Journal of Environmental Science and Engineering A 14 (2025) 156-182
doi:10.17265/2162-5298/2025.03.002

Documenting and Visualizing Sunlight in Toronto's Core

Matthew Canaran, Nadia Amoroso and Afshin Ashari

School of Environmental Design and Rural Development, The University of Guelph, Guelph, Ontario, N1G 2W1, Canada

Abstract: This research documents and visualizes the intricate relationships among sunlight, built form, and public life specifically within Toronto's core. Utilizing photographs and stop-motion videos, the study captured the dynamic movement of sunlight and observed corresponding differences in human behavior under varying light conditions. Maps and diagrams, generated using Rhino3D/Ladybug software, were employed to visualize the annual sunlight conditions throughout the defined study area. Building upon existing scholarship, this research affirms a strong relationship between sunlight and public life, noting that this relationship shifts with the changing seasons. The study concludes with a series of recommendations focused on the protection, expansion, and intensification of public space exposed to winter sunlight, particularly along pedestrian-oriented shopping streets, and advocates for the strategic use of large deciduous trees to manage sunlight across different seasons. The rapid transformation of downtown Toronto's built form necessitates swift action to address these issues. While the research and its recommendations are centered on Toronto, they are potentially applicable to other cities that share similar climates, sunlight conditions, and built environments.

Key words: Sunlight, environmental visualization, Toronto, public space, Rhino3D.

1. Introduction

This study aims to document and visualize the relationships between sunlight, built form, and public life in Toronto's core. The core, as defined for this research, is bounded by Church Street to the east, just west of Spadina Avenue to the west, College Street to the north, and the rail corridor to the south, covering approximately 440 hectares. The graphics illustrating the 3D massing model extended this area slightly to include Lake Ontario to the south, Bathurst Street to the west, Jarvis Street to the east, and just north of College Street to the north. A map of the study area (Fig. 1) highlights its distinct built forms: a high-density, high-rise district and high-density, low-rise district, with a dashed line indicating the division between them.

This research attempts to answer the question: how does sunlight move through Toronto's Core, and what happens where it does—and does not—make landfall? The goal is not only to describe this movement verbally but also to create accessible visualizations that enhance understanding. While the benefits of sunlight are intuitively understood to the individual, its path, its interaction with built forms, and its capacity to influence public life are often poorly documented and understood, especially in the context of Toronto. This study aims to fill this gap.

The research process contains three key phases: (1) the Documentation Phase, (2) the Visualization Phase, and (3) the Planning and Design Phase. The Documentation Phase focuses on the human-scale experience, using photographs and stop-motion videos to capture moments of sunlight and public life on the ground. The Visualization Phase adopts a top-down, district-level perspective, employing software to model sunlight conditions across the study area annually. Finally, the Planning and Design Phase leverages the findings from the first two phases to develop recommendations for environmental

Corresponding author: Matthew Canaran, master, research fields: landscape architecture, exploring sunlight in relationship with the built form, in public spaces, using data visualization to capture this documentation.

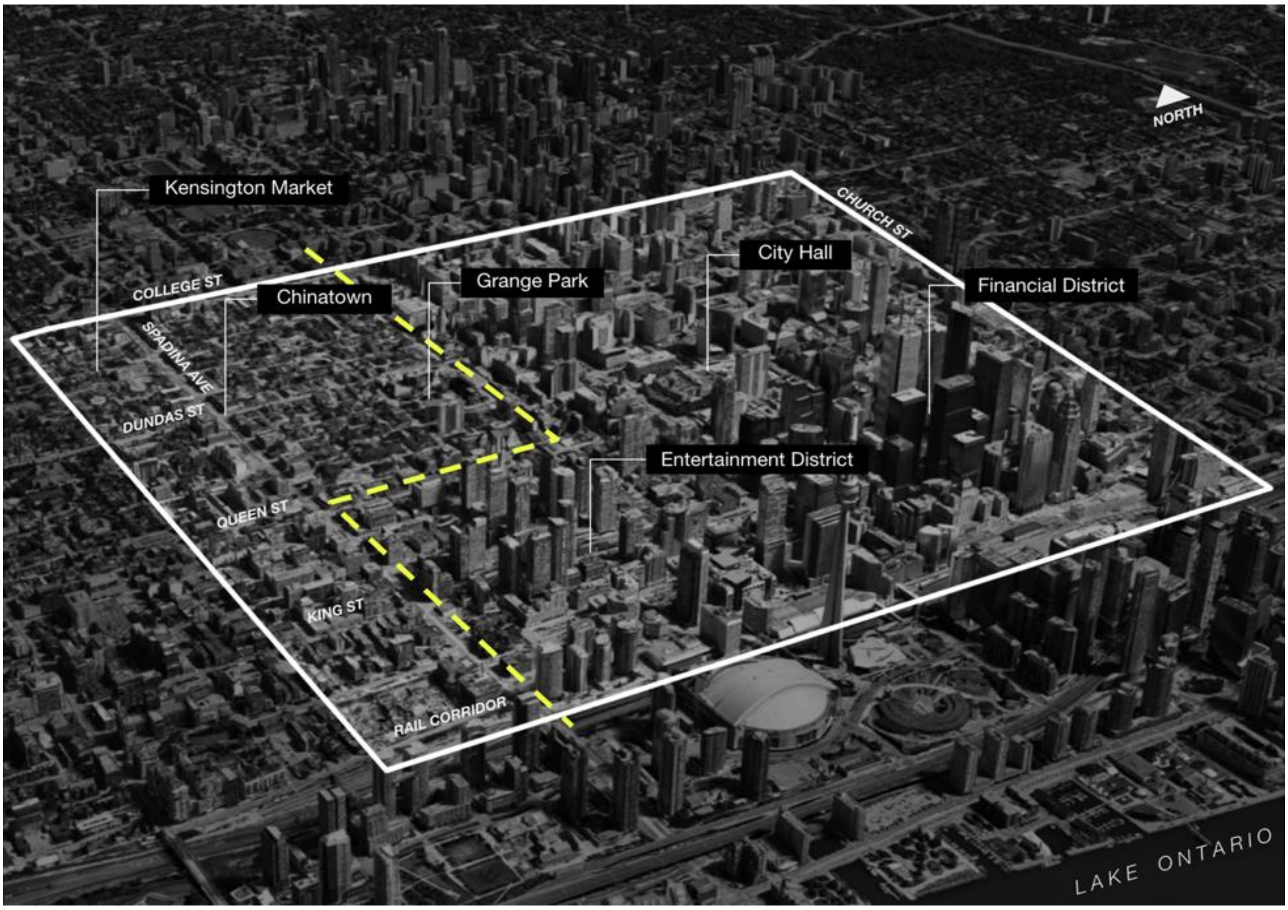

Fig. 1 Map of study area in Toronto's core.
Note: The study area contains two distinct built forms: high-rise towers, and lower-rise buildings. The yellow-dashed line represents the dividing line between these two predominant built forms in the study area. Image source: Matthew Canaran, based on a 3D model from Google Maps.

design fields, specifically demonstrating how sunlight maps can inform the expansion and intensification of public space in areas with favorable sunlight conditions. The methods and findings are presented in detail in the subsequent sections.

This research also contributes to the broader discussion on why sunlight in public space matters. Drawing upon the work of influential design experts like Hugh Ferriss, Jane Jacobs, Jan Gehl, Christopher Alexander, William H. Whyte, Peter Bosselmann, and Robert Brown, the literature reveals a consensus on the importance of sunlight for thermal comfort, human health, and behaviour. This research focuses on the human dimension. Sunlight's contribution to beauty is often captured in the visual arts but less so in environmental design fields. This study highlights this connection, suggesting that a more sensitive relationship with sunlight can contribute to addressing major challenges such as climate change, biodiversity loss, and social isolation by influencing thermal comfort, health, behaviour, and perception of beauty.

A limitation of this research is its timeframe, taking place between October 2021 and April 2022. This period impacts the photographic and stop-motion results, which reflect fall, winter, and early spring conditions, omitting late spring and summer experiences. The literature review is used to supplement understanding of summer conditions. The analysis relied on the City of Toronto's 3D massing model current as of early 2022, meaning buildings constructed or approved since then are not included, implying that sunlight conditions at ground level may have already diminished due to continued intensification. Pandemic-related shifts in public behavior during the study period could also influence observations, though the observed responses to sunlight are likely reflective of future conditions too. Despite these limitations, the research offers valuable insights into the relationship between sunlight and public life in Toronto, with future research encouraged to confirm or adjust findings influenced by potential pandemic effects.

2. Literature Review

The literature review establishes a historical and theoretical context for the study of sunlight in urban environments.

2.1 Historical Context—Darkening Cities

Societies have historically planned communities considering the sun's energy, from ancient Greek architecture providing seasonal shade and sun, Roman public baths using solar heat, to ancient American communities ensuring sunlight access for dwellings [1]. However, the rapid growth of cities, particularly in the 19th century, led to increasingly dense and unhealthy living conditions, where buildings blocked access to light and air. New York City is a prominent example, with descriptions of housing as "small, dirty, very badly ventilated, poorly lighted, and wretched" [2]. The construction of skyscrapers, while providing light and air to their tenants, simultaneously plunged adjacent streets and buildings into darkness, exacerbating the problems of the "dark, gloomy, and damp" city; streets began to feel "like the bottom of a canyon" [3].

Progressive reformers pushed for improvements, leading to requirements for windows in every dwelling, zoning regulations, and building massing rules to ensure more equitable sunlight distribution. While many cities adopted maximum building heights, New York City implemented unique "setback" rules, linking building height to street width (a 1.5 multiplier) and allowing additional height for setbacks [4]. These regulations influenced the iconic designs of buildings like the Empire State and Chrysler buildings, demonstrating how sunlight considerations "sculpted New York's most distinctive architecture" [3].

Architect Hugh Ferriss critiqued the overly dense urban conditions of his time and envisioned future cities in his book *The Metropolis of Tomorrow*. He imagined cities with ample spacing between skyscrapers, sometimes up to half a mile, with lower-rise buildings filling the gaps [5]. Ferriss advocated for a building-height-to-street-width ratio of 1:1, even more conservative than New York's 2:3 ratio, to ensure more sunlight reached the streets. He argued against the "monotonous repetition of formidable masses" that blocked light for most of the day [5].

Ferriss's vision (Fig. 2) remains relevant today, as dense clusters of skyscrapers in cities like Toronto continue to block light and create uncomfortable microclimates, indicating a failure in limiting the massing and clustering of buildings.

2.2 Sunlight in Design

Jane Jacobs [6], a key urban thinker, discussed the negative impact of building shadows on public life, referring to them as "killers", a "pall", and "erasers of humans". While not always recognized as a sunlight advocate, Jacobs argued for the use of zoning to "protect a park's supply of winter sun" [6].

Jan Gehl's [7] work emphasizes the need for a pleasant environment in public spaces, requiring "a maximum number of advantages, and a minimum number of disadvantages". Key considerations include microclimate generally, and sunlight specifically.

