Hotspots of nitrogen deposition in the world's urban areas: a global data synthesis

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Human activities have altered the global nitrogen (N) cycle, elevating rates of atmospheric N deposition up to tenfold above pre-industrial levels, with consequences for ecosystem function and human health. To date, most N deposition studies have been carried out in rural areas; however, there has been a recent surge of N deposition studies conducted in urban ecosystems due to the increased recognition that humans are greatly altering the N cycle in these environments. We synthesized data from 174 publications over a period of 40 years that examined rates of N deposition in urban and nearby rural areas worldwide. Results of this meta-analysis help to quantify urban N deposition, demonstrate that total N deposition in cities is predominately composed of chemically reduced – as opposed to oxidized – forms of N like ammonia, and identify regional hotspots of urban N deposition, particularly in China. These findings highlight the need to examine and address the N cycle in cities as the world continues to urbanize.

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Human activities have altered the global nitrogen (N) cycle, more than doubling the availability of reactive N in the biosphere and elevating rates of atmospheric N deposition up to tenfold above pre-industrial levels, with consequences for both ecosystem function and human health (Galloway *et al.* 2004). Most research on atmospheric N deposition has been conducted in rural areas and has demonstrated declining deposition rates in places like the northeastern US, Europe, and the central Indo-Pacific (Ackerman *et al.* 2018). Indeed, many terrestrial ecosystems are facing N limitation due in part to warming temperatures and declining N availability relative to increasing atmospheric concentrations of carbon dioxide (Craine *et al.* 2018). However, the importance of the urban N cycle is gaining recognition, given that an increasing majority of people live in cities (UN 2015) and the water they drink and air they breathe directly affect their health (Kampa and Castanas 2008; Schwarzenbach *et al.* 2010). Furthermore, a growing body of evidence indicates that urban ecosystems are hotspots of atmospheric N deposition (Lovett *et al.* 2000; Michopoulos *et al.* 2007; Fang *et al.* 2011), although we are unaware of any studies that have quantitatively examined whether this pattern is evident in cities around the world.

Understanding N dynamics, including the important urban contribution to these dynamics, is crucial for safeguarding ecosystem function. For example, two-thirds of forest plots measured across Europe in one study exceeded critical loads for N inputs (Lorenz and Granke 2009); likewise, in an unrelated investigation, rates of N deposition across the US were associated with declining plant species richness in both forested and non-forested ecosystems (Simkin *et al.* 2016). Elevated N deposition has also been associated with increased soil acidification in both rural (van Breemen *et al.* 1984; Lu *et al.* 2014) and urban (Huang *et al.* 2015) areas, eutrophication of waterways (Chen *et al.* 2018), and elevated emissions of climate-forcing greenhouse gases (Xie *et al.* 2018), which also impair air quality (Mushinski *et al.* 2019). In regions with high rates of N deposition, such as Eastern Asia (for details on regions described in this paper, see the Methods section; Vet *et al.* 2014), an additional pulse of N from urban areas may exacerbate ecosystem damage.

Quantifying urban N deposition is also important for closing the gap in regional N budgets, which are necessary for policy makers to manage atmospheric inputs to and outputs from local ecosystems, given that a portion of total

In a nutshell:

- When deposited from the atmosphere, nitrogen (N) can promote eutrophication, soil acidification, and poor air quality, thereby harming both humans and the environment; around the world, cities are associated with elevated levels of N deposition
- In China, the US, and Europe, there have been numerous measurements of N deposition, but other regions are characterized by gaps in knowledge
- The largest proportion of N deposition originates from ammonia emissions, which are largely unregulated by most national governments
- Conducting research on N deposition in urban environments is challenging, in part due to knowledge gaps and difficulties in comparing studies
- Some of these challenges can be resolved by building partnerships, using new platforms for measurements, and applying less costly and time-intensive sampling methods

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emitted urban N is transported out of the city into the surrounding region. For instance, in the 12,000 km^2 Central Arizona–Phoenix Ecosystem, which includes a large US city, almost one-half of the 33.8 gigagrams of N (as nitrogen oxides [NO_x]) annually produced by combustion was exported out of the ecosystem, with the other half deposited locally (Baker *et al*. 2001). Similarly, in two Louisiana bays located more than 400 km downwind from major Texas Gulf Coast cities, atmospheric deposition accounted for 37% and 71% of the total N inputs to those estuaries, respectively (Castro *et al*. 2003). It has been suggested that the observed disparity between modeled emissions and measured deposition in the US (Holland *et al*. 2005; Zhang *et al*. 2012) could be due to the lack of urban deposition data (Holland *et al*. 2005). Understanding urban N deposition inputs is therefore crucial for informing practices for sustainable urban development to minimize any associated negative influences on downwind ecosystems.

