**Chapter 5: Conclusion**

We characterized urban greenspace across the 96 cities of the C40 network, representing every major world region. We found that cities vary greatly in their type, amount, and spatial distribution of nature, including both green and blue spaces. Using high resolution satellite data, we tracked member city progress towards the C40 Climate Leadership Cities’ two Urban Nature Declaration (UND) targets. We found that**r**oughly 80% of member cities met at least one target and almost half met both. We further developed a methodology for determining the city-specific Normalized Difference Vegetation Index (NDVI) equivalent values to meeting each of the UND targets. We explored converting targets that combine both green and blue space into the NDVI scale.

In subsequent work, we employed this methodology to estimate the associated health benefits of incremental progress towards each of the UND targets across the 96 C40 member cities. In line with the two UND targets, we estimated that uniformly increasing green area and the percentage of the population with nearby access to natural space by one percentage point, was associated with a median of 1.74 (range: 0.63, 3.44) and 0.55 (range: 0.11, 1.66) fewer annual premature deaths per 100,000, respectively. We further explored the importance of where greenspace is added on its health benefits and how a more limited exposure-response curve might affect estimated health impacts. We found that adding greenspace in areas with the greatest concentration of people or the least amount of nature, was associated with 2.7 or 1.4-1.7 (depending on the target) times the average associated health benefits of uniform increases, respectively. If the relationship between NDVI and all-cause mortality were limited to an NDVI range of 0.2-0.5, as some studies suggest, about half of the reported benefits could be expected, on average, with large variation across individual cities.

Considering urban greenspace over time, we observed large annual variability in NDVI, likely reflecting not only urban greenspace policies but also weather and climate change. While five-year average NDVI remained relatively constant in 2014-2018 vs. 2019-2023, individual cities experienced changes of over 20% across these time periods. We estimated that changes in NDVI between these five-year periods were associated with 5.04 more deaths per 100,000 globally, ranging from 569.84 fewer to 521.82 more deaths per 100,000 across 1,041 global cities. In this work, we highlighted the large diversity of NDVI trends across time and space and the difficulty of capturing urban greenspace interventions in observed NDVI, as this metric contains considerable variation from year to year.

Collectively, this work provides a better understanding of the health impact of expanding urban greenspace across a broader, more diverse set of global cities. We quantify greenspace in a consistent manner to allow for comparisons across cities. We suggest a methodology for converting area- and access-based urban nature policies into the NDVI scale. We further estimate the health impacts associated with real-world policies and observed changes in NDVI to contribute relevant, decision-oriented results. While prior health impact assessments have estimated results at the city level, we show that the spatial distribution of added greenspace has important health implications. Our analysis using annual peak-season NDVI reveals substantial fluctuations year-to-year over the past decade, highlighting some of the difficulties of measuring urban greenspace this way. Finally, we use free, globally available, open-access data in all our analyses, allowing others to use and advance upon our research.

In addition to its contributions, our work highlights some key limitations that could be the subject of future work. First, our ability to estimate the health benefits of urban nature was limited by the available metrics. While psychological theory and experimental studies have a more inclusive view of nature, the health literature has focused on greenspace. Despite evidence that blue space offers many of the same health benefits as greenspace, there is no best practice for measuring blue space or combining it with greenspace. Furthermore, the health benefits of other forms of nature, such as snow or desert, have not been widely studied. The only measure for which there is a meta-analysis using consistent exposure definitions and low-bias cohort studies is NDVI. In addition to only capturing nature in the form of greenspace, NDVI does not consider important factors that could affect health such as greenspace accessibility, quality, and use. Additionally, our results show substantial inter-annual variation in NDVI, implying that short-term changes in NDVI may not reflect true changes to residents’ health. A city park in a wet or dry year, which may have a very different NDVI values, offers many of the same hypothesized pathways to health, such as a place to gather, exercise, or escape the commotion of city life. Finally, meta-analyses of the association between NDVI and all-cause mortality are based on studies primarily set in American and European cities, which tend to be some of the greenest worldwide.

Second, there is no established “ideal” level of greenspace. Even the World Health Organization’s recommendation that every person have access to 0.5 hectares of greenspace within 500m of their home is an arbitrary goal. Without an understanding of how much greenspace people should have for good health, setting urban nature policies and estimating their health impacts is difficult. For this reason, many health impact assessments have calculated the benefits of increasing NDVI by 0.1, which is not particularly helpful for policymakers.

Future studies to understand how much nature contact, and of what type, people need for optimal health could help inform urban nature policies and urban nature metrics to best capture these exposures. Establishing a consistent metric for measuring urban blue space exposure could help to inform future epidemiologic studies and lead to a better understanding of how closely or not blue space mirrors greenspace in its health benefits. Additional epidemiologic studies considering urban nature beyond blue and green space could help inform urban nature policy in drier climates. Furthermore, studies considering joint exposures to different forms of nature would better reflect the landscape across a wide array of urban settings and improve health estimates. Finally, studies exploring how much urban nature exposure is needed for meaningful health benefits, as well as if there is an exposure level above which benefits taper off, would be useful to decision makers who are faced with limited resources and policy tradeoffs.