In his book, *The Social Life of Small Urban Spaces*, William H. Whyte [8] writes about the relationship between the public life in Seagram Plaza in New York City and the presence of direct sunlight. He and his team set up stop-motion cameras one day in May and recorded a narrow wedge of sunlight streaming between buildings. As time passed, the wedge of sunlight grew, and so too did the number of people sitting in the square. Whyte called this relationship

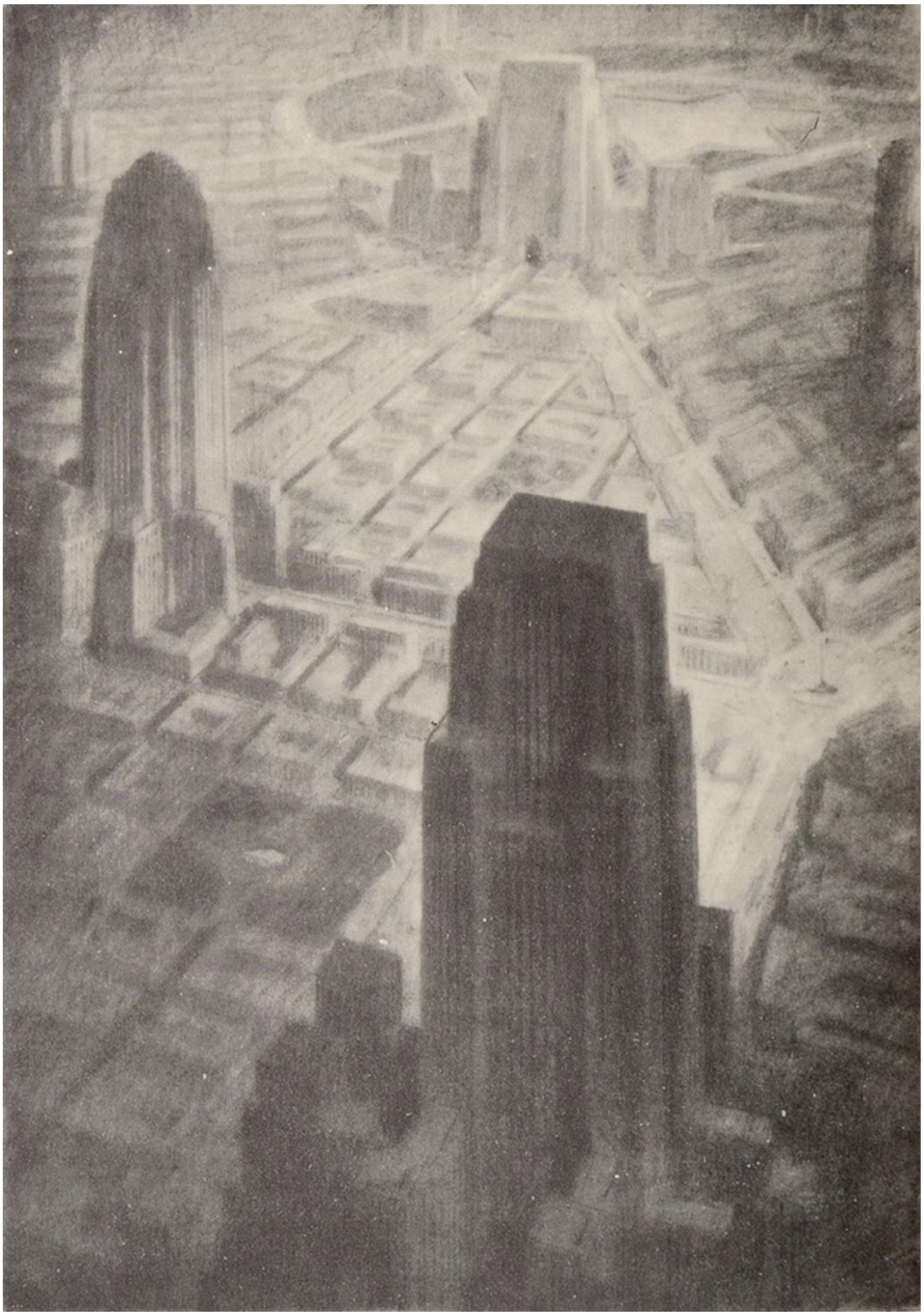

Fig. 2 Wide spacing between skyscrapers, as imagined by Hugh Ferriss [5]. (Image from The Metropolis of Tomorrow, 1929, by Hugh Ferriss)

between public life and direct sunlight a "perfectly splendid correlation" [8]. Whyte's use of stop-motion video to capture sunlight movement and human response inspired the methods in this research.

As the year progressed, and his studies of Seagram Plaza continued, Whyte noted that the relationship between direct sunlight and number of users changed. This happened sometime in June, when the air temperatures became warm enough for people to feel comfortable outside without the sun [8]. This leaves eight to nine months of the year (September through May) during which outdoor air temperatures are low, and incremental additions of sunlight help to achieve favourable thermal comfort conditions in the public realm.

Whyte acknowledged the difficulty of protecting direct sun access in dense urban areas but suggested "borrowing sun" from reflective surfaces of tall buildings. He noted this potential for adding light in this way but questioned its quality compared to direct sun [8]. Whyte also highlighted the crucial role of trees, particularly large deciduous ones, for climatic reasons along sidewalks and open spaces. He observed that trees, like awnings, provide a sense of enclosure and protection, and offer cooling shade in warmer months. In cooler months, deciduous trees with bare canopies allow sunlight and warmth to pass through, enabling people to sit underneath them year-round [8].

The distinction between building shade and tree shade is significant. Building shadows are dense and indiscriminate, blocking sunlight year-round. Building shadows change seasonally. In winter when the sun is lower on the horizon, buildings cast longer shadows. In summer when the sun is higher in the horizon, buildings cast shorter shadows, despite the need for more shade at this time of the year. Trees—especially deciduous ones—provide shade when needed in summer and allow sunlight through their bare branches in winter, aligning with seasonal human comfort needs [9]. See Fig. 3.

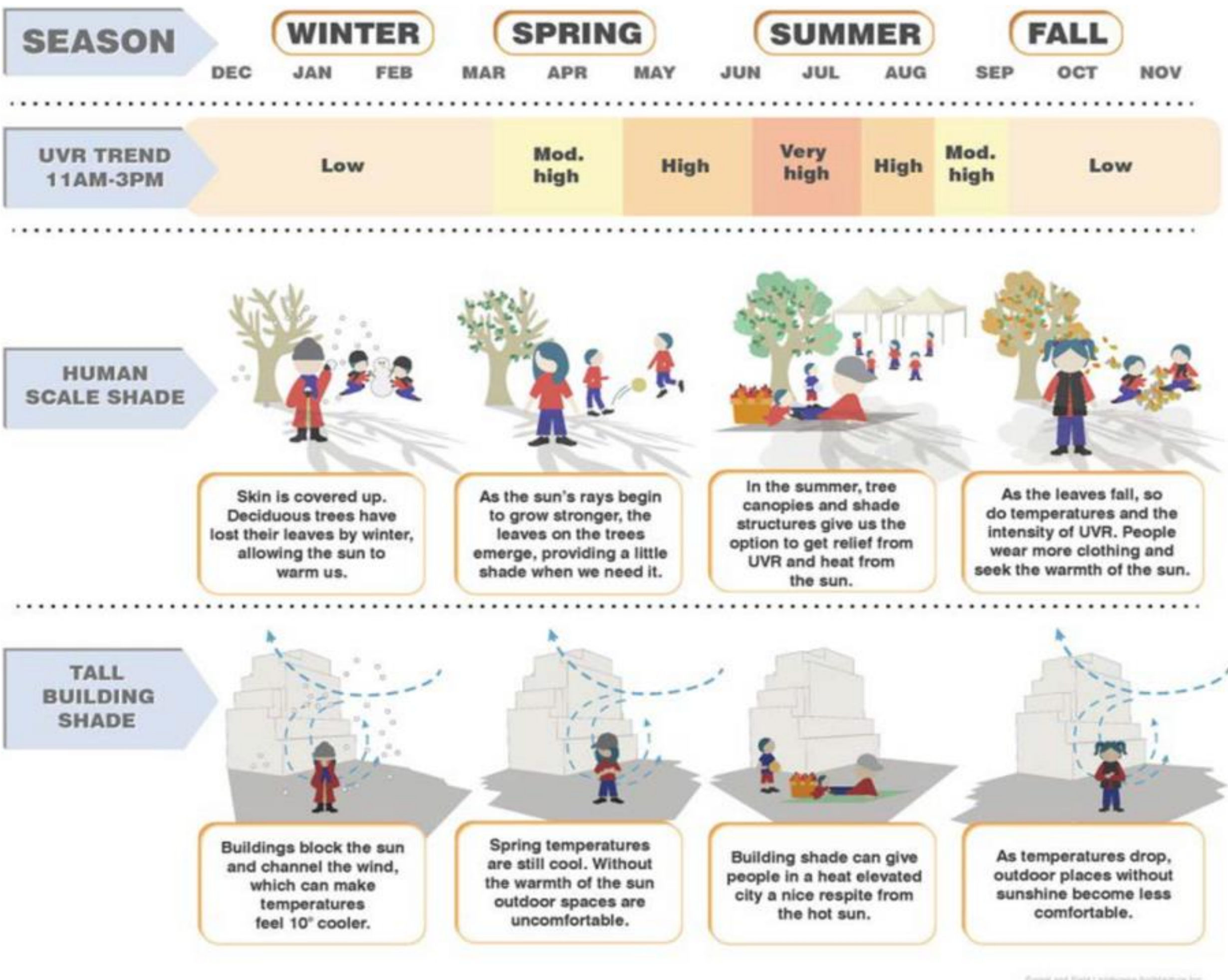

Fig. 3 Shade from building vs. tree: Considering climate variations in Toronto.

Note: This illustration communicates the seasonal nuances of human-scale shade provided by deciduous trees compared to building-shade. Source: Forest and Field Landscape Architecture Inc. [9].

Addressing shadows in challenging spaces, like those overshadowed by tall buildings, might involve an exploration of alternatives to direct sunlight. Teardrop Park in New York City, designed by landscape architect Michael Van Valkenburgh, uses heliostats—to reflect sunlight to previously shaded areas (see Fig. 4). While not a perfect substitute for sunlight, these heliostats can reflect up to 90% of the sun's light spectrum, and track the path of the sun and reflect its light onto a fixed place in the park [10]. Another approach is designing building to mitigate their own shadow impacts, such as the No Shadow Tower concept in London. This concept involves shaping a building to reflect and diffuse sunlight to minimize the shadow impacts of an adjacent tower [11].

2.3 Modeling & Designing for Sunlight

The need to manage sunlight in urban design intensified with population growth and the rise of tall buildings. Early methods for understanding the sun's path relative to buildings relied on geometric diagrams and calculations. William Atkinson's work in *The Orientation of Buildings or Planning for Sunlight*, in 1912 provided tools like sunpath diagrams and methods for drawing shadows, demonstrating the complexity of visualizing sunlight conditions. These historical works highlighted the importance of orienting buildings and open spaces to maximize solar access, particularly in northern climates where sunlight is crucial [4]. Christopher Alexander [13] also supported this, stating that urban spaces on the north side of buildings that never receive sun are wasted and suggesting important open spaces should be located on the south side for good solar access.

The Cerdà Plan of 1859 for Barcelona's Eixample district is an early example of a large-scale urban plan incorporating sunlight considerations. Designed with a grid of blocks featuring chamfered corners and intended internal courtyards, the plan aimed to improve living conditions, including sunlight and air circulation. Cerdà proposed building heights relative to street width (16-m buildings on two sides of a 20-m street), a ratio more conservative than today's standards, contributing to more sunlight on streets and courtyards. While later intensification enclosed many blocks on all four sides and increased building heights, the original plan demonstrates an early, large-scale attempt to design for sunlight [14, 15].

Ralph Knowles [16] introduced the concept of the "solar envelope" to "regulate development within limits derived from the sun's relative motion". A solar envelope defines the maximum building volume that will not cast shadows on surrounding properties during specific "critical periods" of the day [16]. This involves considering property boundaries, surrounding buildings, desired sunlight access timeframes, and creating a "shadow fence" on adjacent properties that must remain free of shadow [17]. The resulting envelopes are unique, angled forms that constrain building massing to protect solar rights.

2.4 The Bosselmann Study & Toronto's Policies on Sunlight

Peter Bosselmann and his team [18] conducted a significant sun and wind study for Toronto's central area in 1990. Their report provided an inventory and analysis of sun and wind conditions, along with extensive recommendations ranging from city-wide guidelines to site-specific interventions. Bosselmann's study included graphics, models, and photographs to visualize the relationships between built form and comfort conditions on streets and in parks, documenting conditions that were largely unseen at the time. He used fish-eye lens views to show the sunpath over specific locations, like Roundhouse Park near the CN Tower (Fig. 5 illustrates this fish-eye view). Calculating sunpaths and sunlight received based on built form was complex geometry at the time, making Bosselmann's work technically impressive. Modern tools like Rhino3D & Grasshopper, coupled with environmental analysis plugins such as Ladybug can achieve similar precision much faster, hence why they were chosen as modeling tools for this research.

