be realized with the built environment and the green infrastructure of urban centers [14,78,79]. A large amount of research now underpins our growing knowledge about the relationship between nature and human physiological and psychological health. A summary of that research is provided below:

- Engaging with nature, whether by exercising, gardening, relaxing, reflecting, volunteering, or other, provides physiological health benefits. Research has shown that physical activity within a nature setting results in improvements to physical fitness, cardiovascular health, immune response systems, reduces stress hormones, and increases the operation of the parasympathetic nervous system [15,79–82].
- Engaging with nature has been shown to improve an individuals' outlook on life, reduce stress, improve both cognitive performance and cognitive recovery, reduce depression and anxiety, and facilitate personal reflection that aids spiritual health [21,79,83–86]. In addition, engaging with nature provides opportunities for socialization that build social capital and community

connections. Feeling part of a community and social network has been found essential for mental health.

- Functioning urban ecosystems, biophilic principles, and UGI assets have further been shown to reduce crime rates, increase hospital patient recovery, and reduce the need and reliance on pain medication in hospital patients [21,87]. Equitable access to quality UGI that aligns with the HNCT can also reduce the vulnerability of populations in respect to health impacts brought about by heatwaves and extreme weather events [21].

8. Realigning and Refocusing Towards 2100 and Beyond

Due to the dominant impact of humans on the systems of planet Earth, the new geological series of the Anthropocene, also sometimes referred to as the Human Dominated Geological Epoch, has been recognized [80–88]. While somewhat contested, this epoch is proposed to have commenced in the 1950s, the Anthropocene is characterized by trends of urbanism and the depletion and/or contamination of natural resources [1,89]. Despite these negative trends, surveys show that urban dwellers, in the main, consider urban city life as largely positive [14,90]. However, concern is growing about the equity of access and opportunity, a correct power balance, and the current social and environmental crises, which includes the impact of climate change and declining human health addressed in this article. Current approaches to urban development has been seen to be lucrative for a number of industries, which can perpetuate challenges such as poor planning practices and development for financial gain, lack of availability and demand for alterative sustainable practices, lack of demand for different outcomes and community planning values, a perception of a cost premium for the adoption and implementation of alternative practices and measures, and low support and incentives from regulatory bodies [90].

The current dominant paradigm suggests that the primary purpose of nature is the provision of raw materials and environmental services for the benefit and enjoyment of humans. Under this paradigm, humans are not part of nature, but rather nature exists to be conquered for gain on the basis that short-term human growth and progression will provide benefits in the future that are able to compensate for abstraction and destruction now [91]. Also known as the Technocratic Paradigm, this approach is prefaced on most of humanity perceiving that technological advancements will be able to overcome current and future threats to human populations [11,91]. The dominant paradigm suggests that economic growth needs be continuous for communities, cities, and societies to advance [9,11].

Evolving a sustainable dominant paradigm that is focused on equity, opportunity, risk reduction, and resilience is greatly needed. The barriers to adopting a sustainable paradigm need to be investigated, debunked, and worked through to achieve change.

9. The Promise of Urban Green Infrastructure

The URT and HNCT both show that there are suitable alternatives to the current dominant paradigm, many of which can be realized through the employment and implementation of UGI. While this article only examined the contributions of these theories in the context of climate change and declining human health, it is thought that many other crises may be similarly mediated and mitigated by the application of the URT and HNCT to conserve, protect and reintroduce UGI through inclusive community planning and sustainable development.

As reported above, substantial mitigation and mediation of the twin crises can be achieved through the conservation, reintroduction, enhancement, and protection of UGI as a response that addresses both climate change and declining human health, as advocated by the URT and HNCT. Informed by the documentary analysis presented in this article, the four-set Venn diagram conceptual model presented in Figure 1 demonstrates the complex and highly interrelated nexus between the twin crises examined and the combined application of the URT and HNCT. Key points are provided for each interrelationship to provide a starting context to the relationship. Further, the existing literature of this field has a gap with respect to advocating for that combined approach to the implementation of the URT and HNCT in urban centers. The novel approach of integrating the

application of those two theories via the equitable provision of easily accessed quality UGI can mediate and mitigate both climate change and declining human health and can positively contribute to the refocusing and reframing of unsustainable development many urban centers are currently pursuing.