In this study, we synthesized data from scholarly publications measuring rates of N deposition in cities around the globe and examined patterns of different forms of N deposition. Although some research into atmospheric N deposition in rural areas has been synthesized (eg Bytnerowicz and Fenn 1996), we are unaware of similar efforts focusing on urban ecosystems. We hypothesize that synthesizing worldwide urban N deposition data would reveal that hotspots of urban N deposition are a global phenomenon, that reduced forms of N deposition are the predominant form of N deposition in cities (Li *et al*. 2016; Sun *et al*. 2017), and that Eastern Asia would have relatively high rates of urban N deposition as compared to other regions. We present regional and global patterns of urban N deposition, compare oxidized to reduced forms of N deposition, and identify opportunities for future work to address the sources and consequences of elevated rates of N deposition in cities.

Methods

We performed a Web of Science search on 14 Dec 2017 using a keyword search with the following terms: "nitrogen or nitrate or ammonium", and "deposition or throughfall or precipitation concentration or precipitation chemistry or rainwater concentration or rainwater chemistry or snow concentration or snow chemistry", and "urban or urbanization or urbanized or city or metropolitan". This search produced 1542 publications, from which we extracted publications that measured concentration and/or atmospheric deposition of N in rain or snow in urban areas. We excluded publications that did not include urban data, publications that measured only gaseous or particulate matter concentrations, publications where models were used in place of measurements to estimate concentration and/or deposition, publications reporting measurements that were recorded for less than one month, and publications that were not written in English. Applying these criteria yielded 133 publications that were included in this analysis. We incorporated another 41 publications that did not appear in our keyword search but were referenced within the 133 included publications, making a total of 174 publications. These 41 additional publications did not appear in our original keyword search because either their titles and abstracts mention only a city by name (eg "Tokyo") rather than using the words "urban" or "city", or because the titles and abstracts did not mention the word "nitrogen"

Table 1. Location of sites within the publications used in this meta-analysis

Region	Publications	Top country in region	Top two cities in region
Eastern Asia	61	China (41)	Guangzhou (9), Beijing (8)
North America	32	US (27)	Boston (4), Mexico City (3)
Europe	31	Greece (7)	Athens (4), Rijeka (3)
Southern Asia	17	India (15)	Varanasi (3), Delhi (2)
South America	14	Brazil (11)	São Paulo (6), Rio de Janeiro (3)
Western Asia	9	Turkey (5)	Istanbul (2), Al-Hashemiya (1)
Southeastern Asia	8	Singapore (3)	Singapore (3), Petaling Jaya (2)
Africa	3	Nigeria (2)	Ibadan (1), Harare (1)
Total	**175**		

Notes: numbers in parentheses indicate the total number of times that location appeared in the 174 publications included in the meta-analysis. The number of publications in the "publications" column adds up to a total of 175 because Galloway *et al*. (1987) reported data from both China and the US; however, there were only 174 separate publications included in the meta-analysis.

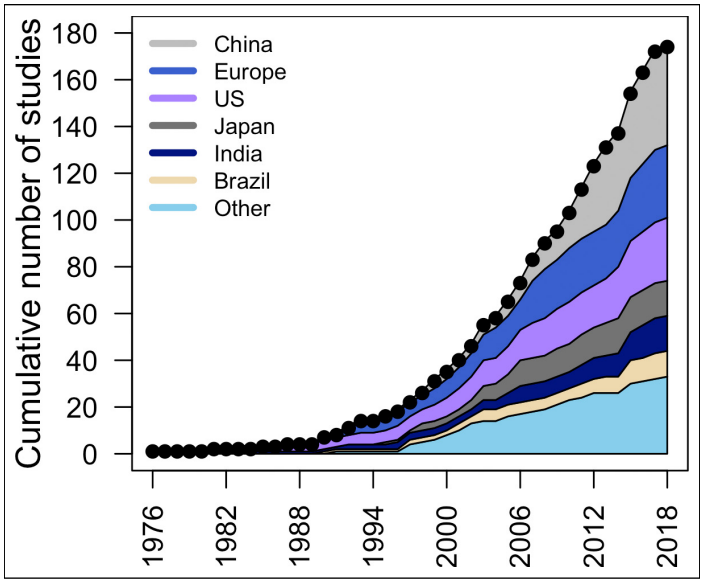

Figure 1. Cumulative number of scholarly papers on urban nitrogen (N) deposition, sorted by publication year. Solid black circles represent the cumulative count of all papers published within a given year; colored bands represent the cumulative count of each of the six largest contributors to urban N deposition publications (cities from China, Europe, the US, Japan, India, and Brazil).