Fig. 4 Heliostats reflect sunlight into a dark corner of Teardrop Park in New York.
Image from John Hill, Archidose Blog, 2010 [12].

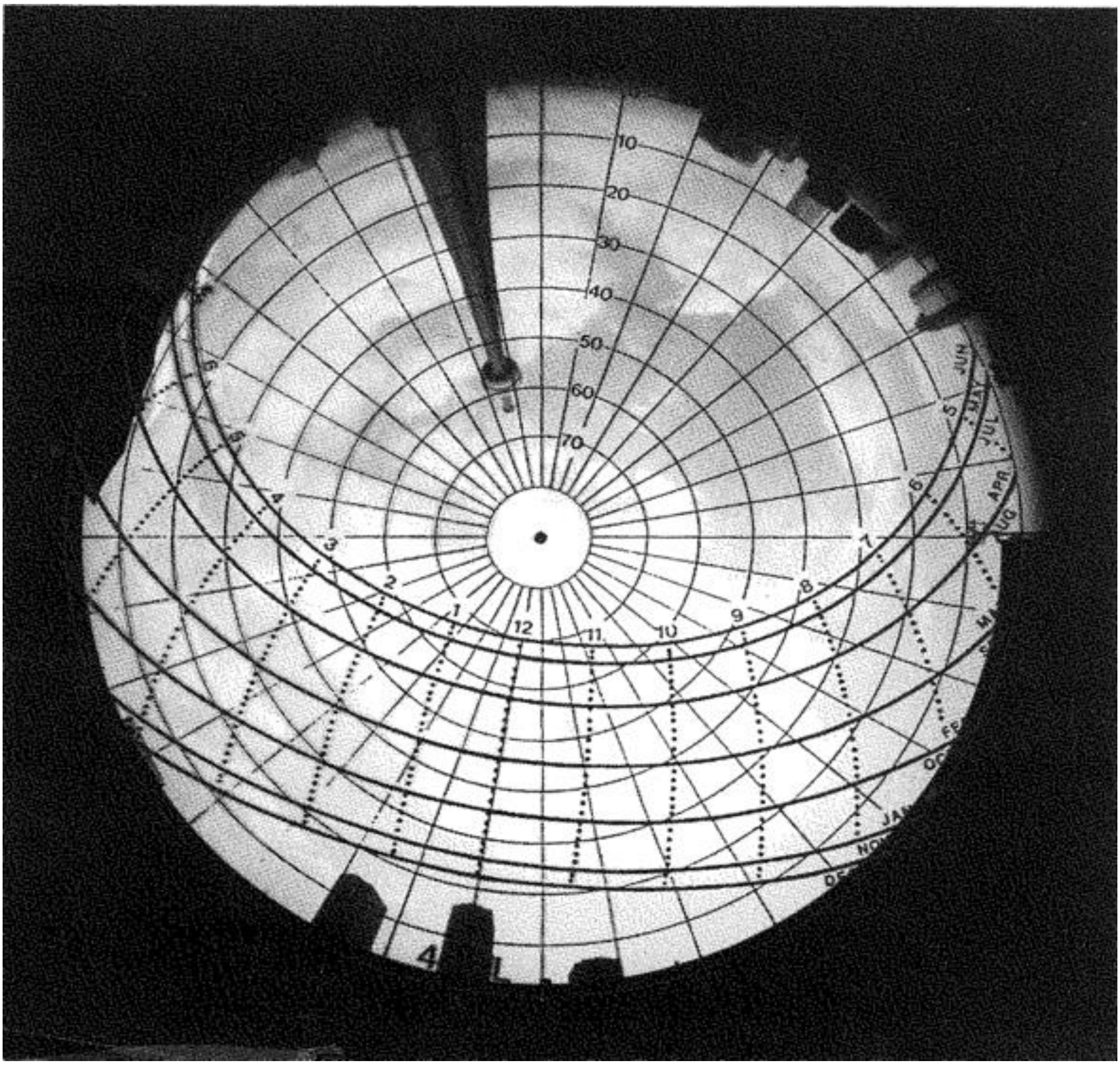

Fig. 5 Bosselmann's fisheye lens illustrating the sunpath.
Note: The sunpath is visible on the bottom half of the sky view. The dotted lines represent the hours of the day, and the curved lines perpendicular to the hour lines represent the monthly intervals between Jun. 21st (Summer solstice) and Dec. 21st (Winter solstice). The month labels are seen on the right side of the view. Source: Bosselmann et al. [18].

The Bosselmann study presented illustrations of the sun's path relative to Toronto's street grid, highlighting how the north side of east-west streets receives more sunlight than north-south streets due to the sun's generally southern position in the northern hemisphere (Fig. 6 shows this relationship).

Two key recommendations from the Bosselmann study were adopted into official City of Toronto policy documents guiding the city's development [19-21]. These recommendations included:

1. Protecting sunlight on greenspaces.
2. Requiring sun/shadow analysis to maintain a minimum of 5 h of sunlight on streets opposite new buildings between March 21st and September 21st [18].

A significant gap in Toronto's adoption of the Bosselmann study recommendations is the inadequate consideration of winter sunlight. Bosselmann's original study devalued winter sun, stating that low angles did

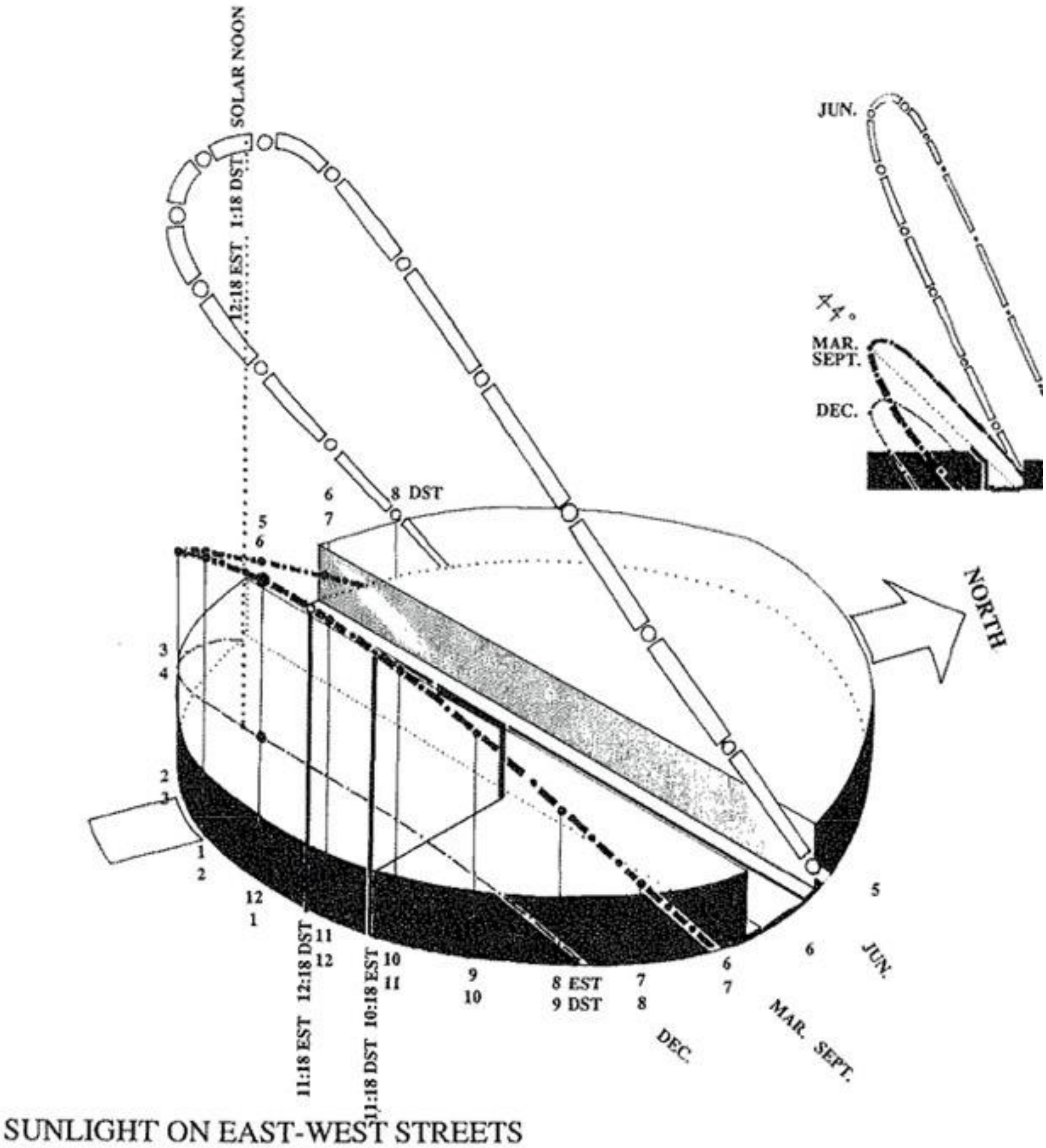

Fig. 6 The path of the sun relative to east-west streets in Toronto.

Note: Three different line types annotate the path of the sun during different times of year. See the legend in the top-right corner of this image. The dots within those lines represent different hours of the day. Source: Bosselmann et al. [18].

not provide enough radiation to compensate for cold and wind [18]. Consequently, official policy primarily protects sunlight only for the six warmest months (March 21st to September 21st). This overlooks the importance of winter sun for thermal comfort and public life during the long, cold months. While greenspaces have some winter sun protection, pedestrian-oriented streets, which often see high volumes of people and support local businesses, receive no mandated protection for winter sun access. Furthermore, the policy only protects mid-day sun for 5 h, neglecting morning and evening sun year-round.

Other Bosselmann suggestions were not fully implemented either, these include height restrictions around parks and plazas [18], and providing deciduous street trees for all-season comfort [18]. Despite the policy gaps and misinterpretations, Bosselmann's work was foundational for Toronto's approach to sun and wind studies.

In a journal article published a few years later, Bosselmann et al. [22] state: "A city in a cold winter/hot summer climate like Toronto's can have comfortable streets year-round. Many streets in Toronto's inner city are in fact comfortable, yet streets in the financial district are rarely so." This statement is buried in the middle of the article and may have gone unnoticed by Toronto policy makers. By this point, Bosselmann's 1990 primary recommendations had been adopted by Toronto City Council and were already being used to change the built form of the city in ways that undervalued or ignored winter sunlight access.

2.5 Literature Review Gaps

The literature review revealed several gaps that this research attempts to address. While there is extensive historical context and discussion of sunlight's importance, there is a lack of detailed documentation on how sunlight specifically interacts with Toronto's built form and influences public life, especially in winter. Although Bosselmann provided analysis, his recommendations adopted by the city largely neglected winter sunlight on streets. Gehl's work highlights the need for pleasant environments, suggesting a gap in incorporating winter sunlight protections into Toronto's urban landscape design. While tools exist for environmental analysis (like Rhino3D/Ladybug), there was a need to demonstrate their application to create accessible visualizations like sunlight maps for Toronto. There was a gap in documenting the relationship between sunlight and public life in Toronto specifically, using visual methods like photographs and stop-motion videos, mirroring the work of Gehl and Whyte, but tailored to Toronto's unique urban landscape.

3. Methods

The research employed methods across three phases: Documentation, Visualization, and Planning and Design. These phases aimed to capture both the human-scale experience ("bottom-up") and a broader overview ("top-down") of sunlight conditions.

3.1 Documentation Phase: Objectives and Procedures

The objective of this phase was to understand the experiential aspects of sunlight in Toronto's core from a human perspective. Data collection involved using photographs and stop-motion videos to capture moments of sunlight, shadow, and human behavior. Photographs capture a single instance, while stop-motion sequences document changes over time, allowing for a rapid playback of trends.

