The calendar of tree greening in cities

Warmer and brighter cities trick trees into thinking spring arrives earlier

Do you remember the moment when you saw the first budburst this spring? Trees don't have calendars or watches, but they seem to know when spring arrives better than we do. The timing of seasonal biological events — such as when trees leaf out, flowers open, and leaves turn yellow — is called phenology (1).

Phenology involves incredibly complex processes, but temperature and day length have been identified as critical environmental cues for trees to track time (2). To protect themselves from harsh winters without having to move to Florida, trees take a long winter's nap and stop growing (3). After experiencing a certain amount of cold temperature, they break dormancy and start to countdown to spring. As days get warmer, their vibrant green leaves emerge. Compared to temperature that varies each year, the length of natural light provides a more consistent and reliable signal for trees to initiate growth safely, preventing frost damage from late spring (4).

Although climate warming has unambiguously shifted phenology across the world (5, 6), complex urban environments pose additional challenges for trees. Cities are 1–3°C warmer than the nearby countryside, a phenomenon known as the urban heat island effect (7). Artificial light at night from advertising lights, buildings, public street lights, and vehicle lights profoundly alters the regular day-night cycle that plants rely on (8). These human-induced changes in the urban environment may impact phenology even more than climate warming, having cascading ecosystem effects such as affecting allergies and mosquito season, carbon cycling, and plant-pollinator match-up (9, 10).

Cities can serve as natural laboratories to examine phenological responses to long-term environmental change before they happen more generally in nature (11). This inspired me to wonder: how does the timing of tree greening change in cities compared to in rural areas?

Facing warmer cities

Satellites observe the changes in the greenness of plants and thus allow me to determine the timing when plants turn green in spring across the globe. I compared these spring green-up dates in urban versus rural areas in the 85 largest U.S. cities for the period of 2001–2014. I found spring green-up occurred 6 days earlier in urban areas compared to rural areas on average (12).

This 6-day difference was mainly caused by warmer urban temperatures, which were 1.3 °C higher on average than the surrounding rural areas across the study cities (Fig.1). I further found that daytime and nighttime temperatures, which are increasing at different rates, play distinct or even contrasting roles in changing the spring green-up (13).

Under the same climate warming, phenology occurs earlier in both urban and rural areas over years, but possibly at different rates (14). To understand the changing rates of phenology in urban and rural areas, I examined how sensitive the spring green-up was to temperature. I found that the urban phenology tended to be less sensitive to temperature — shifting earlier but at a slower rate under climate warming — than rural phenology in more than half of the study cities (12). In contrast, urban trees in some warm southwestern or coastal regions (e.g., Texas, Louisiana, and Florida) became more responsive to temperature than rural trees, perhaps as a strategy of coping with dryer conditions (12).

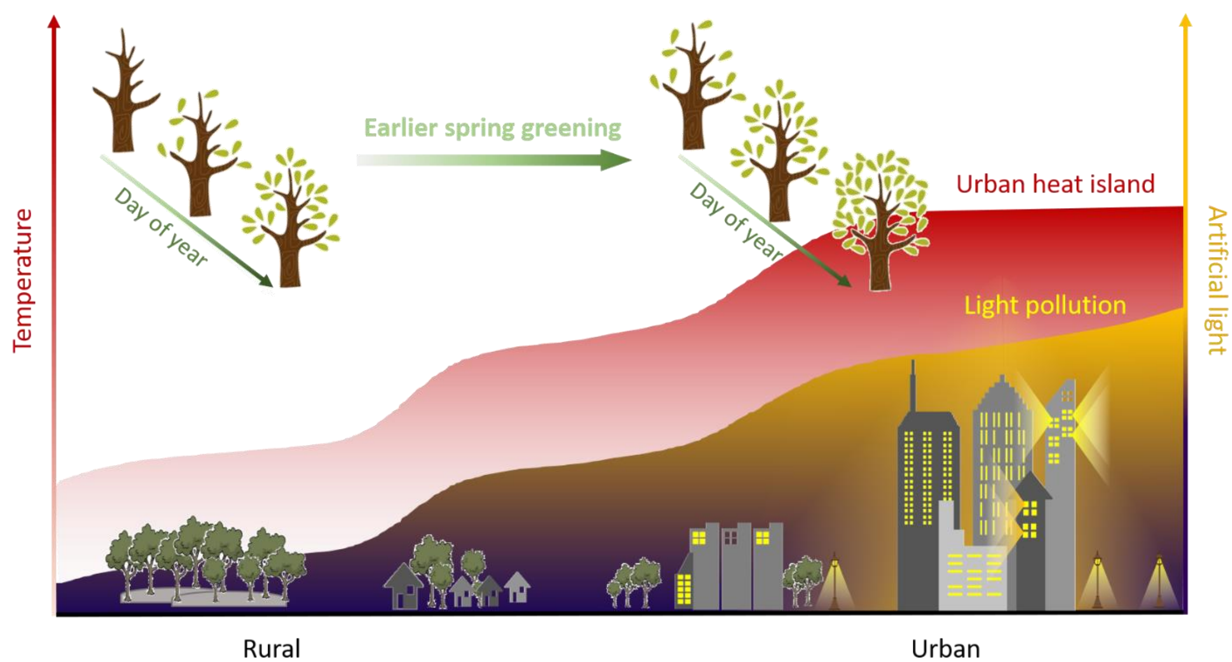

Figure 1: The date of spring green-up is shifting earlier because of urban warming and artificial light in major cities in the United States.

Next, I used existing models to simulate the underlying processes of these observed phenology changes. The explanation I found was that the reduced temperature sensitivity was caused by warmer winters in cities. Urban trees were not chilled enough in winter so they were less responsive when days warmed up in spring (12). These findings suggest that spring phenology in the natural ecosystem will likely continue arriving earlier, but the changing rate will slow down under climate warming.

Facing brighter cities

As spring green-up shifts earlier under a warming climate, the corresponding day is shorter in terms of day length — also known as photoperiod. It is unclear whether this shortened day length will slow down the early shift in green-ups due to climate warming. One of the challenges to answering this question is to disentangle the effects of temperature and photoperiod, which change in a similar way across latitudes and days of the year.

I found that the unique topography of the northern Alps of Europe can serve as a natural experiment to overcome this challenge. In this region, the elevation decreases with the increase in latitude, providing a relatively uniform temperature distribution but changing daylengths across latitudes. I examined the photoperiod effect on spring green-up using 8653 records from the Pan European Phenological Network in this region (15). In this case, the photoperiod reduced the magnitude of the early shift in spring green-up caused by climate warming (16).

In the context of a city, does this conclusion mean that artificial light acts as extended daylength and removes the photoperiod constraint on the earlier trend in green-ups? I used newly released artificial light satellite data (17) and 2613 records from the USA National Phenology Network to examine phenology with and without artificial light in the United States. I found artificial light made the spring green-up early by 9 days while delaying autumn leaf-coloring by 4 days on average across the study sites. My findings highlight artificial light as an understudied factor on phenology, which may supplement daylength and facilitate earlier spring greening under a warmer climate.

The transition from winter to spring is an exciting process to witness. The next time you see the first budburst in spring, remember that it not only shows the beauty of nature, but also opens a window to understanding the environment we live in.