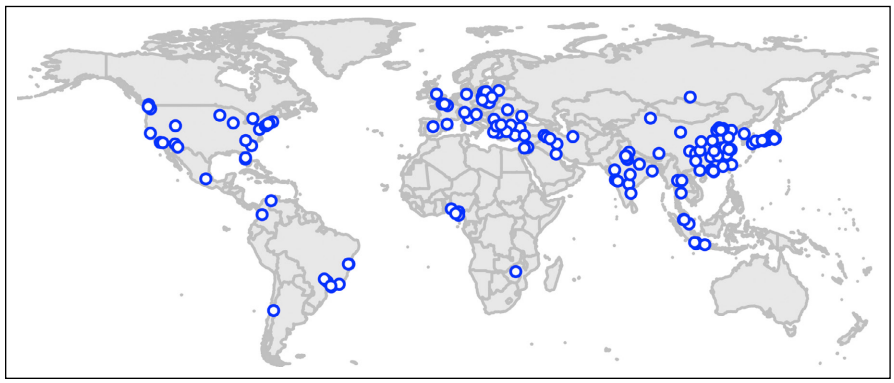

Figure 2. Cities across the 174 publications included in this meta-analysis.

or related N compounds (which can happen when N is measured alongside a suite of other chemicals).

We designated a study as occurring in an "urban" or "rural" location based on the designations of the authors. Within the 174 publications included in this meta-analysis, we identified a total of 69 paired urban and rural sites. Where more than one rural area was included in a publication, only the rural area closest to the urban site was chosen for comparison with the urban site. Though many rural sites in the meta-analysis almost certainly included agriculture of some sort, when a site was explicitly designated by the author(s) as agricultural land, we excluded it as a rural area due to the large sources of local N inputs in agricultural areas (Sutton *et al.* 2008). Where urban and rural designations were not made explicit in publications, the authors were contacted for clarification. For publications reporting more than one year of data, the most recent year of data was used for analysis, except for cases when only the mean across years was reported. Fluxes of wet (N dissolved in precipitation; sample collectors were physically covered in between precipitation events), bulk (sample collectors not positioned beneath the tree canopy and not covered in between precipitation events), throughfall (sample collectors positioned beneath the tree canopy but not covered in between precipitation events), and dry (N delivered directly in particles or gases) N deposition were analyzed separately. We refer to nitrate (NO_3^-), nitrite (NO_2^-), nitrogen dioxide (NO_2), nitrogen monoxide (NO), nitric acid (HNO_3), and nitrous acid (HNO_2) as "oxidized N", and ammonium (NH_4^+) and ammonia (NH_3) as "reduced N". Regions were largely classified according to the UN M49 Geographic Regions (https://unstats.un.org/unsd/methodology/m49). In this paper, the regions of Africa, Eastern Asia, Europe, Oceania, South America, Southeastern Asia, Southern Asia, and Western Asia are identical to the regions in the UN M49 geoscheme; however, we added Mexico to the UN-designated region of "Northern America" and labeled this area as "North America" and refer to the UN-designated region of "South-eastern Asia" as "Southeastern Asia".

To quantify patterns of urban versus rural N deposition and to compare reduced to oxidized forms of N deposition, we calculated the natural log of the response ratio as the effect size for each comparison. With widely varying sampling designs and methods across studies, a measure like the log response ratio facilitates inter-study comparisons. Log response ratios were calculated by subtracting the natural log of one measurement (eg rural N deposition, deposition of