The procedures included:

- Photographing moments of sunlight and shadow to understand their impact on space and behavior. This involved conducting photo-walks in the study area, capturing images with an iPhone 12 Pro, and recording date, time, and weather. A subset of the most telling photos were selected and described to explain the documented phenomena.
- Recording stop-motion sequences to understand how changing sunlight conditions affect spaces and behavior. The Skyflow app on an iPhone was used for recording. Sequences ranged from 5 min to over 2 h. A subset of still frames from the most telling sequences were selected for print, exported, and sometimes edited in Adobe Photoshop to draw attention to features or converted to black-and-white with selective color isolation to highlight reflections. GIFs (Graphics Interchange Format) were created for digital use. Descriptions were provided for context, to highlight trends, and to draw attention to key elements. Shadow movement calculations were also included where visible to the naked eye.

The documentation took place between November 2021 and April 2022, focusing on days with sunny or partly sunny conditions to specifically examine the impact of built form shadows. Over 500 images and 25 stop-motion sequences were recorded in total, with 18 photographs and 10 stop-motion sequences shared in the original research paper.

3.2 Visualization Phase: Objectives and Procedures

This phase aimed to understand ground-level sunlight conditions from a broader perspective, covering multiple districts. Objectives included exploring the relationship between the sunpath and built form through diagrams and visualizing sunlight conditions across the study area using maps.

Procedures involved:

Exploring the relationship between sunpath and built form. This utilized the Rhino3D/Ladybug/Grasshopper ecosystem. The Ladybug sunpath for Toronto was loaded. A 3D building massing model of the study area was compiled and refined from the City of Toronto's Open Data Portal. This model was imported into Rhino3D and reassembled from tiles, cross-referenced for accuracy, and simplified by clipping buildings outside a two-block buffer around the study area. Simplified versions provided by the City were used where available, considered acceptable given the multi-district scale. The model assumes a flat ground plane, which was deemed acceptable due to the study area's relatively flat topography. Diagrams and composite images were created to illustrate sunpath features and shadow studies at different times of the year. Shadow studies were generated using the RhinoSun component in Grasshopper, linking the 3D massing model geometry to the sun's position defined by the sunpath. The sunpath was scaled and centered over the model for visualization. Diagrams were captured from Rhino viewports.

Visualizing sunlight conditions through sunlight maps. The Direct Sun Hours analysis in Ladybug was used to aggregate sunlight conditions over longer durations. The year was divided into two main periods: the "dark season" (September 21st to March 20th) when the sun is lower and nights are longer, and the "bright season" (March 21st to September 20th) when the sun is higher and days are longer. These periods were selected as they are centered on the extremes of the sunpath. A Ladybug script (Fig. 7) was created for the Direct Sun Hours analysis. The ground plane of the

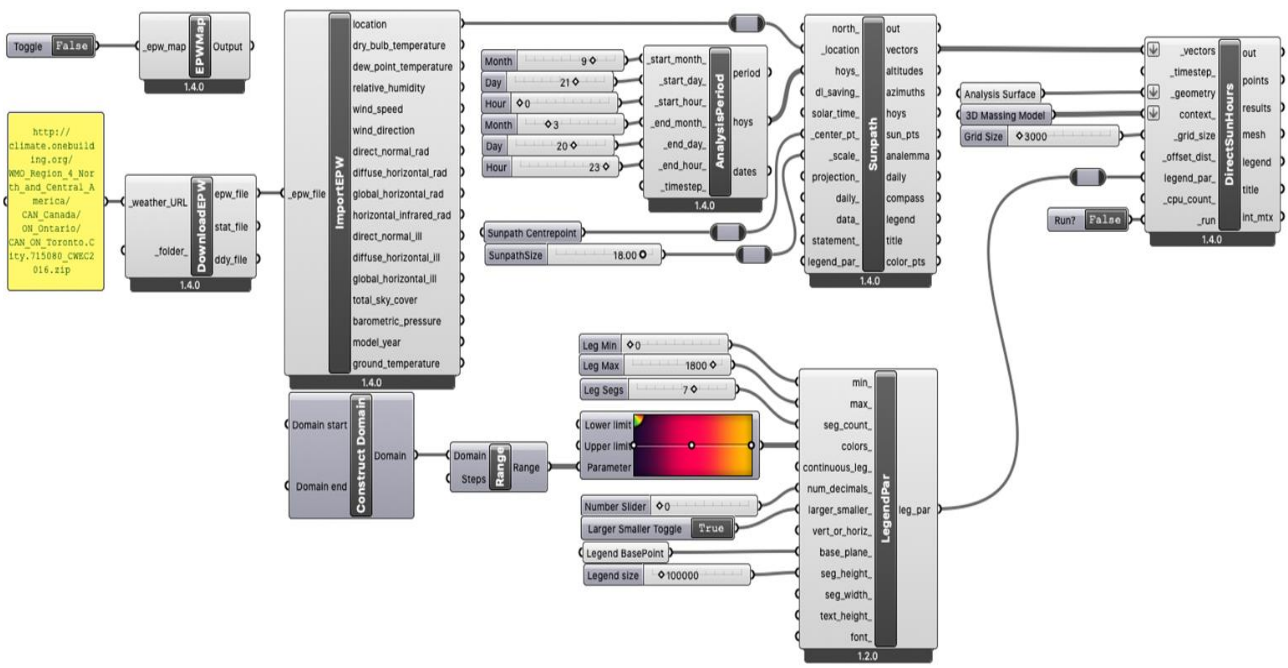

Fig. 7 Components used in the direct sun hours analysis, configured for the dark season.

Note: The *Analysis Period* component is set to start on September 21st at midnight and run through to the end of the day on March 20th. The bright season model would be set to start on March 21st at midnight and run through to the end of the day on September 20th. Source for components, McNeel, 2010 [23].

study area, represented by a large rectangular surface in Rhino, served as the analysis surface, with the 3D massing model as the context geometry causing shadows. The analysis outputs the aggregated hours of direct sunlight for the defined period onto the analysis surface. This analysis represents the maximum possible sunlight given the built form, as atmospheric conditions like cloud cover are not considered. The output provides values for any period of time specified. Maps were formatted for legibility in Adobe Photoshop, adding labels for streets, parks, and districts. Legend values were presented as both total aggregated hours and average hours per day in each six-month period.

3.3 Planning and Design Phase: Objectives and Procedures

This final phase aimed to apply the research findings to inform planning and design decisions. Objectives included developing an approach to expand and intensify public space based on the sunlight findings and making recommendations for environmental design professionals in Toronto.

Procedures involved:

- Demonstrating an approach to expand and intensify public space. The rationale for expanding public space in areas with favorable winter sunlight was articulated by analyzing observed human behavior in documented moments of sun during cooler temperatures. An overlay study mapped the locations of people sitting in the sun onto the dark season sunlight map to demonstrate the preference for sunny spots in winter. This rationale underpinned the demonstration of using sunlight maps for site selection. Existing public spaces (parks, plazas, enhanced streetscapes) were identified and mapped onto the dark season sunlight map. Potential sites for expanding or intensifying public space were then identified based on areas receiving sufficient sunlight during the dark season. Areas with unfavorable sunlight conditions ("trouble zones") were also identified as potential opportunities for adding reflected light using interventions like heliostats.
- Developing recommendations for environmental design fields. The results from the documentation and visualization phases were synthesized into key findings. Relevant insights from the literature review were incorporated to reinforce these takeaways with findings from previous studies. Actionable recommendations were then derived from these key takeaways. A summarized list of these recommendations is presented in the conclusion.

4. Results

This section presents the findings from the three research phases, offering both human-scale observations and broad-scale visualizations.

4.1 Documentation Phase: Photographs

Photographs captured during walks in November and December 2021 illustrate the relationship between sunlight and public life. For example, photos from December show people actively seeking and occupying sunny spots, even simple ledges or steps, while nearby designated seating in the shade remains empty (Fig. 8). Photographs also demonstrate how sunlight enhances the visual beauty of the urban landscape, making colors more vivid (e.g., red twig dogwoods) and forms more apparent (e.g., branching structures of honey locusts) compared to elements in shadow (Fig. 9).

4.2 Documentation Phase: Stop-Motion Sequences

Stop-motion sequences provided dynamic views of sunlight and shadow movement and related human behavior. These sequences captured phenomena like slivers of sunlight appearing between buildings, shadows casting over public spaces, reflections animating dark areas, and people following patches of sun. The sequences varied in duration, condensing hours of movement into short videos. Stills from the sequences (provided in the source document) communicate the trends captured in the videos. For example, a sequence on John Street showed a narrow

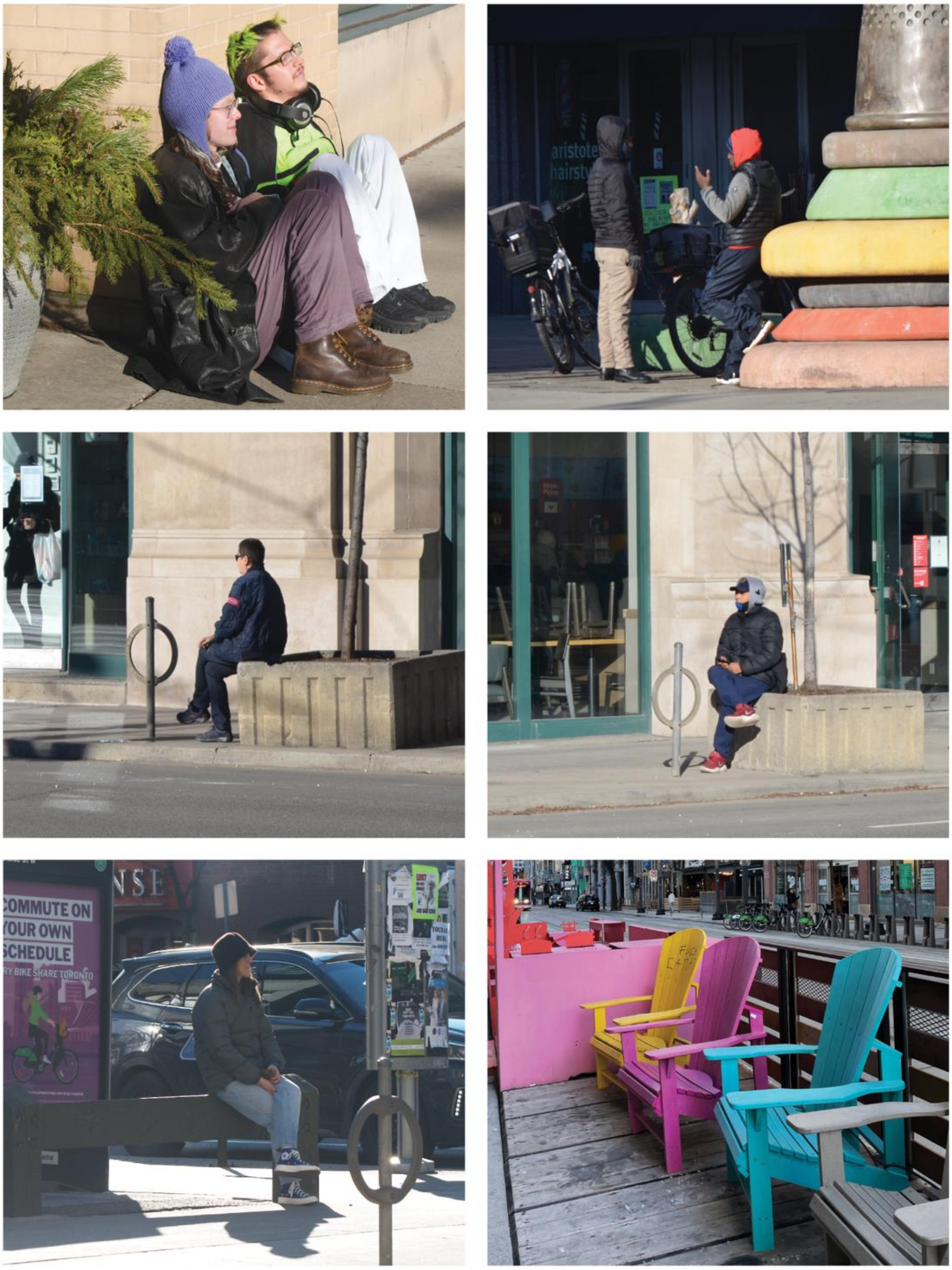

Fig. 8 People sitting and resting on anything in the sun in December.

