Green Design for Climate Resilience & Well-being

A Better Practice Guide

October 2020

CONTENTS

EXECUTIVE SUMMARY

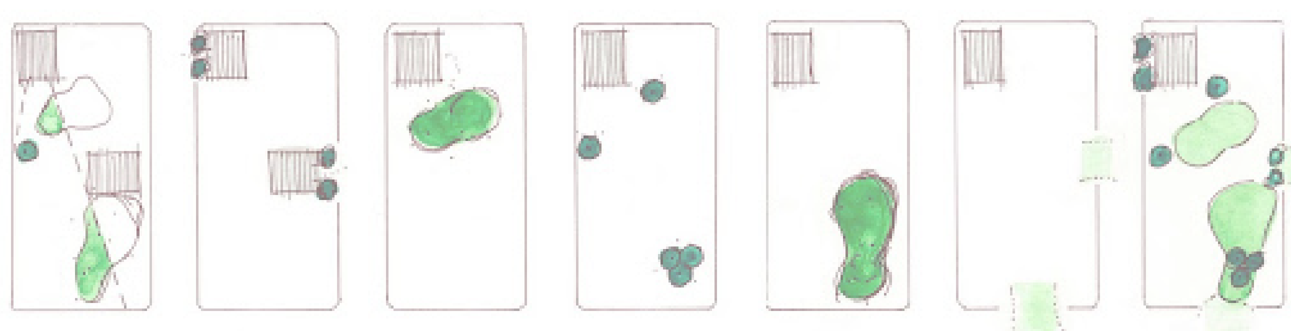
Exposure to green landscape elements benefits human health in many ways. Urban green space is also recognized as an important adaptation response to predicted changes in climate. To maximize the impacts of urban greening on our cities, planners and designers need evidence-based guidance to design and retrofit urban green spaces that maximize co-benefits for both human health and climate resilience.

This guidance document proposes strategies that provide strategic green space retrofits at the neighbourhood and block scale. These strategies represent a hierarchy of functional design concepts that respond to experiential qualities and physical/psychological dimensions of health, and which enhance resilience at a range of social scales from the individual to the neighbourhood.

This document presents a typology of eight tangible green space strategies and associated metrics to integrate climate resilience and public health co-benefits into urban green space design and planning:

1) View from within
2) Plant entrances
3) Bring nature nearby
4) Retain the mature
5) Generate diversity
6) Create refuge
7) Connect experiences
8) Optimize green infrastructure.

These strategies are introduced, and then applied to two case studies in a scenario-based exercise. The exercise provides decision-support tools through a method of assessing alternative urban greening scenarios.



THE CHALLENGE

This guidance document is the result of a collaboration among healthcare, local government, and climate research. It is intended as a contribution to the facilitation of healthy, climate-ready communities. Despite significant recent evidence on the contributions of urban greening to issues such as human well being and urban heat island impacts, little work was being done to combine the two, *Figure 1*. Also, little work was being done to translate research outcomes to practical strategies usable by local government or managers of large institutional campuses.

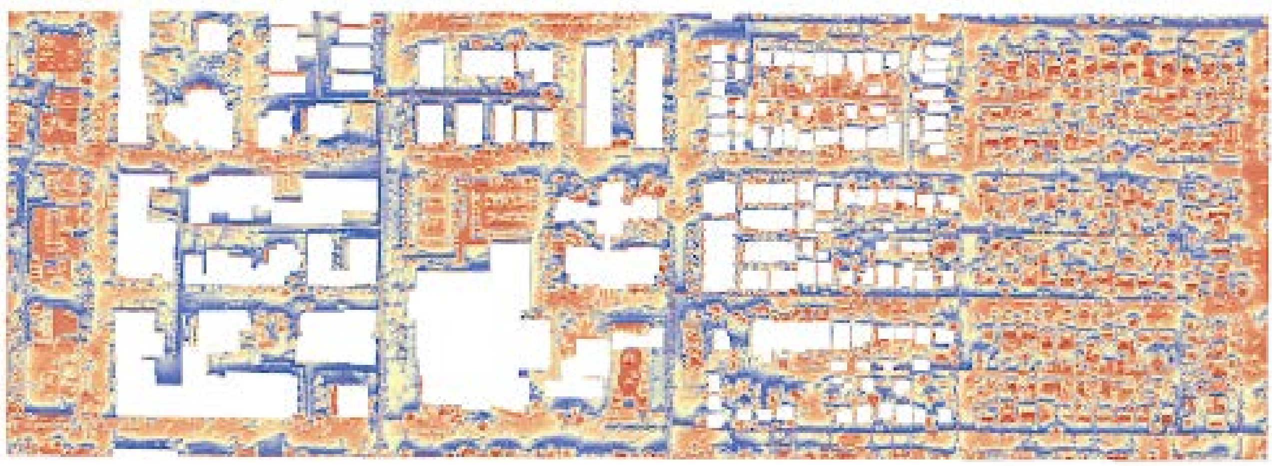


Figure 1*. An urban heat map of a case study site. Areas in red indicate higher heat areas, while areas in blue indicate cooler areas. Tree shade is visible at close range.*

INTRODUCTION

This guidance document proposes needed intersections between the fields of landscape architecture, urban forestry, healthcare, and climate change planning. Decision-support tools and clear and compelling guidance are needed to enable interdisciplinary stakeholders to apply evidence-based strategies to create, expand, or enhance urban green space in their communities. We propose design strategies and associated metrics that integrate climate resilience and public health co-benefits in urban green space design and planning.