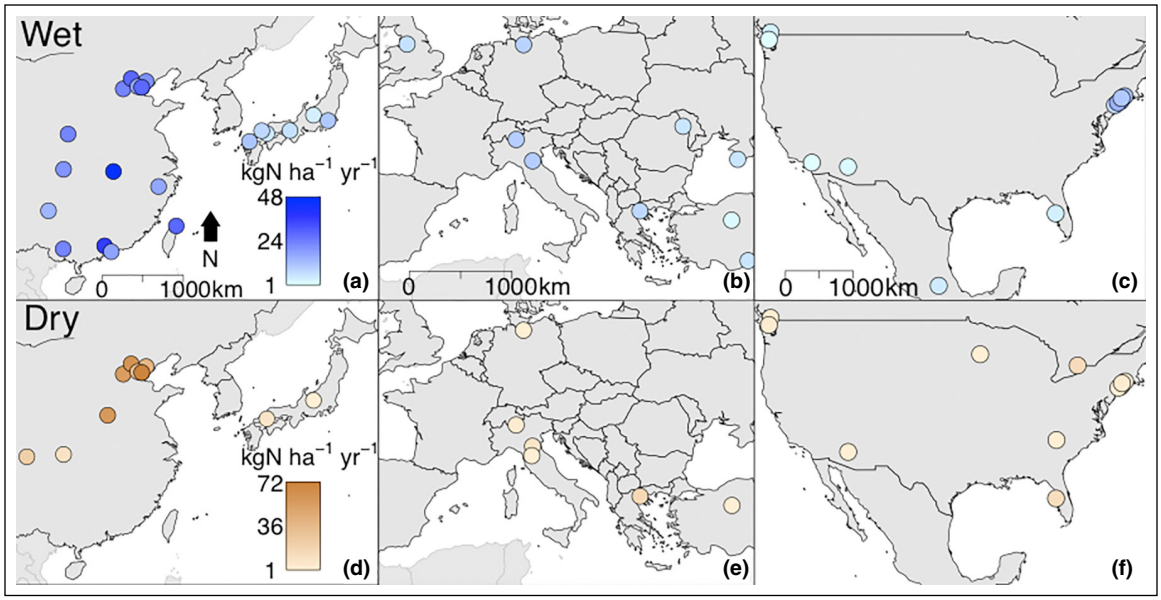

Figure 3. Map showing location of studies and rates of (a–c) wet and (d–f) dry inorganic N (oxidized N + reduced N) deposition in (a and d) Eastern Asia, (b and e) Europe and Western Asia, and (c and f) North America. Scale bars in the top row pertain to maps in the bottom row as well. North arrow in map (a) pertains to all other maps. Legends quantifying deposition rates in maps (a) and (d) pertain to all maps in the top and bottom rows, respectively. Maps for bulk and throughfall N deposition can be found in WebFigure 1.

oxidized N [hereafter, "oxidized N deposition") from the natural log of the related measurement (eg urban N deposition, deposition of reduced N [hereafter, "reduced N deposition"], respectively). Each log response ratio corresponds to a single comparison made at a study site for an individual measurement type (ie wet, bulk, throughfall, dry). Bootstrapped medians and 95% confidence intervals (CIs) of log response ratios for each metric were then calculated. Differences between the median values of any two parameters being compared (eg urban and rural N deposition rates) were considered significant if their CIs did not overlap with zero. To calculate a metric of central tendency across all regions and individual regions, we also relied on bootstrapped medians and 95% CIs. Data analysis was conducted using RStudio (v1.1.442).

Results and discussion

Geographic trends in urban N deposition

Our meta-analysis of 174 publications (WebTable 1) found N deposition data for 155 cities worldwide (Table 1; Figures 1 and 2), demonstrating widespread interest in this subject. The countries or regions with the greatest number of urban sites mentioned in those publications were China (41 total sites), followed by Europe (31) and the US (27; Table 1); note that almost 65% of the publications on Chinese cities were published after 2010. Although we found that N deposition was measured in cities in 37 countries around the world, the greatest number of publications were associated with only five countries (China, US, Japan, India, and Brazil), which accounted for 63% of all publications. The regions of Western Asia (nine publications), Southeastern Asia (eight publications), Africa (three publications), and Oceania (zero publications) remain critically understudied, as does South America outside of Brazil (three publications). Even within highly studied areas such as China, Europe, and the US, there are many cities (eg Hangzhou, Rome, Philadelphia) that remain unstudied, whereas other cities (eg Guangzhou, Athens, Boston) have been sampled numerous times. Across all forms of deposition (oxidized N, reduced N, and inorganic N) and methods of measurement (wet, bulk, throughfall, dry), rates of N deposition in Eastern Asia are among the highest in the world (Figures 3 and 4; WebFigures 1 and 2; WebTables 2 and 3).

Urban N enhancement

Our results demonstrate that cities are subject to higher rates of N deposition than nearby rural areas (inorganic N in Figure 5; oxidized and reduced N in WebFigure 3). Cities from diverse regions – varying in parameters such as size, topography, and biome – show elevated rates of inorganic N deposition as compared to rates in neighboring rural sites (Figure 5). Across all publications in this meta-analysis that have an urban–rural comparison, N enhancement in urban areas is about twice as high as in nearby rural areas