Adopting the evidence-based approach, advocated in this article and illustrated in the conceptual model provided in Figure 1, is essential for delivering the inclusive community planning and sustainable urban development as humanity recalibrates our focus towards the end of the 21st-century and beyond.

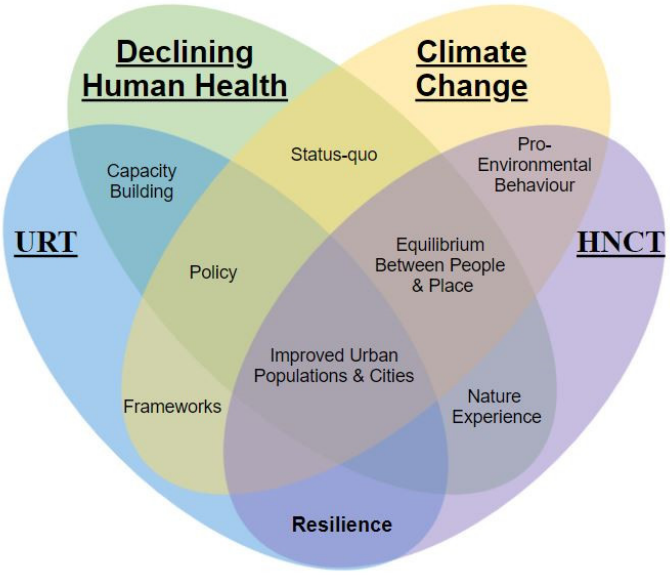

Figure 1. Conceptual model of the interrelationships between the twin crises of climate change and declining human health in urban centers and mitigation and mediation measures offered by the Urban Resilience Theory (URT) and the Human-Nature Connection Theory (HNCT).

10. Conclusions

This article highlights that the URT and the HNCT can both make multifaceted contributions to mitigating and mediating the drivers and impacts of the twin crises of climate change and declining health among urban dwellers. With respect to both theories, conserving, protecting, and restoring quality UGI is the foundation for action to reduce the severity and impact of those crises and for progressing inclusive and sustainable community planning and urban development that focuses beyond 2050. While some UGI can be found within the fabric of most modern cities, the URT, the HNCT, and this article advocate for an increase in the amount, the resourcing, and the perceived value of those UGI assets.

Historically, the benefits that UGI provides in terms of mitigating and mediating climate change and providing physiological and psychological health benefits for urban dwellers have been considered as intangibles. As such, UGI has not been valued in terms of the economic return-on-investment those spaces provide with respect to the resources expended to realize the environmental and social value of the ecosystem services that quality UGI delivers for modern urban centers. However, this article highlights how, congruent with the URT and the HNCT, access to quality UGI can assist in changing from "business as usual" to a more sustainable and resilient approach to community planning and urban development in the second half of the 21st-century.

Implementing the combined approach to URT and HNCT advocated in this article is likely to have limitations in the global context. The limitations could include geographical and cultural considerations at the local scale, resources that are available to land managers, community demand

and expectations for UGI installations, stability of current political environments, and the quality of governments and government structures. However, given the previously identified gap in the literature regarding the complementary implementation of URT and HNCT through the medium of UGI, the nature and magnitude of such limitations remains unknown. Clarification of such limitations will most likely be facilitated by the anticipated increase in volume of research URT, HNCT, and UGI. Further, the rapid global changes and growing research interest highlighted in this article, will generate additional insights that are not yet apparent.