They provide guidance to the diverse range of stakeholders necessary to champion urban forest and green space investment and design. They are adaptation measures that potentially increase environmental and human health resilience from the scale of individuals to neighbourhoods. The proposed strategies also inform future research needs in green design, particularly in local community contexts.

We present this novel typology as an opportunity to capture qualitative, tangible, and holistic aspects of green spaces as well as providing important functions, that could together appeal to a broad range of stakeholders concerned with both health and climate change adaptation. The range of stakeholders considered included: site users and general members of the public; nearby residents; onsite staff and building occupants; facility managers and maintenance workers responsible for buildings and infrastructure; and urban planners and policy-makers. The design strategies should be particularly useful to policy- and decision-makers focused on health and climate issues, as for these practitioners they may achieve two broad, relatively new and increasingly important aims at one stroke.

SCALE

The strategies focus on the scale of the neighbourhood block. The neighbourhood scale is an important and often missed opportunity to connect local residents with the strategies and practices of urban forestry and green space planning. At this scale, design strategies and indicators connect with tangible and realizable outcomes that directly connect to people's lives.

The scale of the neighbourhood thus represents an important social and perceptual landscape unit, but the concept and spatial extent of neighbourhood is often not clearly defined. A neighbourhood can range from a few blocks to a larger area of the city encompassing many blocks, ***Figure 2****.* For the purpose of this paper, we focus on what we term the 'experiential' neighbourhood: defined as a cohesive unit of about 8-12 blocks, where a 10 minute walk (800 metres) can take a person from one end of the area to the other. Residents can realistically conceptualize this scale of neighbourhood as a landscape unit, with a higher proportion of familiar social contacts and encounters, strong recognition of identity, and strong place attachment. This scale is common for campus environments such as hospitals and colleges, and has been recognized as a suitable scale for mobility and tranquility planning in residential environments, as in the superblock concept of approximately 160,000 sq metres in Barcelona (Ajuntament de Barcelona, 2014). This smaller scale of neighbourhood captures green space exposure at shorter distances, allowing for consideration of accessibility, sightlines, aesthetics, vegetation layering, and quality of green space design.

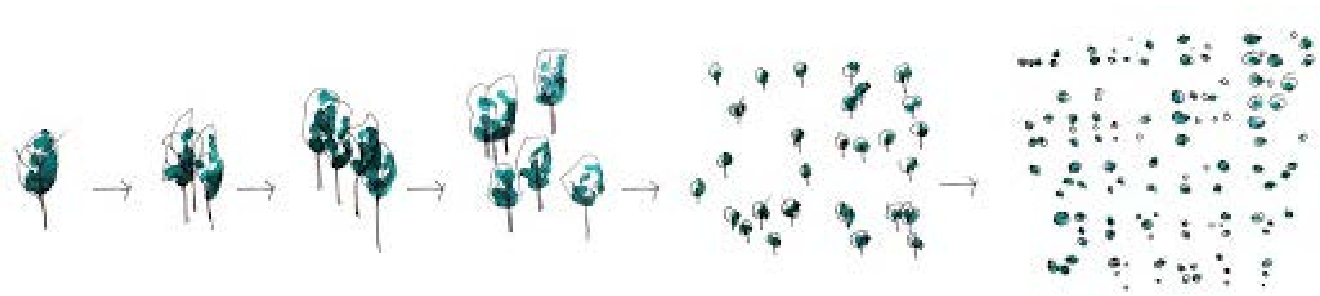


Figure 2. *The scales of urban greening discussed here range from the individual tree to the neighbourhood.*

URBAN GREENING STRATEGIES

The typology introduces eight types of urban greening strategies along with associated benefits and suggested metrics, ***Table 1***. For example, when conceiving an urban greening plan for your neighbourhood, you might want to consider how many buildings have green entrances, or how many mature trees are retained, or perhaps how much greenspace is connected.

The following section describes each strategy, its rationale, benefits, evidence-base, metrics for assessment, a proposed threshold or goal for performance, and opportunities to improve the approach.

NOTE*: The text in this and the next section is modified slightly for this document:*
Barron, S., Nitoslawski, S., Wolf, K. L., Woo, A., Desautels, E., & Sheppard, S. R. (2019). Greening Blocks: A Conceptual Typology of Practical Design Interventions to Integrate Health and Climate Resilience Co-Benefits. International Journal of Environmental Research and Public Health, 16(21), 4241.

Table 1. *Urban Greening Strategies and a short list of their associated co-benefits.*

Design Strategy	Anticipated Climate and Health Co-benefits
1. View from Within	✓ Visual biophilic experiences ✓ Wildlife habitat and biodiversity ✓ Stormwater mitigation
2. Plant Entrances	✓ Social gathering space ✓ Orientation/navigation ✓ Shade provisioning/cooling ✓ Building energy savings (depending on aspect)
3. Bring Nature Nearby	✓ Social gathering space ✓ Shade provisioning/cooling ✓ Wildlife habitat provision and biodiversity ✓ Stormwater mitigation
4. Retain the Mature	✓ Air filtration ✓ Shade provisioning/cooling ✓ Building energy savings ✓ Carbon storage and sequestration
5. Generate Diversity	✓ Visual biophilic experiences ✓ Wildlife habitat provision & biodiversity ✓ Climate Resilience
6. Create Refuge	✓ Social gathering space for cohesion and enhanced social capital ✓ Shade provisioning/cooling ✓ Air filtration ✓ Wildlife habitat and biodiversity
7. Connect Experiences	✓ Visual biophilic experiences ✓ Shade provisioning/cooling ✓ Wildlife habitat provision and biodiversity (e.g. ecological corridors) ✓ Stormwater mitigation
8. Optimize Infrastructure	✓ UHI mitigation ✓ Carbon storage and sequestration ✓ Stormwater mitigation ✓ Wildlife habitat provision and biodiversity

1. View from within

Have you considered the view from within when implementing urban greening?