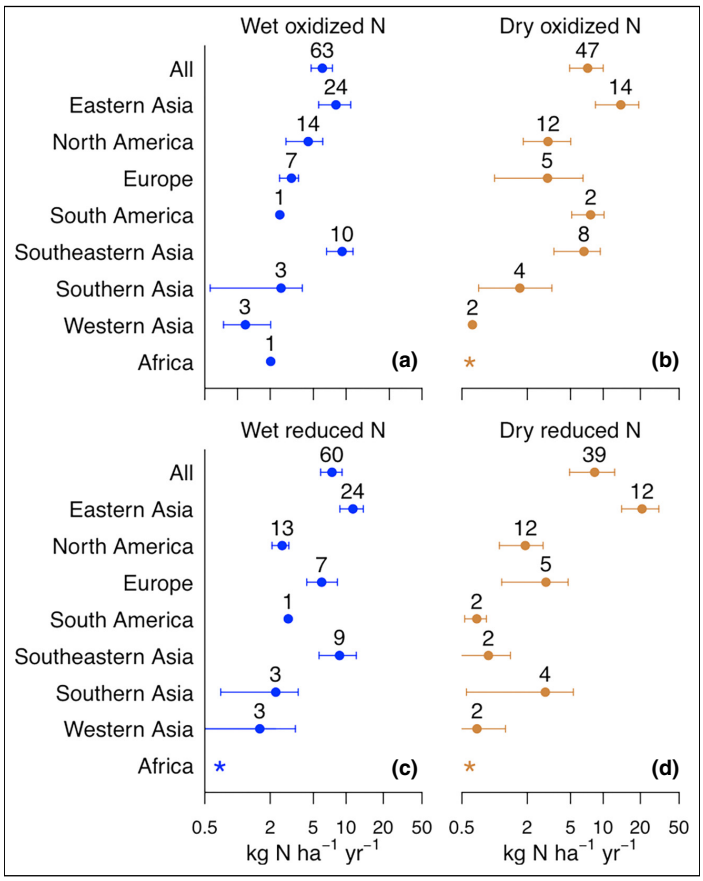

Figure 4. Bootstrapped medians (solid circles) and 95% confidence intervals (CIs; horizontal bars) for N deposition in cities within each region for (a) wet oxidized N, (b) dry oxidized N, (c) wet reduced N, and (d) dry reduced N. Values above circles are the number of publications in that region in that measurement type. Regions with asterisks indicate no publications from that region for that measurement type and form of N. Lower CI bar for Western Asia in (c) has a bound that falls below 0.5 kg N ha^{-1} yr^{-1} (0.04 kg N ha^{-1} yr^{-1}). Note that the x axis is plotted on a logarithmic scale. Plots for bulk and throughfall oxidized and reduced N deposition, as well as for wet, dry, bulk, and throughfall inorganic N deposition, can be found in WebFigure 2.

(bootstrapped median urban-to-rural ratio [95% CI]: 2.02 [1.75–2.34] for oxidized N; 2.14 [1.81–2.56] for reduced N; and 2.19 [1.79–2.72] for inorganic N). These elevated urban rates are significantly higher than rates in counterpart rural areas for every type of N deposition measured. This result suggests that although rates of rural N deposition have declined in some parts of the world (Ackerman *et al.* 2018), urban areas remain hotspots of N deposition; therefore, measuring N deposition in urban areas is important for understanding regional N deposition and examining its potential impacts on ecosystem function and human health.

Prevalence of reduced forms of urban N deposition

Publications synthesizing atmospheric N data across rural sites worldwide show that atmospheric input of oxidized forms of

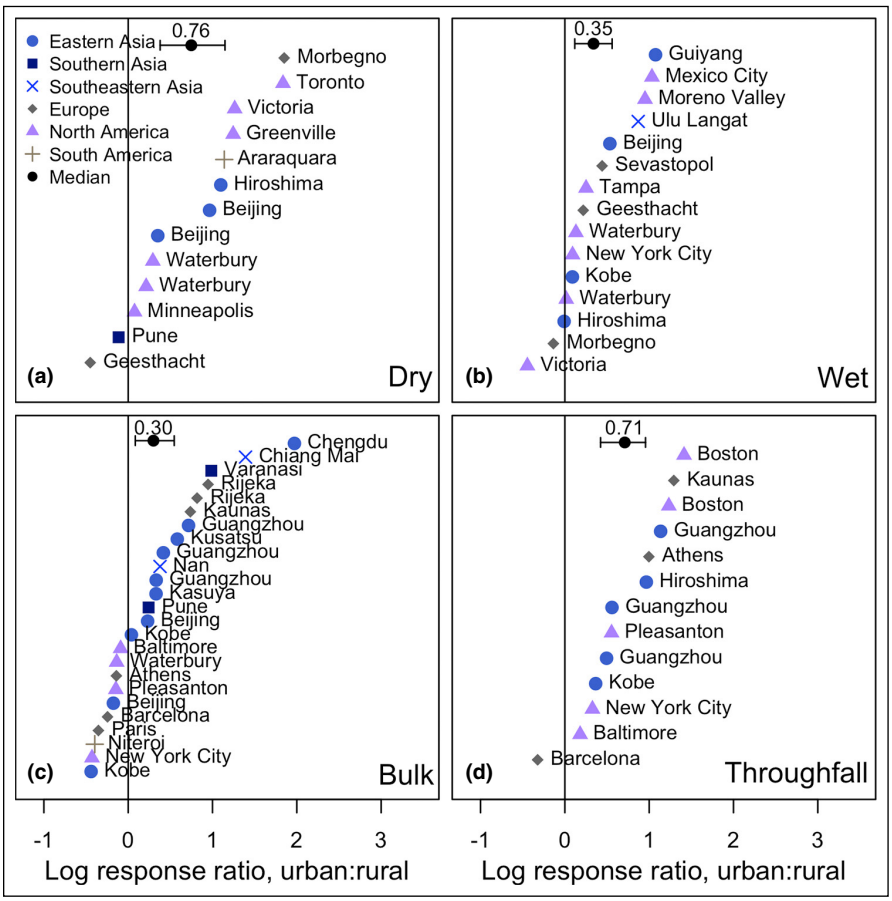

Figure 5. Log response ratio of the difference between urban and rural rates of inorganic (oxidized + reduced) N deposition across numerous locations (city names with various colored symbols), as well as the bootstrapped medians and 95% CIs (solid black circle and horizontal bar) for (a) dry, (b) wet, (c) bulk, and (d) throughfall deposition. City names appearing more than once were measured for inorganic N deposition in more than one study, with values from each study presented individually within the figure. Plots for oxidized and reduced N deposition can be found in WebFigure 3.