Note: People prefer to sit in the sun in winter over sitting in a chair. Tactical urbanism projects on King Street are not used in the cold months when they are in the shadows. Photos taken on Sun. Dec. 12th, and Mon. Dec. 13th, 2021. Source: Matthew Canaran.

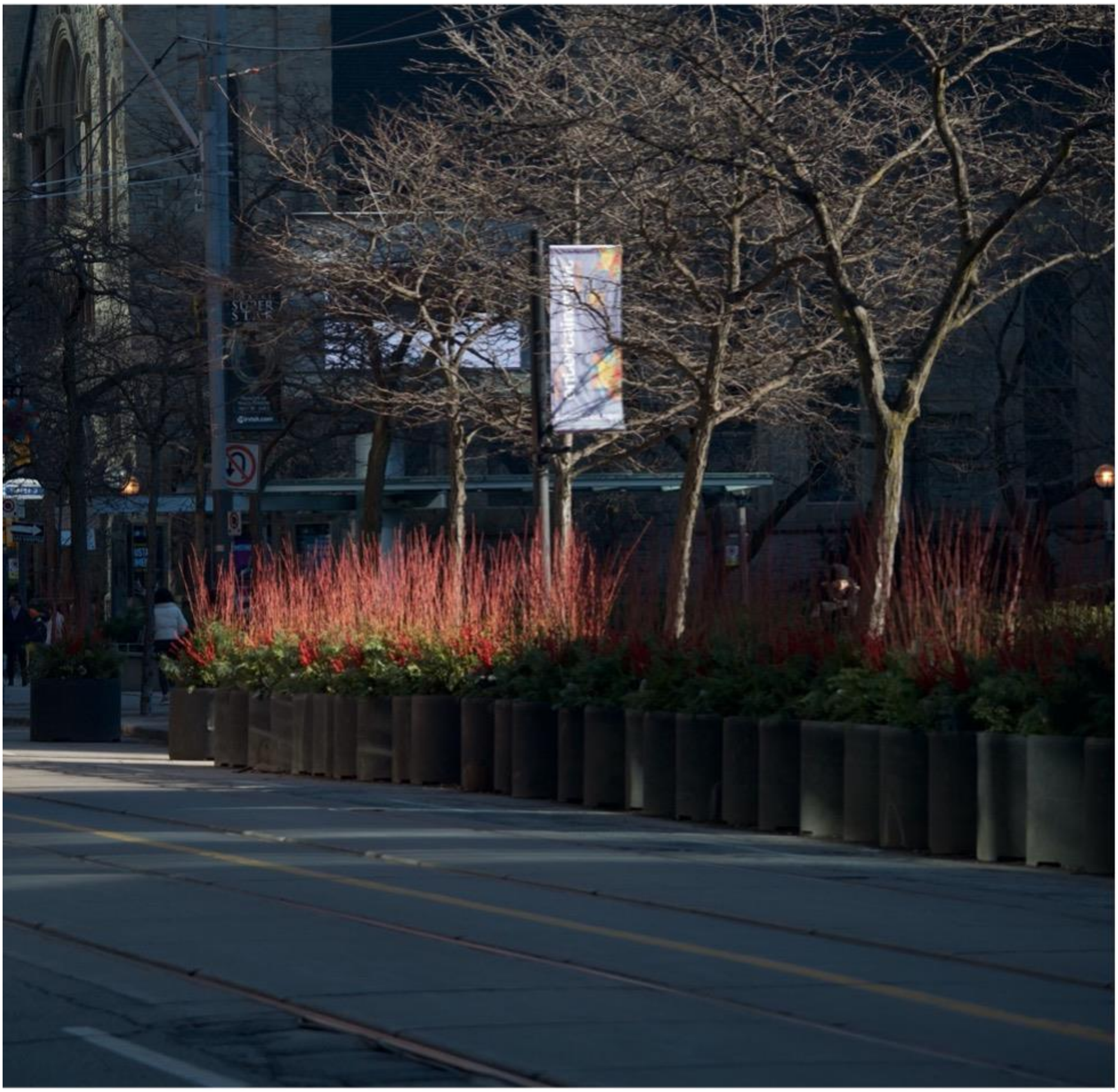

Fig. 9 Colour and form of vegetation is more easily appreciated in sunlight.
Note: Photograph taken on Mon. Dec. 13th, 2021 at 12:01 pm. Source: Matthew Canaran.

band of sunlight moving across the street (Fig. 10). Another sequence illustrated multiple sunlight sources, including direct sun, shadows, and reflections, interacting on a sidewalk near King Street West (Fig. 11). The sequence showed reflections disappearing when the sun was blocked by a building, demonstrating their dynamic nature.

Stop-motion sequences in Grange Park highlighted the difference between building shadows and deciduous tree shadows. Fig. 12 shows that in April, a deciduous tree canopy allowed light to pass through its bare branches, casting a dappled or light shadow. This reinforces that deciduous trees are effective tools for managing sunlight seasonally, providing warmth in winter and shade in summer, as discussed in the literature review.

Fig. 10 Sliver of sunlight on John Street—black and white stills.

Note: Stop-motion stills show the movement of the sun between two buildings on John Street over an eight-minute period. Photographed on Feb. 5th, 2022, starting at 1:11 pm. Source: Matthew Canaran.

Fig. 11 Multiple sunlight sources acting on the sidewalk.
Note: Black and white stop-motion stills show the multiple sources of sun, and therefore multiple shadows created by people walking in front of the TIFF Lightbox. Recorded over a three-minute period. Photographed on Feb. 5th, 2022 starting at 1:38 pm. Source: Matthew Canaran

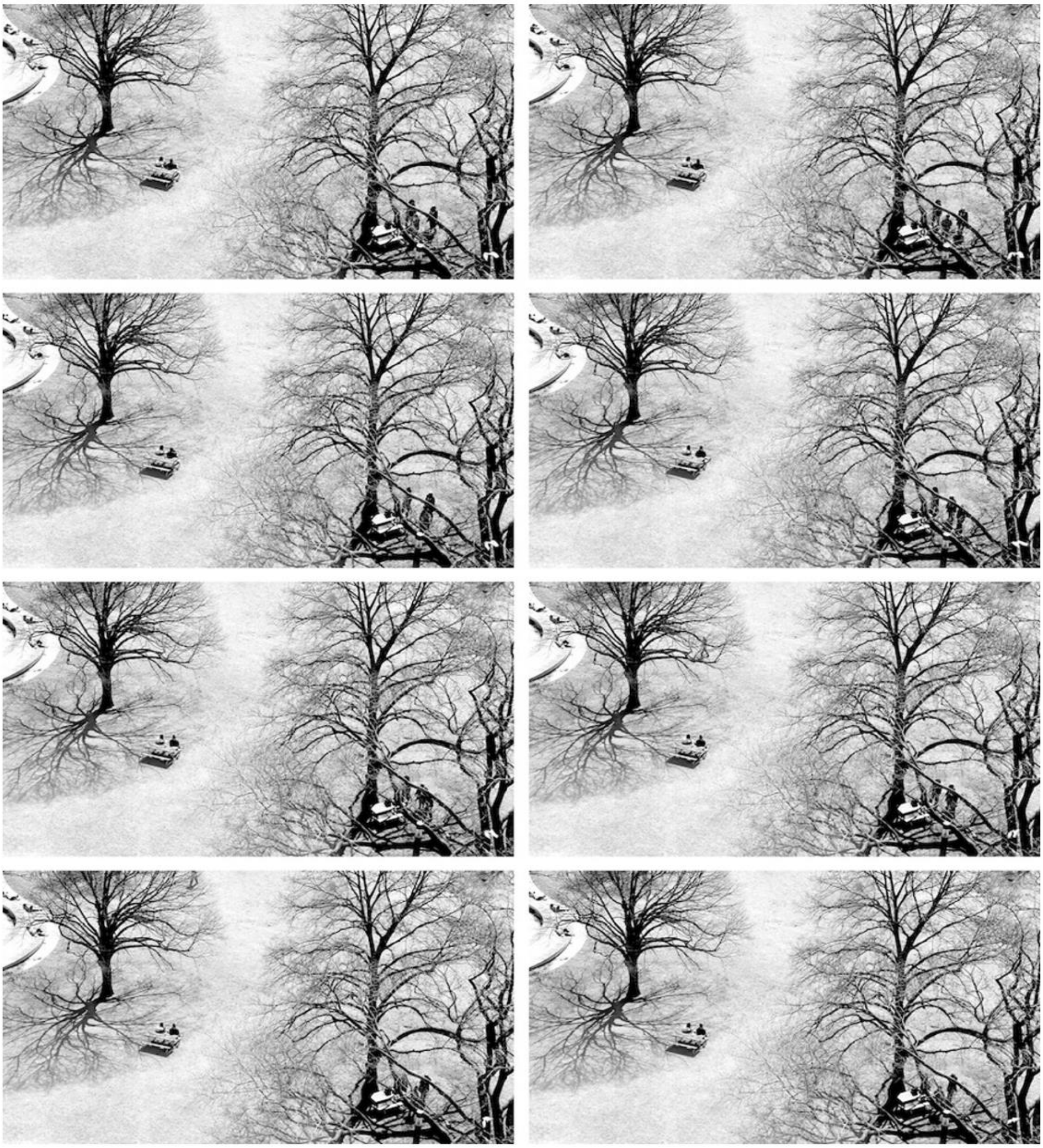

Fig. 12 The nuanced shadows of deciduous trees—black and white stills.
Note: Black and white stop-motion stills show how people are using the space under and adjacent to large deciduous trees in Grange Park over a five-minute period. Photographed April 2nd, 2022, starting at 12:47 pm, captured over 5 min. Source: Mathew Canaran.

4.3 Visualization Phase: Sunpath Diagrams & Shadow Studies

Sunpath diagrams visualize the sun's position in the sky throughout the year for a specific location, like Toronto. Fig. 13 shows the sunpath over a 3D massing model of Toronto, illustrating how the sun's path changes seasonally. Shadow studies using the 3D model and sunpath demonstrate the impact of built form on ground-level sunlight at specific times of the year and of the day.

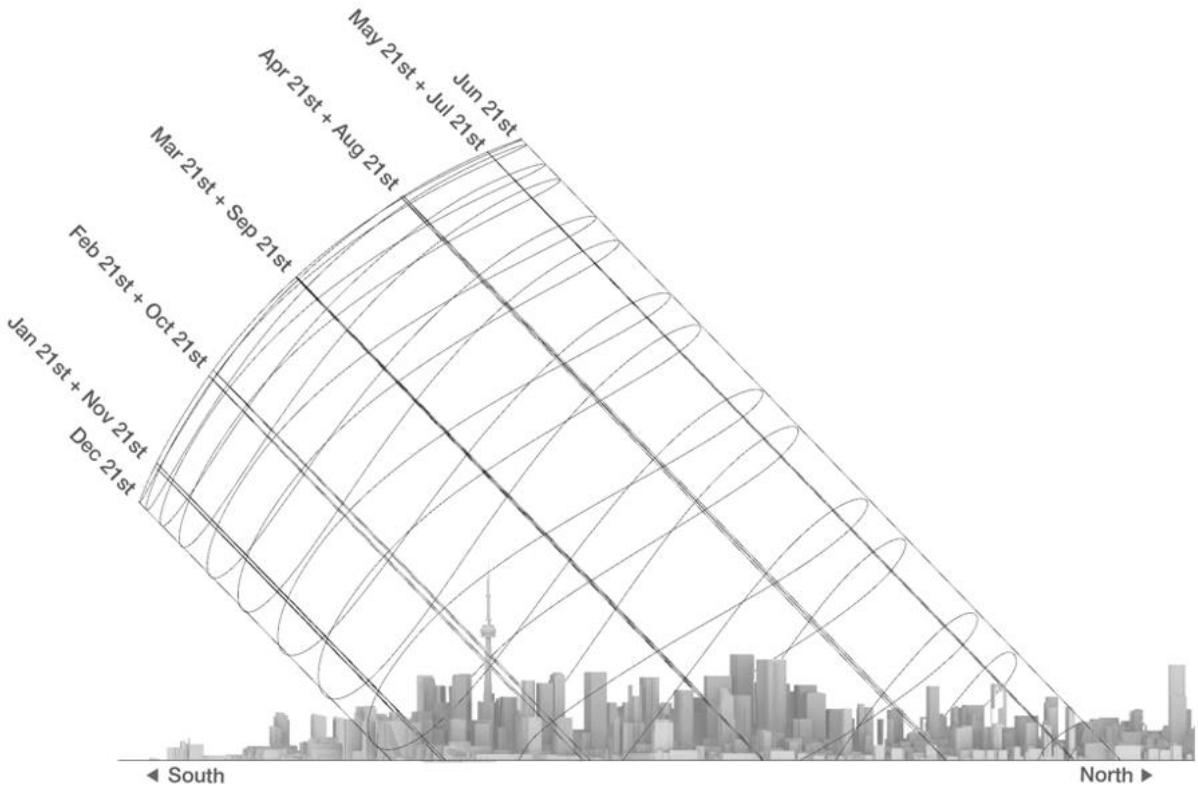

Fig. 13 A section of the sunpath over Toronto showing periods one month apart.
Note: Looking west, the topmost diagonal line represents the path of the sun during the summer solstice on June 21st. The bottommost diagonal line represents the path of the winter solstice on December 21st. The diagonal lines in-between are spaced at one-month intervals from those key-dates. The sunpaths on February 21st and October 21st, are close, but not actually the same, hence why multiple lines appear next to those dates. The same is true for all the combine dates listed above. Source: Matthew Canaran, using the City of Toronto's 3D massing model and Ladybug's sunpath.