The **View from Within** strategy refers people's views from within buildings; whether or not they are able to see natural objects, such as trees, plants, water, or distant landforms, from the inside of a building can have an impact on health and productivity, ***Figure 3***. Recent studies suggest that humans experience positive emotional responses from having views of nature. Viewing landscapes dominated by plants, flowers, trees, and other greenery can produce a significant restorative effect, even within a few minutes. Studies have shown that even 40 seconds of green roof views, for example, can improve cognitive performance and boost attention span (Lee et al. 2015). Visual access to green space and highly visible landscape features such as tall trees should therefore be included as a design strategy for health, particularly where outdoor exposure to green is not always possible. This may be the case for hospital patients confined to the indoors, schoolchildren and students who spend most of their time in the classroom, and office workers.

Considering visibility as a design strategy also promotes the creation and management of green space in less traditional spaces and at varying levels. Green roofs, vertical gardens, and green walls can play an important role in improving access to visible green space, particularly in higher-density neighbourhoods, where development occurs upwards rather than outwards, and in cities with increasingly high demand for physical space. Additionally, such biophilic building designs offer direct benefits for building efficiencies, by offering temperature moderation and energy savings. View from Within can also incorporate distant views to natural spaces such as mountains and water bodies, and ensure the sightlines are preserved or enhanced. Seasonality should be considered when implementing the View from Within strategy. Green views should be available year-round, and seasonal colour could enhance the view at certain times of the year.

Select references:

Kaplan, R. The Nature of the View from Home: Psychological Benefits. Environ. Behav. 2001, 33, 507–542.

Lee, K.E.; Williams, K.J.H.; Sargent, L.D.; Williams, N.S.G.; Johnson, K.A. 40-Second Green Roof Views Sustain Attention: The Role of Micro-Breaks in Attention Restoration. J. Environ. Psychol. 2015, 42, 182–189

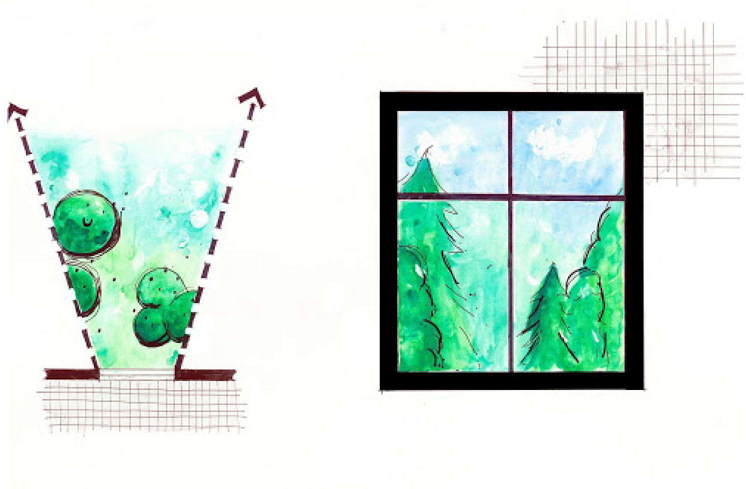


Figure 3. *View from Within diagram.*

Metric:

In order maintain a uniform way to assess the amount of green which can be seen from the windows of a building, grey/green analysis of the view of the windows can be used.

The floors from which the views should be assessed is based on the height of the building.

Google Earth Pro allows a viewer to enter a modelled building. If 3D models of your neighbourhood's buildings are available on Google Earth, you can virtually enter the building and take photos at the appropriate floors.

Once the view is calibrated, only the height and the direction for the view is changed to capture views from all facades and various heights. The angle of the view is not changed.

Screengrabs from buildings and facades can then be opened in software such as Adobe Photoshop. Using the magic wand tool, all green pixels can be selected and the number recorded. The same can be done for all of the blue pixels that form the sky.

The green grey percentage of the view that we used for our calculations was the number of green pixels divided by the total sumber of pixels minus the number of sky pixels times one hundred.

The result is the % of green in the picture without the sky. Removing the sky removes some of the noise in the calculations.

Goal:

The team consensus was to aim for at least 30% green visible in all the views captured for the study.

Taking it a step further:

Since each view is different and distant views of landscape elements such as waterbodies, mountains can greatly enhance a view, having a qualitative measure of the view might be beneficial. This could be in the form of a description of the elements and the quality of the elements seen from views of windows. Example of descriptions could be snow capped mountains in the distance, view of the ocean or lake, views of healthy lush forests. It would also be ideal to bring in elements of biodiversity in the natural landscape elements seen from the windows.

2. Plant Entrances

Green entrances create opportunity for all building visitors to experience some nature in their day. Do your entrances have a welcoming green frame?