N deposition is declining in many regions, whereas deposition of reduced forms remains elevated and in some cases is increasing (Templer *et al.* 2012; Li *et al.* 2016; Ackerman *et al.* 2018). From the publications in this analysis, we calculated that reduced N deposition makes up a greater fraction of inorganic N deposition across all types of deposition in cities as well (bootstrapped median reduced-to-oxidized ratio: 1.53 [95% CI = 1.43–1.63]), which is in agreement with publications measuring and/or modeling reduced N deposition (Ellis *et al.* 2013; Li *et al.* 2016; Sun *et al.* 2017).

With the exception of a European regulation on heavy-duty diesel vehicles, emissions of reduced N compounds, such as NH_3, remain largely unregulated around the world (Sun *et al.* 2017). Numerous studies have shown the presence of substantial vehicular-based emissions of NH_3 in urban areas (Li *et al.* 2006; Phan *et al.* 2013; Felix *et al.* 2014), and have found that these local NH_3 emissions can obscure N deposition signals from regional agricultural emissions (Zbieranowski and Aherne 2012). Like urban NO_x emissions, urban NH_3 emissions are due to excessive vehicular traffic in urban areas, which produce NH_3 by some of the very technologies that have decreased emissions of oxidized N – namely, through the over-reduction of NO_x in three-way catalytic converters (Heeb *et al.* 2006) and emissions from the addition of urea and NH_3 to diesel engines in order to meet Selective Catalytic Reduction (SCR) standards (Reche *et al.* 2012). Because NH_3 is highly soluble in water and has a high deposition velocity, vehicle-emitted NH_3 is likely to be locally deposited close to its source, as has been demonstrated in roadside studies (Cape *et al.* 2004; Kirchner *et al.* 2005; Bettez *et al.* 2013). Our own recent study in Boston, Massachusetts, revealed positive relationships between local vehicular traffic intensity, NO_x and NH_3 emissions from vehicles, and deposition of N locally (Decina *et al.* 2017). The elevated deposition of reduced N compounds, combined with the lack of regulation on the emissions that produce these compounds, presents an opportunity for policy makers to reduce urban N pollution.

Future directions in addressing urban N pollution

In this quantitative meta-analysis, we present evidence that – regardless of region, form, or type of deposition – N deposition is greater in urban than rural areas. Addressing and understanding this difference further will require using some of the tools developed for, and lessons learned from, measuring rural and regional N deposition, as well as novel approaches tailored for cities.

Increased urban monitoring

Over the past half-century, numerous scholarly publications have examined urban N deposition in various countries. In this data synthesis, we show that cities are hotspots of N deposition, and that this is a global phenomenon. This finding provides the impetus to support a more concerted effort to understand the urban N cycle, in terms of both sources and effects of urban N inputs. Current knowledge of potential urban hotspots will be improved both by existing studies that report not only consistent measurements of similar forms of N deposition (eg wet, bulk, throughfall, dry) but also long-term measurements for evaluation of seasonal and multiyear trends, and by future studies focused on areas outside of Europe, Eastern Asia, and North America. Further mechanistic understanding of N sources would contribute to our knowledge of drivers of urban hotspots of N deposition, through

Panel 1. Assessing atmospheric nitrogen deposition in cities

Measuring nitrogen (N) deposition in urban areas presents unique challenges. Numerous localized sources such as power plants create high spatial variability in cities, requiring a high density of measurement sites. While rural deposition measurements take advantage of sparsely inhabited areas, urban studies must contend with high population density. The large population presents difficulties, such as risk of vandalism, multiple landowners, and constant change, which impede standardized sampling designs and long-term studies.

One challenge in cities is finding suitable study sites. To this end, urban scientists often must dedicate time to building stakeholder partnerships. For example, our recent urban studies (Decina *et al.* 2016, 2017, 2018) relied on partnerships with multiple universities, the City of Boston, the Massachusetts Department of Environmental Protection, and private landowners (Figure 6). This type of partnership can also engender community engagement and involvement in the research process, crucial aspects of urban science. Numerous publications referenced in this meta-analysis partnered with a variety of local stakeholders to make measurements possible.

Urban deposition studies also frequently take advantage of rooftop sampling, given that rooftops are often secure. In this meta-analysis, of the 85 publications that described the physical location of measurements, 66 (78%) used rooftops. While ground-level measurements may be ideal to determine the flux of nutrients to the ground surface, one urban study showed no significant difference in rates of rooftop and ground-level wet N deposition inputs (see Supplemental Information in Decina *et al.* [2018]).