4.4 Visualizing Phase: Sunlight Maps

The Direct Sun Hours analysis addresses the limitation of single-time shadow studies by aggregating sunlight conditions over defined periods. This research produced two sunlight maps for the study area using this analysis: one for the "dark season" (September 21st to March 20th) and one for the "bright season" (March 21st to September 20th). These periods, while equal in length, show substantially different results due to the sun's position.

Fig. 14 presents the Direct Sun Hours map for the dark season. This map visually depicts the total hours of direct sunlight received on the ground plane between September 21st and March 20th. The legend includes both total aggregated hours and average hours per day. The dark season map reveals significant variations in sunlight access across Toronto's core. Areas like the Entertainment District and Financial District receive much less sun than places like Kensington Market and Chinatown. Grange Park is highlighted as the largest parcel of sun in the area during this period. The map also shows that east-west oriented streets receive more sunlight than north-south streets, consistent with Bosselmann's observations.

Fig. 15 shows the Direct Sun Hours map for the bright season (March 21st to September 20th). This map displays the total hours of direct sunlight received during the warmer months. Compared to the dark season map, the bright season map shows generally more widespread sunlight coverage because the sun is higher in the sky, resulting in shorter shadows.

These maps effectively communicate the significant differences in sunlight conditions seasonally and geographically within the study area. They serve as a valuable tool for identifying areas with remnant sunlight as "opportunities" and those with less favorable conditions as "trouble zones".

4.5 Planning and Design Phase: Expanding Public Space

The research demonstrates a fundamental link between public life and sunlight, particularly from September to May when cooler temperatures make sunlight desirable for comfort. Observed behavior in the documentation phase showed a strong preference for sunny spots in winter. Fig. 16 maps observed instances of people sitting in the sun onto the dark season sunlight map, reinforcing this preference.

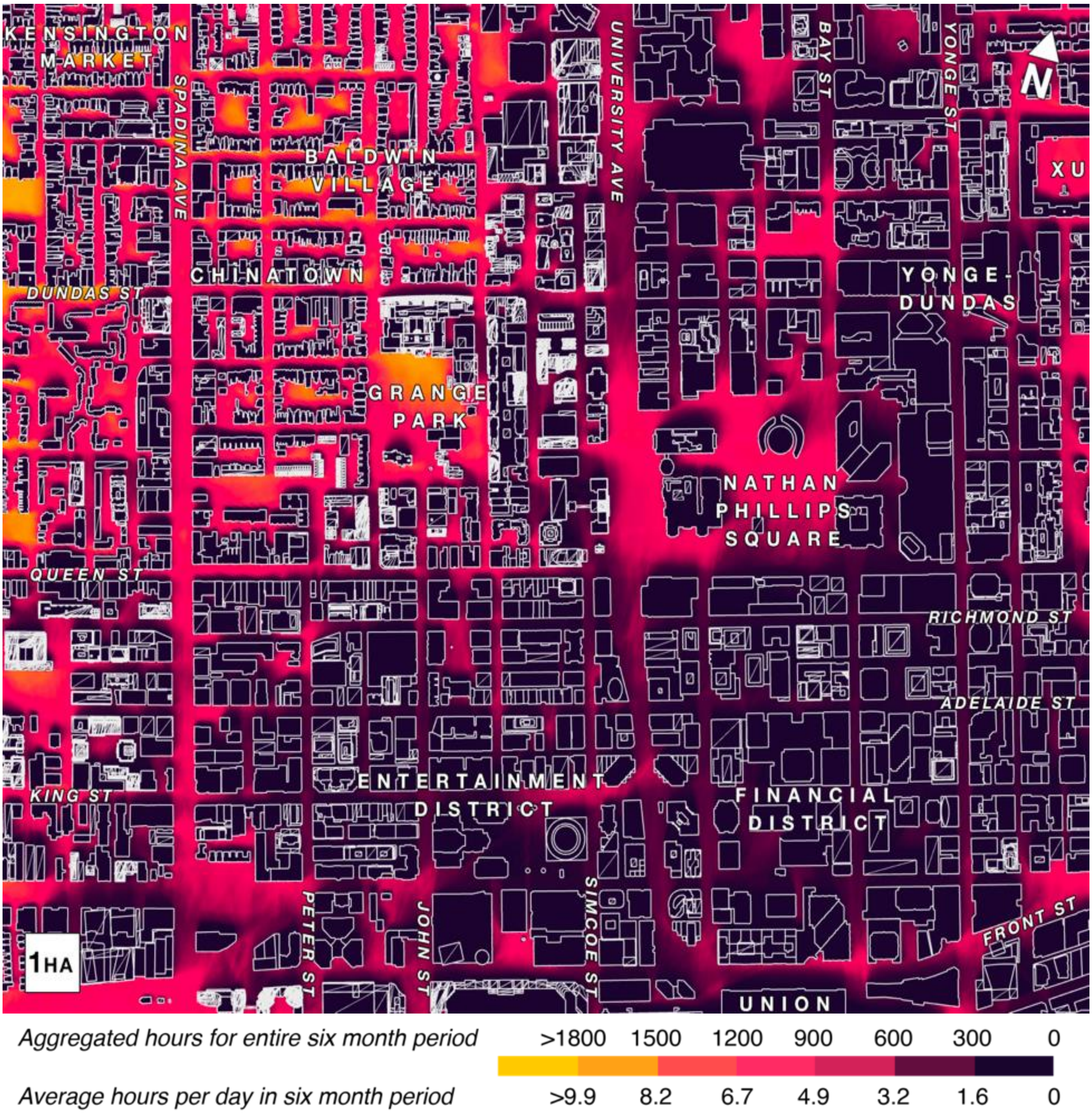

Fig. 14 Direct sun hours for the dark season (Sep. 21st to March 20th).
Source: Matthew Canaran, using the City of Toronto's 3D massing model and Ladybug's Direct Sun Hours analysis and sunpath.

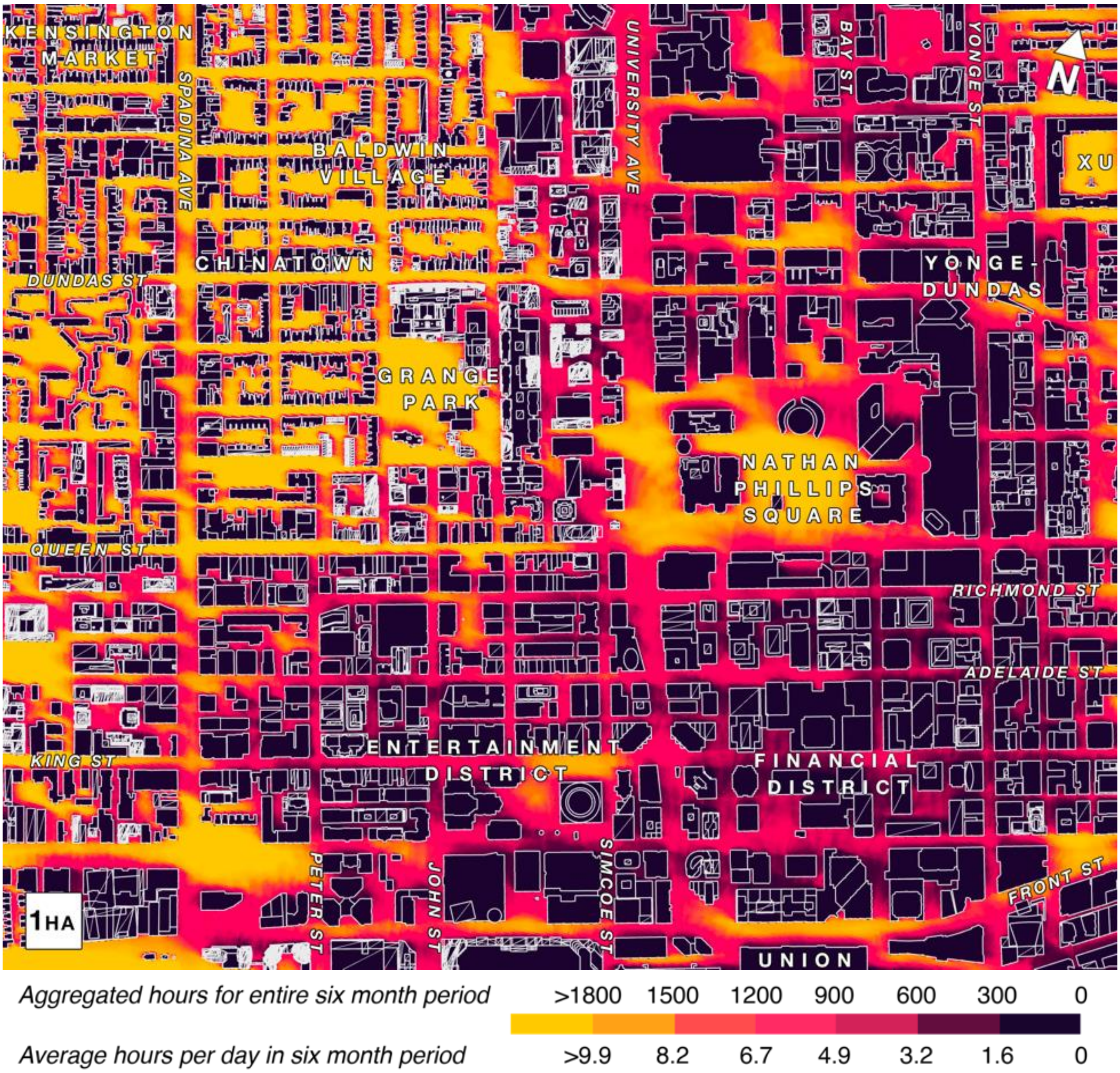

Fig. 15 Direct sun hours for the bright season (Mar. 21st to Sep. 20th).

Source: Matthew Canaran, using the City of Toronto's 3D massing model and Ladybug's Direct Sun Hours analysis and sunpath.