The **Plant Entrances** strategy refers to the presence of green, which may include trees or other vegetation, at building or site entrances or exterior doorways, ***Figure 4***. Having green elements in close proximity to site or building entrances serves multiple purposes. Depending on the location of the building entrance and vegetation, trees can provide shade, cooling effects, and subsequent energy savings. Building entrances are high-traffic areas as well as social spaces, drawing occupants to the outdoors as well as welcoming occupants inside. The presence of vegetation at building or site entrances ensures that all users are exposed to the associated green benefits as they enter and exit.

The presence of green space at entrances is not a commonly used metric in green space or urban forest evaluation. When applied appropriately, however, smaller-scale strategies such as these are generally more feasible compared to larger scale strategies in terms of financial, legal, and other resource constraints. Concerns about safety and security should be considered when designing plantings near entrances to ensure that the spaces created feel welcoming to all members of society.

Select references:

Kuo, F.E. Social Aspects of Urban Forestry: The Role of Arboriculture in a Healthy Social Ecology. J. Arboric. 2003, 29, 148–155.

Ryan, C. Eco-Acupuncture: Designing and Facilitating Pathways for Urban Transformation, for a Resilient Low-Carbon Future. J. Clean. Prod. 2013, 50, 189–199.

Unt, A.; Bell, S. The Impact of Small-Scale Design Interventions on the Behaviour Patterns of the Users of an Urban Wasteland. Urban For. Urban Green. 2014, 13, 121–135.

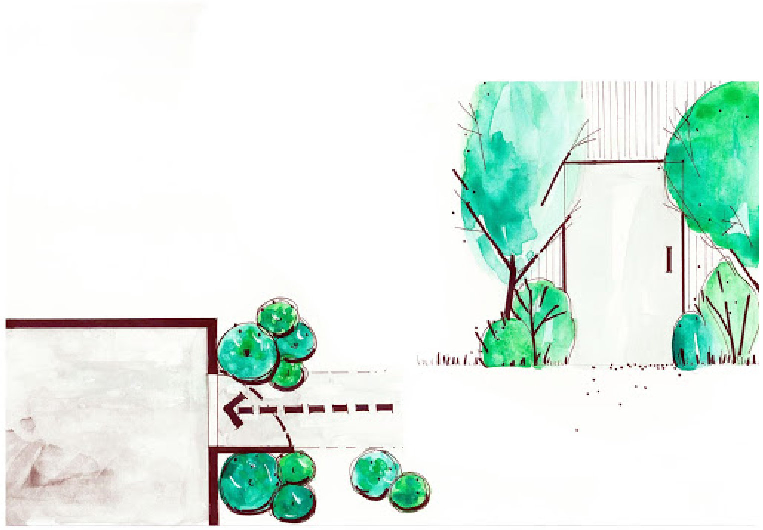


Figure 4. *Plant Entrances diagram.*

Metric:

The percentage of green to grey around the entrances in plan view can be used to assess how green the entrance is. The area assessed around the entrance depends on the physical size and amount of people using the entrance. For our case studies, the area of assessment for a well-used, larger entrance was a rectangular shape the size of 20m by 40m. The area of assessment for smaller, less used entrances was 10m by 20m. Orthophotos were used to identify the green elements (such as trees, shrubs, and pervious surfaces) and grey elements (impervious surfaces such as paved surfaces). Using the Adobe Photoshop magic wand function, all of the green elements were selected and number of pixels recorded.

The final calculation would be:

$$\frac{green}{grey}\% = \frac{\#\ of\ green\ pixels}{total\ pixels\ in\ entrance\ assessment\ box} \times 100\%$$

Goal:

The aim is to get the lowest ranking entrances (those with a lower green/grey ratio) to include more green. Through team consensus, a target of fifty percent green within the measured entrance area was chosen for our case studies.

Taking a step further:

A simple measurement does not capture the experiential quality of the entrance. To do this, one could include a description of the experience of walking through an entrance to add a qualitative component for assessment. Write 3 evocative lines about the entrance experience to include in your assessment for an empirical and experiential assessment.

3. Bring Nature Nearby

Not everyone can travel to a park or garden. Are there spaces near your building that can provide an opportunity to relax surrounded by plants?

The **Bring Nature Nearby** strategy refers to the presence of green within close proximity of all neighbourhood dwellers, regardless of demographic, cultural or socio-economic conditions, ***Figure 5***. Example may include "pocket parks" and linear greenways. Exposure to green space, along with its associated benefits, has been shown to correlate with demographic and socio-economic conditions, often noted as disparities in availability of parks and trees in underserved communities. It is vital for urban forest managers to ensure that all community members have equal access opportunity to the physical and psychological benefits provided by urban trees.

Vertical distance to green space is an interesting issue to consider. Do urban dwellers who live twelve storeys up experience fewer green benefits compared to those living on the ground floor, due to the time it takes to reach a certain amount of green? Do building users respond similarly to nature placed on multiple floors in biophilic buildings compared to ground plane landscapes? Larger cities are becoming increasingly dense, and residential high rises are prevalent in areas with higher demand for physical space and rising housing costs. It is therefore essential to develop and test green space indicators that account for changes in city demographics and urban planning trends.