Because cities exhibit great variability in N inputs across space (Sudalma *et al.* 2015; Decina *et al.* 2017), the multiple sites necessary to capture the range of that variability require a sampling density that can be cost- and labor-intensive. For example, installation of an NADP (US National Atmospheric Deposition Program) wet deposition site costs over $10,000 and must be sampled weekly at additional cost. Having numerous NADP sites across one city would be a large financial and labor outlay. An alternative method is the use of ion exchange resin (IER) sample collectors (see Templer and McCann 2010). Briefly, an IER sample collector contains a resin through which precipitation percolates and deposits charged particles, including ions. This resin is then collected and analyzed once every 4–8 weeks. When measuring bulk deposition, IER has shown agreement with wet bucket-style collectors (Cook *et al.* 2018) and a co-located NADP wet deposition site (see Supplemental Information in Decina *et al.* [2018]). IER is low-cost, does not require permanent installation of equipment, and saves labor. In this meta-analysis, ten of the 174 publications employed this method.

Despite the advantages of using IER, however, obtaining accurate measurements in urban areas can be challenging. While wet deposition can be analyzed using bucket-style collectors or IER, dry deposition is difficult to measure (Cook *et al.* 2018). A common tactic in deposition studies is to use throughfall to approximate wet + dry deposition (eg Lovett and Lindberg 1993). However, when compared with bulk measurements made alongside inferential dry deposition measurements, Cook *et al.* (2018) reported that throughfall underestimated wet + dry N deposition by almost 70% and did not capture the urban N deposition enhancement. Throughfall methods can also cause overestimates of dry deposition if within-canopy processes (eg production of pollen) lead to the collection of greater amounts of N. Thus, caution is required when selecting methods and interpreting results of urban deposition studies.

the use of techniques such as ion correlation, stable-isotope analysis, and back-trajectory or wind-pattern analysis (techniques found in 82, 18, and 39 of the 174 publications referenced in this meta-analysis, respectively). An improved appreciation of the effects of urban N deposition on ecosystem function is crucial as well. Measuring N deposition alongside parameters of ecosystem function (such as N mineralization or soil respiration) is a technique that 19 of the 174 publications undertook to identify effects on ecosystems. Urban monitoring presents unique challenges, however, and we provide suggestions on how to address these challenges in Panel 1.

Addressing atmospheric deposition of reduced N

Reduced forms of N comprise a larger fraction of urban atmospheric inorganic N deposition than do oxidized forms of N. Actions to decrease NO_x emissions have demonstrated the effectiveness of policy to offset N pollution (Vestreng *et al.* 2009; Hand *et al.* 2014). For example, in the US, regulations targeting NO_x succeeded in reducing NO_x emissions by over 40% from 1990 to 2010 (Li *et al.* 2016); over the same period, rates of wet NO_3^- deposition also fell dramatically across the country (see wet NO_3^- deposition maps for these years at http://nadp.slh.wisc.edu/NTN/annualmapsByYear.aspx). Conversely, inaction in addressing reduced forms of N deposition has likely been a factor in its increasing relevance (Li *et al.* 2016) and high prevalence in urban areas. A major source of reduced N deposition, NH_3, is a primary product of fertilizer application and livestock operations in rural areas (Sutton *et al.* 2008); however, emissions from agriculture are difficult to regulate, partly due to concerns over food security (Frank *et al.* 2017). In vehicles, the technology used to mitigate emissions of NO_x (an oxidized form of N) could be improved to emit less NH_3 (a reduced form of N) (Heeb *et al.* 2006; Kean *et al.* 2009). Such technological advancements, in combination with stricter regulation of vehicular-based NH_3 emissions, would help to curb emissions of the reduced forms of N, which would mitigate overall N pollution in urban areas.

Conclusions

Worldwide, atmospheric N deposition is elevated in urban areas as compared to nearby rural areas. Numerous studies have measured urban N deposition in Eastern Asia, Europe,