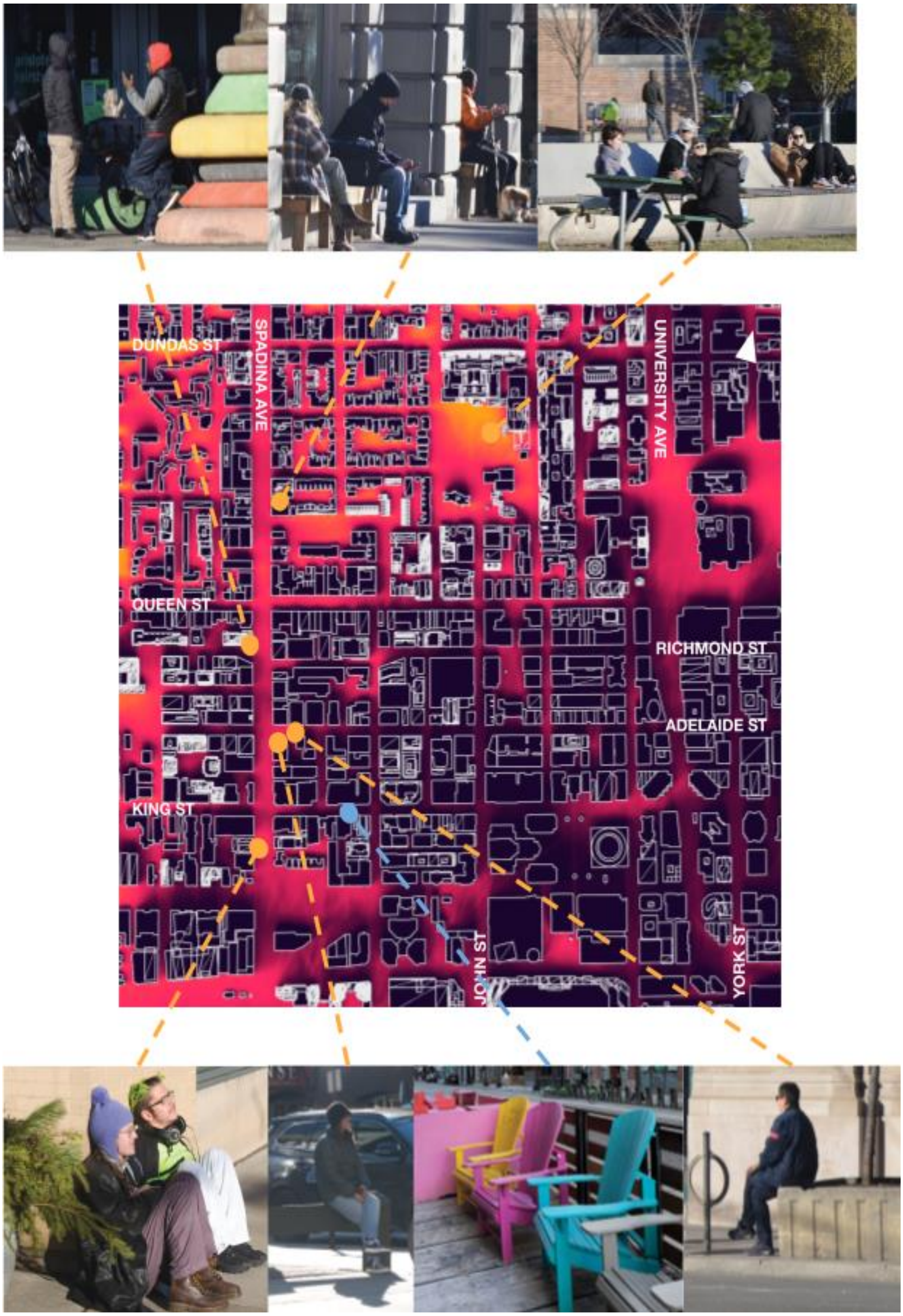

Fig. 16 Dark season sunlight maps pointing to where people were observed sitting.
Note: In winter, people prefer to be in areas in sunshine than areas in shadow. Source: Matthew Canaran.

Using the dark season sunlight map as a site selection tool, the research identifies opportunities to expand or intensify public space in areas receiving ample winter sun. Existing public spaces are noted in Fig. 17. Grange Park, despite being smaller than Nathan Phillips Square, receives more sunlight in the dark season. Potential sites for expansion or intensification of public space are also shown in Fig. 17—these are identified based on areas with remnant sunlight patches in the dark season. Examples discussed include Spadina Avenue, highlighted as potentially a better pedestrian boulevard than University Avenue due to more favorable sunlight conditions.

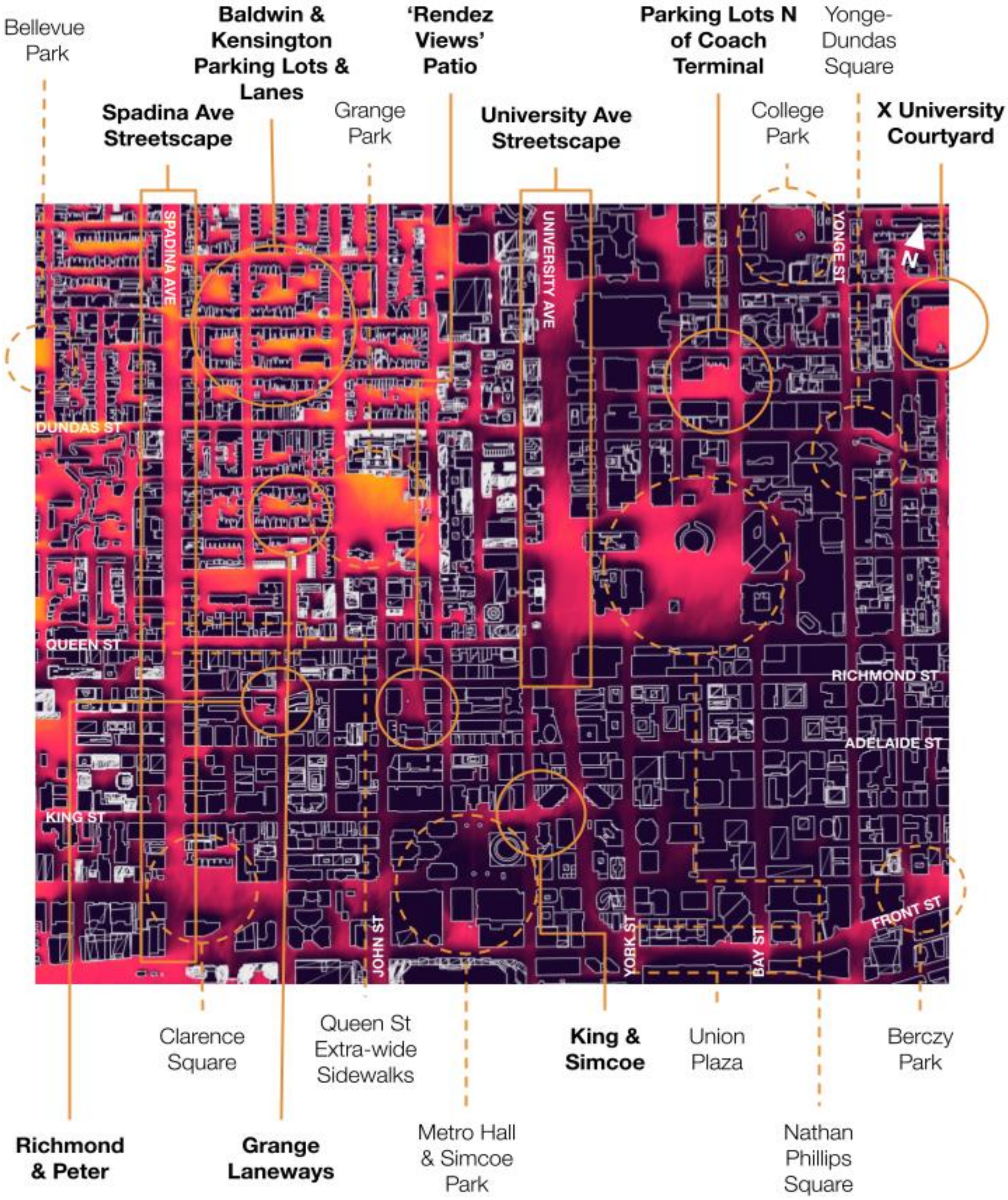

Fig. 17 Opportunities for public space in favourable sunlight conditions.
Note: Dashed lines represent existing public space. Solid lines represent opportunities to expand and intensity public space. Source: Matthew Canaran.

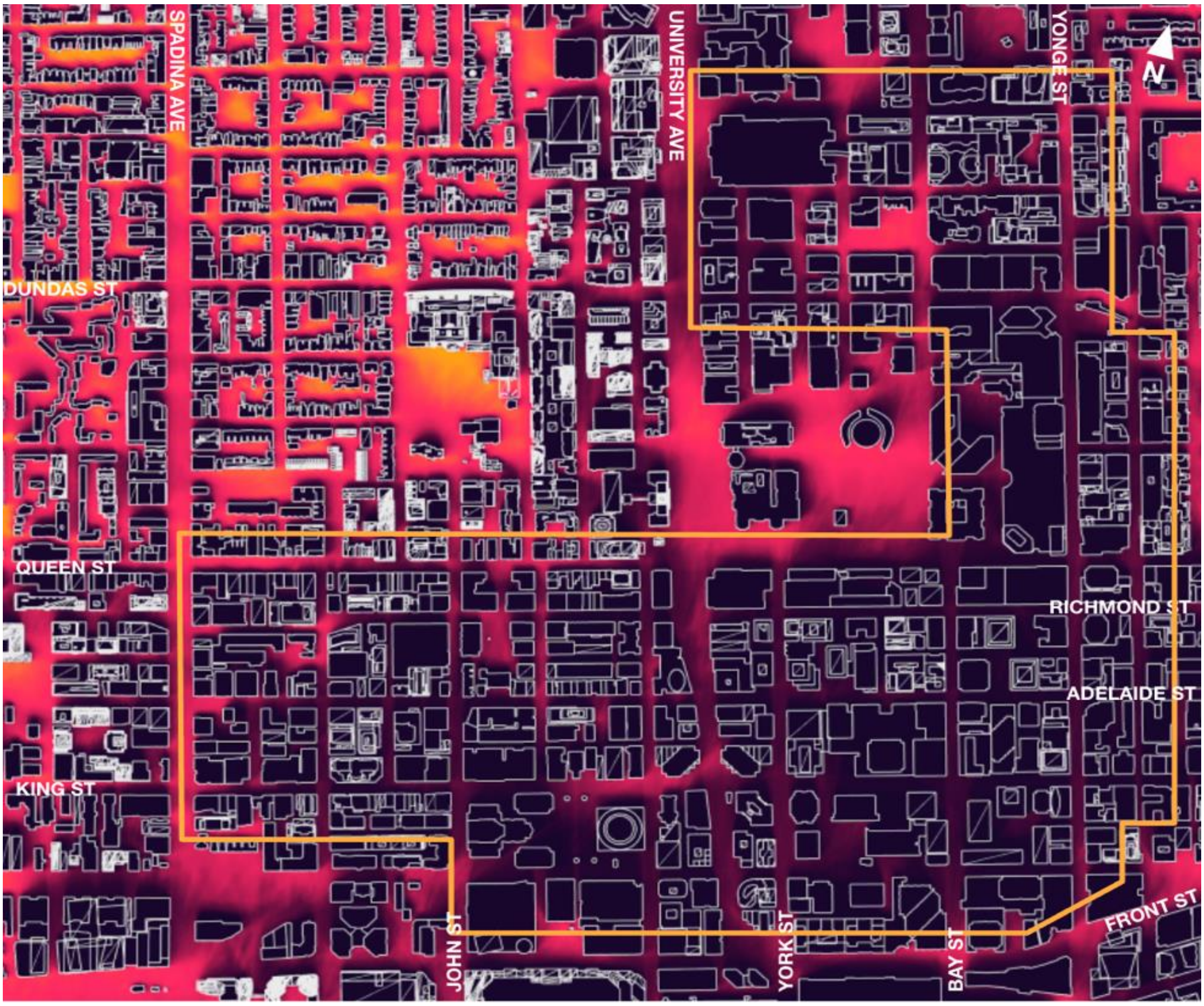

Fig. 18 The darkest areas of the study area in the dark season would benefit from the purposeful addition of reflected sunlight. Note: Areas inside the yellow shape represent opportunities to use heliostats to illuminate and enliven dark space. Source: Matthew Canaran.