Further research is therefore required to investigate and understand the contribution that UGI can make in terms of inclusive community planning and sustainable urban development as our increasingly urbanized human population begins to recalibrate and refocus beyond 2100. That research should investigate different forms of UGI to deliver specific and robust findings aligned to the climate change, human health, urban resilience, community planning, and sustainable urban development foci of this article. To that end, two such studies have been completed in support and are under manuscript development:

1. A study that explores and quantifies how economic, environmental, and social factors influence the theoretical carrying capacity and realized planting of urban tree canopy as an UGI asset.
2. A study that provides proof-of-concept for a framework that quantifies and informs the efficacy of POS management with respect to the delivery of quality UGI spaces with limited resources.

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Appendix A

The tables reported below (Tables A1 to A4) summarize the geographic scope and UGI research focus of the case study, empirical, and documentary research reported in the 87 articles analyzed by Parker and Simpson [14], the 171 articles analyzed by Parker and Zingoni de Baro [16], and the 38 UGI related articles cited as evidence in support of the synthesis of the URT and HNCT presented in this article.

Table A1. Geographic distribution of case studies and sources of data that informed this article.

Continental Region	Parker and Simpson [1] [14]	Parker and Zingoni de Baro [2] [16]	Cited in this Article [3].
Global Reviews	18	31	32
East & SE Asia	16	12	4
Europe	9	49	7
Middle East	0	0	1
North America	6	48	7
Oceania	20	16	7
South America	0	0	0
Sub-Saharan Africa	3	4	0

1. Data extracted from included articles published in Data Descriptor by Simpson and Parker [17].
2. Data extracted from included articles published in Data Descriptor by Parker and Simpson [19].

3. The global-scale analysis of GIS data by Richards and Belcher [43] that covered the five most inhabited continents was coded as a Global Review article.

Table A2. Number of countries represented in the case studies and sources of data that informed this article.

Continental Region	Parker and Simpson [1] [14]	Parker and Zingoni de Baro [2] [16]	Cited in this Article [3]
East & SE Asia	5	3	4
Europe	7	16	8
Middle East	0	0	1
North America	2	2	7
Oceania	2	2	7
South America	0	0	0
Sub-Saharan Africa	3	1	0

1. Data extracted from included articles published in Data Descriptor by Simpson and Parker [17].
2. Data extracted from included articles published in Data Descriptor by Parker and Simpson [19].
3. Richards and Belcher [43] conducted a global analysis of GIS data that covered multiple countries on each of the five most inhabited continents.

Table A3. Number of cities reported in the case studies and sources of data that informed this article.

Continental Region	Parker and Simpson [1] [14]	Parker and Zingoni de Baro [2] [16]	Cited in this Article [3]
East & SE Asia	7	5	6
Europe	10	18	6 [4]
Middle East	0	0	1
North America	7	21	7
Oceania	4	4	6
South America	0	0	0
Sub-Saharan Africa	3	1	0

1. Data extracted from included articles published in Data Descriptor by Simpson and Parker [17].
2. Data extracted from included articles published in Data Descriptor by Parker and Simpson [19].
3. In addition, Richards and Belcher [43] conducted a global review of GIS data that graphically reported UGI data for at least 1000 cities across all five of the most inhabited continents (excluding Antarctica).
4. In addition, Biegańska et al. [37] report a GIS-based country-scale comparative analysis of the UGI provided in peri-urban developments associated with approximately 100 urban centers in Germany, Latvia, and Poland.

Table A4. Focus for case studies of the aspects of urban communities and development that informed this article.

Focus of Case Studies	Parker and Simpson [1] [14]	Parker and Zingoni de Baro [2] [16]	Cited in this Article
Climate	NR	8	23
Economic	45	23	33
Environmental/Ecological	54	41	41
Health/Wellbeing	59	24	37
Liveability/Quality of Life	57	NR	22
Planning/Policy	50	43	40

Greenspace/Public Open Space (POS)	87	8	31
Quality/Performance of Greenspace/POS	59	21	25
Social	80	38	44
Other	NR	5	NA

1. Data extracted from included articles published in Data Descriptor by Simpson and Parker [17]
2. Data extracted from included articles published in Data Descriptor by Parker and Simpson [19].
NR = Not Reported – NA = Not Assessed

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