Select references:

Cordoza, M.; Ulrich, R.S.; Manulik, B.J.; Gardiner, S.K.; Fitzpatrick, P.S.; Hazen, T.M.; Mirka, A.; Perkins, R.S. Impact of Nurses Taking Daily Work Breaks in a Hospital Garden on Burnout. Am. J. Crit. Care 2018, 27, 508–512.

Dadvand, P.; de Nazelle, A.; Triguero-Mas, M.; Schembari, A.; Cirach, M.; Amoly, E.; Francesco, F.; Basagaña, X.; Ostro, B.; Nieuwenhuijsen, M. Surrounding greenness and exposure to air pollution during pregnancy: An analysis of personal monitoring data. Environ. Health Perspect. 2012, 120, 1286–1290.

Donovan, G.H.; Michael, Y.L.; Butry, D.T.; Sullivan, A.D.; Chase, J.M. Urban trees and the risk of poor birth outcomes. Health Place 2011, 17, 390–393.

Figure 5. *Bring Nature Nearby diagram.*

Metric:

The metric used for the nearby greenspace strategy is the amount of time it takes to walk to the closest green space. Nearby green space is defined as a spot of green at least 10mx10m in size with public access that has space to sit. Examples may include pocket parks, linear greenways, and roof gardens. In a hospital setting, this greenspace could be used by patients, their families, and the healthcare staff that use the health campus.

Travel time includes waiting for an elevator, elevator travel time to the floor with green space, and walking from the elevator to the green space. To maintain simplicity in our calculations, all elevators are assumed to be at the centre of buildings.

Assumed speeds:

- Waiting time for elevators: 45 s
- Time to walk from Elevator to exit: 10 s
- Travel time for elevators: 2 s/floor
- Walking speed: 0.5 m/s

Goal:

The goal is to minimize travel time through addition of green space within building boundaries (green roofs) or very close to the entrance with minimal road crossings. A suggested travel time of 2 minutes or less was used in our case studies, which provided a reasonable goal at the neighbourhood scale.

Taking a step further:

Include other perceived barriers for travel to nearby space. Examples include the perceived high barrier of crossing a road, a steep sloping path, or stairs to the green space. These all serve as high barriers for people with mobility challenges.

4. Retain the Mature

Large trees provide aesthetic and emotional benefit to people. When designing a landscape, have you retained mature trees?

The **Retain the Mature** strategy refers to paying attention to the size and structure of trees comprising a green space, ***Figure 6***. Given the benefits provided by big trees, these spaces could be designed around a “heritage” or “legacy” tree. Age diversity is important, particularly along city streets, to ensure that many trees are not removed simultaneously at the end of their lifespan, along with their associated benefits. In the context of climate mitigation, one large tree sequesters and stores more carbon than a smaller one. In terms of adaptation, a big, mature tree is also generally understood to provide more benefits compared to one of a smaller stature, such as more shade, greater energy savings, and air quality improvements.

Select references:

Wolf, K.L. Trees and business district preferences: A case study of Athens, Georgia, US. J. Arboric. 2004, 30, 336–346.

Jim, C.Y. Urban Heritage Trees: Natural-Cultural Significance Informing Management and Conservation. In Greening Cities: Forms and Functions; Tan, P.Y., Jim, C.Y., Eds.; Advances in 21st Century Human Settlements; Springer: Singapore, 2017; pp. 279–305.

Schroeder, H.; Flannigan, J.; Coles, R. Residents’ Attitudes toward Street Trees in the UK and US Communities. Arboric. Urban For. 2006, 32, 236.

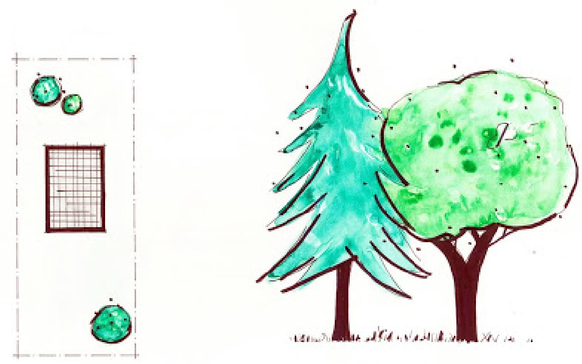


Figure 6. *Retain the Mature diagram.*

Metric:

The metric used for the Retain the Mature trees strategy is the percent of mature trees compared to the total number of trees.

Our project defined mature trees as any tree with the height greater than 15m. We acknowledge that not all mature trees have a height greater than 15m. However, we identified trees using LiDAR, where height and the canopy cover of the trees are the key data points. This criteria allows for easy replicability and data acquisition.

Goal:

The goal is to maximise the number of mature trees in the area. We set a minimum target of 30% of the total number of trees being greater than 15m in height. By planting more trees in the present and not cutting the trees down, the sites will have more mature trees in the future.

Taking a step further:

To support the LiDAR data, one could also include a field inventory which would more accurately determine all the mature trees on the site.

5. Generate Diversity

A more diverse urban forest will be more resilient to pests and diseases. Have you measured diversity in your greenspaces?

The **Generate Diversity** strategy refers to ensuring that a diversity in species of trees and plants is provided within a green space, ***Figure 7***. Species diversity is crucial to urban forest functioning, resilience to pests and disease, and to the enhancement of green benefits. Research has shown that greater species richness is an important mitigator of environmental stressors, including tree pests and disease. The presence of native tree species has been shown to promote the establishment of other native organisms, such as insects and birds, increasing the ecological integrity of urban forest ecosystems. Many are widely used in assessing the quality of an urban green space, namely naturalness and ecological integrity (e.g., representation of native species), the number and representation of species present, other qualitative indicators such as perceived safety and green design aesthetics relate to the diversity of planted landscapes.