Areas with low sunlight access—trouble zones—are particularly found in the Financial District and parts of the Entertainment District due to dense, tall buildings. These areas- as seen in Fig. 18- could benefit from purposeful additions of reflected sunlight, possibly using tools like sun-tracking heliostats, though feasibility studies are needed. While existing buildings already contribute some uncontrolled reflections, strategically harnessing light could improve these dark spaces.

4.6 Planning and Design Phase: Key Takeaways & Recommendations

Synthesizing the research findings and integrating insights from the literature led to key takeaways and corresponding recommendations for environmental design fields.

(1) Key Takeaway 1: Public Life Responds to Sunlight. People seek sunlight for comfort during cooler months (September to May) in Toronto, this is similar to Whyte's observations.

Recommendation: Expand and intensify public space particularly in areas receiving winter sunlight, using a site-selection approach based on sunlight maps.

(2) Key Takeaway 2: Deciduous Trees Sensitively Regulate Sunlight. Deciduous trees naturally align sunlight availability with human needs, allowing sun

through bare branches in winter and providing shade with leaves in summer. They are ideal for managing microclimate.

Recommendation: Prioritize establishing and managing a canopy of large deciduous trees across the city to regulate sunlight and improve microclimate year-round.

(3) Key Takeaway 3: Shopping Streets Benefit from Winter Sunlight Access. Protecting winter sunlight on pedestrian-oriented shopping streets is crucial because these areas see high pedestrian traffic and support local businesses. Current policy protecting only summer sun access on these streets is inadequate.

Recommendation: Update Toronto's mid-rise building policy to include protections for winter sunlight access on pedestrian-oriented streets.

(4) Key Takeaway 4: Reflections Enliven Dark Spaces. While direct sun is preferable, reflections from building surfaces can add light to dark areas, enhancing visual interest and potential comfort. Reflections can highlight architectural details and create dynamic light patterns.

Recommendation: Explore ways to purposefully incorporate reflected sunlight into planning and design, potentially using strategically angled building surfaces or heliostats, particularly in areas with limited direct sun access.

(5) Key Takeaway 5: Toronto's Fast Changing Built Form is Killing Public Life. Rapid, tall-building development in Toronto threatens sunlight access on streets and public spaces. Once lost, this sunlight may be irretrievable. The shift towards residential towers raises questions about prioritizing private space over public realm quality and equitable sunlight distribution.

Recommendation: Act quickly to protect, expand, and intensify public space with favorable sunlight conditions, prioritizing built forms that enhance public life over those that sterilize it.

5. Discussion

This section evaluates the research approach and connects the findings to broader themes in environmental design.

5.1 Evaluating the Research Approach

The combination of on-the-ground documentation (photo-walks, stop-motion) and top-down visualization (sunpath analysis, sunlight maps) provided a comprehensive view of how sunlight interacts with Toronto's core. The highly visual nature of the results allowed for nuanced analysis.

5.1.1 Limitations & Opportunities for Future Research

A key limitation was the documentation period (November 2021 to April 2022), which did not capture the full annual cycle of human-sunlight interaction, particularly late spring and summer. Future research should extend documentation across the entire year.

Another limitation is the dynamic nature of Toronto's built form. The 3D massing model used reflects conditions at a specific point in time (early 2022). Continued construction means the documented and visualized sunlight conditions may have already changed. The findings related to specific sunlight patches are thus time-sensitive. However, the findings on human behavior and preferences for sunlight are projected to remain valid due to Toronto's climate.

Opportunities for future research include:

Continuing stop-motion exercises to capture human response to sunlight in the warmer months (May to October).

Revisiting study sites to document lost sunlight due to new construction, potentially comparing results to past studies to track cumulative loss.

Exploring sunlight map creation in other software ecosystems to validate accuracy.

Using Rhino3D/Ladybug tools like solar envelopes for generative design, applying nuanced development rules to large areas to protect solar access proactively.

5.1.2 Suggestions for Toronto's New Thermal Comfort Strategy

Toronto is developing a new thermal comfort strategy, updating the 1990 Bosselmann study. This research suggests the new strategy should:

Explicitly recognize the value of sunlight for improving thermal comfort during winter.

Acknowledge the value of and actively work to create a canopy of large deciduous trees that regulate sunlight and microclimate year-round. Case studies on achieving urban tree canopies should be included.

Highlight the potential for heliostats and architectural forms to purposefully redirect sunlight onto dark areas.

Future research using Rhino3D/Ladybug could also forecast other thermal comfort factors like air temperature, wind, and humidity.

5.2 The Bigger Picture

This research connects to broader discussions in environmental design fields.

5.2.1 Thermal Comfort

The study confirms sunlight's importance for thermal comfort in Toronto for most of the year, enabling people to use public spaces even in cooler temperatures. While not the only factor, access to sunlight is critical.

5.2.2 A Great Urban Tree Canopy

Large deciduous trees are presented as highly effective design tools for managing microclimate, providing shade in summer and allowing sun through in winter, ensuring public spaces under them are comfortable year-round. Establishing such a canopy, despite urban challenges, is crucial for comfort and addresses larger issues like climate change and biodiversity loss. Toronto has examples of residential streets with large deciduous trees, demonstrating feasibility. Urban forestry should prioritize tree diversity to mitigate risks from pests or diseases.

5.2.3 Sunlight and Housing

Toronto's rapid development pipeline, adding residential units faster than population growth, prompts reflection on prioritizing private development (tall towers) over the quality of the public realm, including sunlight access. The degradation of public space is not a necessary evil for housing. The current context of slowing population growth and increasing housing supply offers an opportunity to encourage development that enhances, rather than sterilizes, public life.

5.2.4 Sunlight and Beauty

Sunlight enhances the perceived beauty of urban spaces by intensifying colors and making forms visible. Human-scale elements cast interesting, dynamic shadows that add to the aesthetic. Indiscriminate overshadowing by large buildings erases this beauty, potentially reducing people's inclination to care for the city.

5.2.5 Moments of Clustering and Moments of Release

The concept of balancing dense urban clusters with areas of lower-rise development moments of clustering and moments of release is proposed as a way to accommodate growth while preserving sunlight and human-scale spaces. This aligns with visions like Hugh Ferriss's and acknowledges that successful cities are often a "messy juxtaposition" of competing forms, requiring a balance. Rebalancing Toronto's urban form to protect sunlight is a critical task for design professionals and policymakers.

6. Conclusion

Sunlight is fundamental to the human experience, influencing health, wellbeing, and our connection to the places we live. This research documented and visualized sunlight in Toronto's core using photographs, stop-motion videos, sunpath analysis, and sunlight maps. It revealed a strong, season-dependent relationship between sunlight and public life. Based on these findings, recommendations were developed for environmental design fields and policymakers in Toronto, applicable to other cities with similar characteristics.

A summarized list of the recommendations includes:

Expand and intensify public space in areas with ample winter sunlight.

Protect winter sunlight access on busy pedestrian-oriented shopping streets.

Use large deciduous trees to regulate sunlight conditions throughout the year.

Explore the purposeful use of reflections to enliven dark spaces.

Act fast to protect valuable sunlight resources due to Toronto's rapidly changing built form.

The research approach was evaluated, finding the results reliable despite limitations such as the documentation period and the currency of the built form model. These limitations offer opportunities for future research, including expanding the documentation period, tracking sunlight loss over time, exploring other software, and using solar envelope tools for design and planning.

Drawing on the work of numerous scholars and practitioners, this research contributes to the ongoing conversation about the intersection of sunlight, built form, and public life. It highlights the need for balance between high-rise development and the preservation of human-scale districts with adequate sunlight. The quality of everyday life on the ground in Toronto depends on year-round access to sunlight: summer sun for a healthy tree canopy, and winter sun for comfortable and enjoyable public spaces.

References

[1] Butti, K., and John, P. 1980. *A Golden Thread: 2500 Years of Solar Architecture and Technology*. Palo Alto, CA: Cheshre Books.

[2] Griscom, J. H. 1845. *The Sanitary Conditions of the Laboring Class of New York with Suggestions for Its Improvement*. New York: Arno Press.

[3] Freund, D. 2012. *American Sunshine: Diseases of Darkness and the Quest for Natural Light*. Chicago: University of Chicago Press. Accessed November 30, 2021. https://books-scholarsportal-info.subzero.lib.uoguelph.ca/en/xml/chapter?id=/ebooks/ebooks3/oso/2013-03-03/1/upso-9780226262819-Freund&chapterId=upso-9780226262819-chapter-1.

[4] Atkinson, W. 1912. *The Orientation of Buildings or Planning for Sunlight* (1st ed.). New York: John Wiley & Sons. Accessed November 20, 2021. https://babel.hathitrust.org/cgi/pt?id=uc2.ark:/13960/t7qn62r0r&view=1up&seq=7&skin=2021.

[5] Ferriss, H. 1929. *The Metropolis of Tomorrow*. New York: Ives Washburn.

[6] Jacobs, J. 1961. *The Death and Life of Great American Cities*. New York: The Random House Publishing Group.

[7] Gehl, J. 2011. *Life Between Buildings*. Washington, DC: Island Press.

[8] Whyte, W. H. 1980. *The Social Life of Small Urban Spaces*. New York: Project for Public Spaces.

[9] Forest and Field Landscape Architecture Inc. 2018. "On Shade and Shadow: A Case Study on the Impacts of Overshadowing by Tall Buildings on Toronto's Greenspaces." Cancer Prevention Coalition. Accessed November 1, 2021. https://www.toronto.ca/wp-content/uploads/2019/05/9122-shade-shadow-impact-of-tall-buildings-public-health-report-november-2018.pdf.

[10] Dumiak, M. 2007. "Simple and Bright, Heliostats Tap Sunlight for Lighting Outdoor and, Increasingly, Indoor Spaces." *Architectural Record* 195 (5): 251.

[11] Woo, M. 2015. "The Plan to Build a Skyscraper That Doesn't Cast a Shadow." *Wired*. Accessed April 22, 2022. https://www.wired.com/2015/03/plan-build-skyscraper-doesnt-cast-shadow/.

[12] Hill, J. 2010. "HELIOSTATS, HO!" *Archidose*. Accessed March 4, 2022. https://archidose.blogspot.com/2010/10/heliostats-ho.html.

[13] Alexander, C. 1977. *A Pattern Language: Towns. Buildings. Construction*. New York: Oxford University Press.

[14] Martín-Ramos, Á. 2012. "The Cerdà Effect on City Modernisation." *Town Planning Review* 88 (6): 695-716. https://doi.org/10.3828/tpr.2012.43.

[15] Soria y Puig, A. 1995. "Ildefonso Cerdá's General Theory of 'Urbanización'." *Town Planning Review* 66 (1): 15-39. https://doi.org/10.3828/tpr.66.1.l330228470wv7m2u.

[16] Knowles, R. L. 1981. *Sun, Rhythm and Form*. Cambridge, MA: MIT Press.

[17] Knowles, R. L. 2003. "The Solar Envelope: Its Meaning for Energy and Building." *Energy and Buildings* 35: 15-25. https://doi.org/10.1016/S0378-7788(02)00076-2.

[18] Bosselmann, P., Arens, E., and Dunker, K. 1990. "Sun, Wind, and Pedestrian Comfort: A Study of Toronto's Central Area." Accessed December 7, 2021. https://escholarship.org/uc/item/0165c77h#page-1.

[19] City of Toronto. 2013. "Tall Building Design Guidelines." Accessed December 7, 2021. https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/design-guidelines/tall-buildings/.

[20] City of Toronto. n.d. "Application Support Material: Terms of Reference." Accessed December 7, 2021. https://www.toronto.ca/city-government/planning-development/application-forms-fees/building-toronto-together-a-development-guide/application-support-material-terms-of-reference/.

[21] Brook McIlroy Planning, 2010. 'Avenues & Mid-Rise Buildings Study'. Accessed: Dec. 07, 2021. [Online]. https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/design-guidelines/mid-rise-buildings/.

[22] Bosselmann, P., Arens, E., Dunker, K., and Wright, R. 1995. "Urban Form and Climate: Case Study, Toronto." *Journal of the American Planning Association* 61 (2): 226-39.

[23] McNeel, R. 2010. *Rhinoceros 3D*. Seattle: WA.