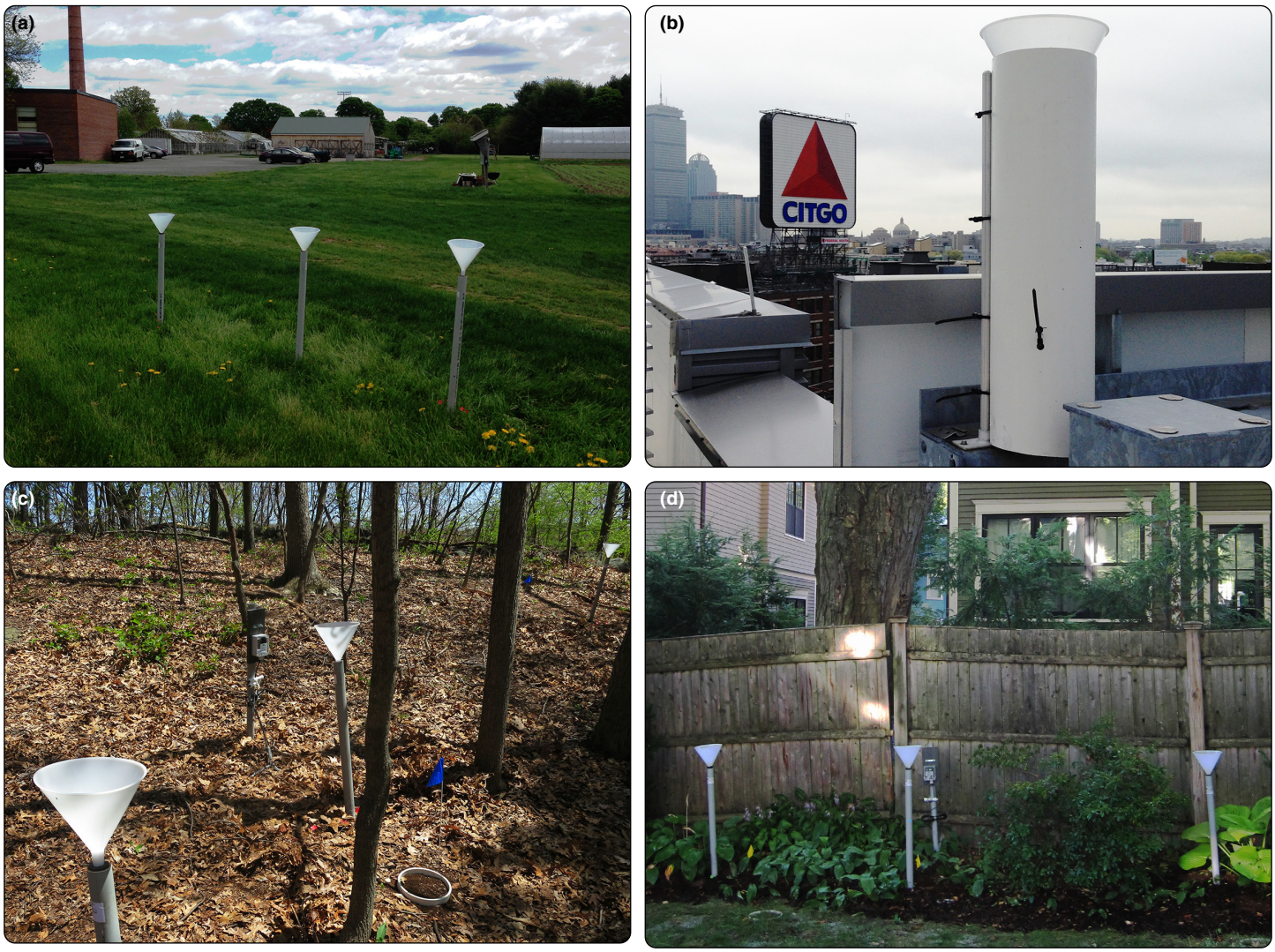

Figure 6. Ion exchange resin (IER) sample collection funnels in urban locations, exemplifying the leveraging of numerous stakeholder relationships: (a) at the Waltham Community Farm, (b) atop a roof at Boston University, (c) in an urban forest at Harvard University's Arnold Arboretum, and (d) in the backyard of a private homeowner.

and North America, with the highest rates found in Eastern Asia, but in the rest of the world urban N deposition remains either unstudied or understudied. From a global perspective, reduced forms of N (NH_3 and NH_4^+) make up the largest proportion of urban N deposition. However, although emissions of oxidized forms of N are regulated in many parts of the world, NH_3 emissions are largely unregulated; this can lead to elevated rates of N deposition in the form of reduced N. Finally, because cities are complex systems that are difficult to study, examining atmospheric deposition in urban areas can leave knowledge gaps (through bias in site selection) and impede long-term sampling and comparisons across studies; obtaining accurate measurements of deposition in urban settings is also challenging. However, by adjusting sampling strategies to address the difficulties presented by urban areas, some of these challenges can be resolved.

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Poyang Lake and wintering Siberian cranes

The Siberian crane (*Leucogeranus leucogeranus*) is identified as critically endangered on the IUCN Red List, with an estimated world population of around 3500. Each year, about 98% of the eastern Siberian cranes migrate from their breeding area in the Arctic tundra of northeastern Russia to spend the winter at Poyang Lake, the largest freshwater lake in China. The lake is characterized by fluctuations in the water level, caused by tributary inflow and water exchange with the Yangtze. As a unique lake–wetland ecosystem, Poyang Lake provides key habitat for millions of migratory waterbirds of global importance.

Because of climate change and other human disturbances, the future of Siberian cranes is uncertain. The Three Gorges Dam, for example, has altered spatial and temporal patterns affecting the water balance of the Yangtze River basin. A proposed Poyang Lake Dam that would mitigate the effects of the Three Gorges Dam and support wildlife conservation through a mechanism that would control water levels has caught the attention of the world. The new dam, if constructed, would transform the area's wetlands as well as its habitat provisioning services. However, what would be the impact of intensified fisheries activity in water bodies that are hydrologically connected to Poyang Lake? Would cranes behave differently if habitat conditions were controlled by humans? The fate of Siberian cranes will be determined not only by how local hydrological regimes and land-use change affect their wintering and stopover sites along the migratory route but also by how climate change affects their Arctic breeding ground. Yet determining the role that humans play during these changing times will be the key question.

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