Select references:

Shanahan, D.F.; Lin, B.B.; Bush, R.; Gaston, K.J.; Dean, J.H.; Barber, E.; Fuller, R.A. Toward improved public health outcomes from urban nature. Am. J. Public Health 2015, 105, 470–477.

Rudd, H.; Vala, J.; Schaefer, V. Importance of backyard habitat in a comprehensive biodiversity conservation strategy: A connectivity analysis of urban

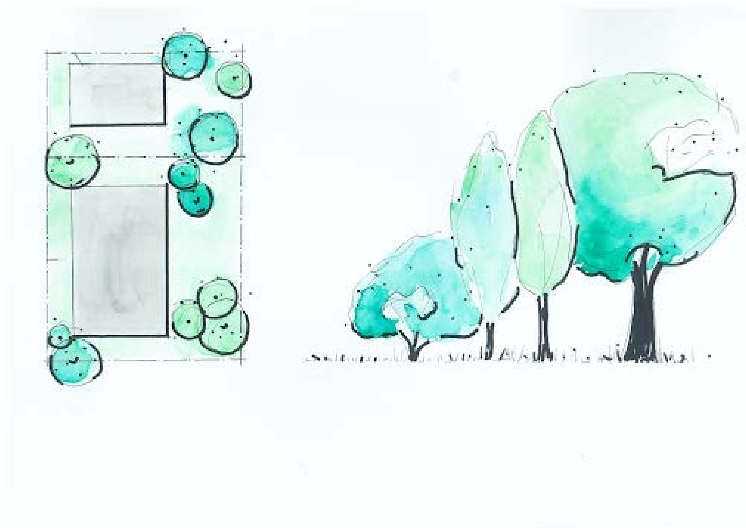


Figure 7. *Generate Diversity diagram.*

Metric:

The metric for diversity is the relative distribution of tree species, the heights of the trees and their collective ecosystem services.

In order to assess this, a tree inventory needs to be done for the site. The data can then be input into free software, such as i-Tree eco v.6 which will provide calculations and graphs for your area. Data collected during inventory includes the height, canopy, species and of the tree.

Goal:

The site should have trees that are diverse with varied species. General guidelines for diversity suggest that no more than 30 percent of trees come from one family, no more than 20 percent from one genus, and no more than 10 percent from one species. Some cities have chosen even higher targets for diversity. Select for trees that are resilient to climate change and low on allergenicity.

Taking a step further:

Consider age, size, and genetic diversity, and consider each species ability to survive in future climate realities. In Metro Vancouver, a species database of climate resilient species can be found here:

http://www.metrovancouver.org/services/regional-planning/PlanningPublications/UFA_UrbanTreesList.pdf

6. Create Refuge

Can green shade accommodate the population of an area during an extreme heat event?

The **Create Refuge** strategy refers to the presence of “cool spots” where neighbourhood dwellers can find protective temperatures during extreme heat events, ***Figure 8***. An example would be a stand of trees with sufficient diversity in size and structure for shade and cooling through evapotranspiration. Urban areas are increasingly subjected to the effects of climate change. Extreme heat events may compound the impact of the more general urban heat island effect, prompting municipal researchers and practitioners to recognize the importance of urban green in mitigating higher temperatures. Creating refuge allows urban dwellers to access public and green spaces in warmer temperatures, and can mitigate associated health risks.

We include another novel metric, namely the number of people that a cool refuge can accommodate at once. The focus on people provides a tangible and accessible metric, and can be calculated as a percentage based on the total population that might have access to a particular refuge or series of green spaces. The tree selection for the trees that make the refuge spots are important too. Urban Forest planners might what to opt for trees with dense canopy and low allerginicity factors. Adding a deciduous, dense canopy refuge spot of the south side of the buildings could insulate the building from direct sunlight in the summer and contribute to energy savings.

Select references:

Wu, Z.; Kong, F.; Wang, Y.; Sun, R.; Chen, L. The impact of greenspace on thermal comfort in a residential quarter of Beijing, China. Int. J. Environ. Res. Public Health 2016, 13, 1217.

Lee, H.; Mayer, H.; Chen, L. Contribution of trees and grasslands to the mitigation of human heat stress in a residential district of Freiburg, Southwest Germany. Landsc. Urban Plan. 2016, 148, 37–50.

Aminipouri, M.; Knudby, A.J.; Krayenhoff, E.S.; Zickfeld, K.; Middel, A. Modelling the impact of increased street tree cover on mean radiant temperature across Vancouver's local climate zones. Urban For. Urban Green. 2019, 39, 9–17.

Morakinyo, T.E.; Kong, L.; Lau, K.K.L.; Yuan, C.; Ng, E. A study on the impact of shadow-cast and tree species on in-canyon and neighborhood's

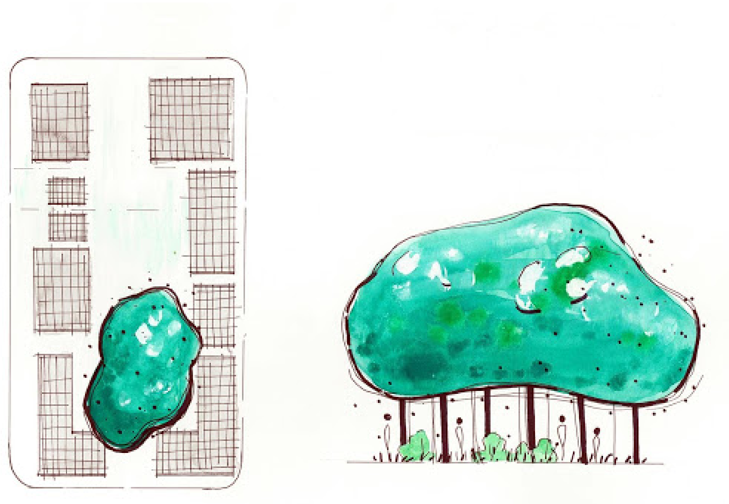


***Figure 8**. Create Refuge diagram.*

Metric:

The metric used for refuge space is the number of people that can be accommodated under a tree. We assumed that a person would use 1.5m X 1.5m of space under a tree. This would allow for sitting, standing, accommodate wheelchairs, and even hospital beds where necessary. This space should provide enough personal space from other individuals under the tree.

We define refuge space as anything with a canopy greater than 30 m in diameter that has no underlying bush, allowing people to occupy the shade. LiDAR data can be used to identify such refuge areas. Using LiDAR data, you can isolate individual trees and categorise them based on their height. Areas under trees with heights greater than 10 m with no tree/ bush under the canopy create refuge spots.

If the refuge area comprises street trees in a residential neighbourhood, with the refuge space in front off a private home, we called them second grade refuge cover. In second grade refuge cover, people would be standing on private lawns or within private gardens for shade.

The number of people under refuge space= Canopy cover of the space (m2)/ (1.5mx1.5m).

During disaster events such as an extreme heat wave accompanied by loss of electricity to a building, more people can be accommodated by reducing the personal space used by one person.

Goal:

To maximise the number of people that can be accommodate by increasing number of quality refuge spots.

Taking it a step further:

You may also want to ground truth all the refuge spots identified by LiDAR by doing a field inventory. You may also designate these spots as refuge spots and to make sure the area under it remains unoccupied by cars/ shrubs etc. It maybe helpful to have certain spots with paved surfaces under the refuge to allow for people with all abilities to access them.

The tree selection for the trees that make the refuge spots are important too. Trees with dense canopy and low allerginicity factors would make better refuge spots.

Strategic placement of refuge spots close to entrances make them easy to access, and also contribute to the green experience of the entrance. Adding a deciduous, dense canopy refuge spot along the south side of buildings could insulate the building from direct sunlight in the summer and contribute to energy savings.

7. Connect Experiences

Can people walk continuously along a shaded pathway?

The **Connect Experiences** strategy refers to continuous greenery along a street or other transit path, meant to encourage active transit and other forms of physical activity, ***Figure 9***. Routes with sufficient trees, vegetation, and open space can serve as an escape from urban stresses like noise, traffic, and pollution. Green corridors or roads can provide ready access to and between public open spaces, including green spaces. Evidence has also shown that the presence of greenery encourages physical activity; in fact, the presence of street-level green space may positively correlate with increased time spent walking. People in dense urban environments are also more incentivized to walk to their destination when street trees are planted closer together. Urban streets have the potential to provide a space for both transportation walking, to reach a destination, as well as recreational walking for pleasure, stress relief, and other health reasons.

We therefore propose green space connectivity as a design strategy, particularly given its close relationship with accessibility to green benefits. Trees in particular arrangements (e.g. tree-lined paths) can create more accessible and aesthetically pleasing areas for pedestrian traffic; these ‘shadeways’ also create cooler walking and cycling routes during extreme heat events. While accessibility measures should ensure that all community members have equal opportunity for green exposure, connectivity design strategies are meant to layer this with additional physical activity and active transit through green strategies.

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Groome, D. Green Corridors’: A Discussion of a Planning Concept. Landsc. Urban Plan. 1990, 19, 383–387.

Lu, Y.; Sarkar, C.; Xiao, Y. The Effect of Street-Level Greenery on Walking Behavior: Evidence from Hong Kong. Soc. Sci. Med. 2018, 208, 41–49.

Langenheim, N.; White, M.; Tapper, N.; Livesley, S.J.; Ramirez-Lovering, D. Right tree, right place, right time: A visual-functional design approach to select and place trees for optimal shade benefit to commuting pedestrians. Sustain. Cities Soc. 2020, 52, 101816.

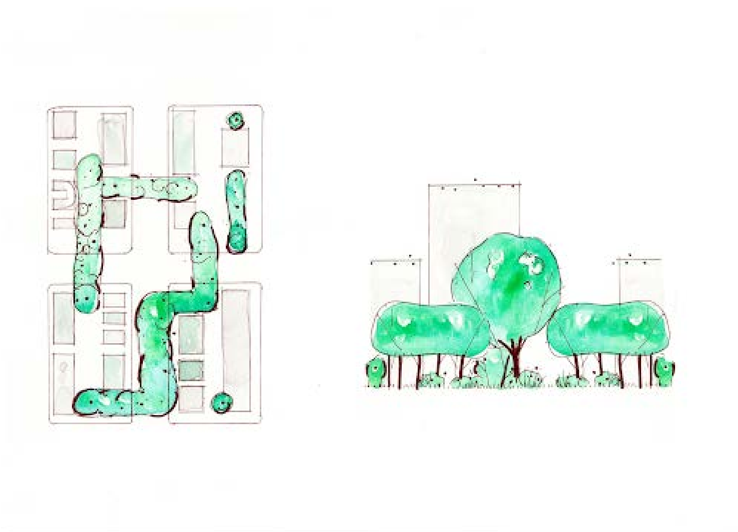

Figure 9. *Connect Experiences diagram.*

Metric:

The metric for connect experiences is the % of green corridors in your neighbourhood. A green corridor is defined as a movement corridor with canopy over head and eye level greenery along at least one side of it.

Goal:

The goal is to have all of the major non-motorized movement corridors green. Having some shaded way along all the movement corridors within the site and along all the roads and paths leading up to the site from public transit stops and major roadways.

Taking it a step further:

Consider connectivity of soil, canopy, and the quality of experience in connected landscapes.

8. Optimize Green Infrastructure

Have you left room for enough green, permeable spaces to manage stormwater and cool the air?

The **Optimize Green Infrastructure** strategy refers to ensuring that you have sufficient canopy cover and other green infrastructure services to support a healthy and resilient living environment, ***Figure 10***. In response to human health, having enough vegetation to filter the air can help mitigate air pollution, noise pollution, and visual stressors that can detract from wellbeing. From a climate change perspective, urban heat islands can be mitigated with sufficient tree canopy and vegetation to provide shade and evapotranspiration. Recent research suggests aiming for 40 percent canopy cover: a study focused on urban heat islands suggests that areas with canopy cover greater than 40 percent had significantly reduced daytime air temperatures, in another study, subjects reported increased stress reduction up to about 40 percent canopy cover.

While the recent studies cited above suggest a quantity to aim for, more research and context-specific exploration would be needed to create a specific target for a given neighbourhood. Generally, those living in environments with more high-quality green space tend to report better physical and mental health outcomes.

It should be noted, though, that while green space provides important benefits, increasing green space within neighbourhoods has been associated with negative impacts, such as gentrification. Nonetheless, recent modeling studies emphasize the importance of measuring daily accessed greenery, rather than relying on top-down remote sensing (such as canopy cover), as the two measurements may not be equivalent in conveying a city resident's experience. While overall tree canopy and green space should be considered when planning or designing a community's blocks, our typology suggests the need for future research that aligns landscape vegetation assessments with block-level experience.

Select references:

Ziter, C.D.; Pedersen, E.J.; Kucharik, C.J.; Turner, M.G. Scale-Dependent Interactions between Tree Canopy Cover and Impervious Surfaces Reduce Daytime Urban Heat during Summer. Proc. Natl. Acad. Sci. USA 2019, 116, 7575–7580.

Jiang, B.; Li, D.; Larsen, L.; Sullivan, W.C. A Dose-Response Curve Describing the Relationship between Urban Tree Cover Density and Self-Reported Stress Recovery. Environ. Behav. 2016, 48, 607–629.

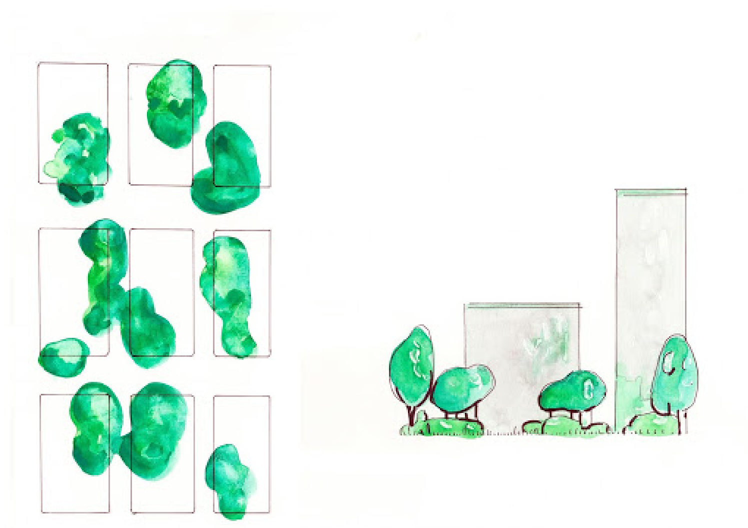

Figure 10. *Optimize Green Infrastructure diagram.*

Metric:

Canopy cover is commonly used to evaluate a city's urban forest and is often used as a proxy for urban forest quantity. Tree canopy cover is comprised of all trees making up the urban forest, as highlighted in Figure X. Many cities set tree canopy targets to guide urban forest decision-making and management. Higher rates of tree canopy cover in a neighbourhood is associated with higher potential for climate adaptation. For example, greater canopy cover would have greater heat island mitigation through increased shade and evapotranspiration. It is also associated with human health benefits, such as better pregnancy outcomes in neighbourhoods with higher tree canopy cover.

Goal:

Canopy cover goals should align with the bioregion of your neighbourhood. In some cases, a high canopy cover might not reflect the regional realities of the environment. For example, a high canopy would not make sense in a desert landscape.

For our case studies, we chose a goal of 40% canopy cover.

Taking it a step further:

Leaf area index and quality of treed landscape should also be considered.