2nd World Forum on Urban Forests
Washington DC, 2023

Leaf Your Worries Behind

How Trees Promote Health by Helping Us Breathe Easier Amidst Air Pollution

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Part One:

The Invisible Killer

Impacts of Climate Change on Human Health

Temperature-Related Disease and Illness

Populations of Concern

Air Quality Impacts

Extreme Events

Vector-Borne Disease

Water-Related Illness

Food Safety, Nutrition, and Distribution

Mental Health

Adapted from Crimmins A et al. USGCRP, 2016

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Air Pollutants and Heath Outcomes

Pollutant – Long Term	2021 Guidelines
PM2.5 and PM10	• All-cause, cardiovascular, respiratory, and lung cancer mortality
O3, NO2	• All-cause and respiratory mortality

Pollutant – Short Term	2021 Guidelines
PM2.5 and PM10	• All-cause, cardiovascular, and respiratory mortality
CO, O3, NO2, SO2	• Hospital and Emergency Room admissions related to asthma or ischemic heart disease, and/or all-cause mortality

Adapted from WHO, 2021. https://iris.who.int/bitstream/handle/10665/345329/9789240034228-eng.pdf?sequence=1

Air Pollution as a Risk Factor

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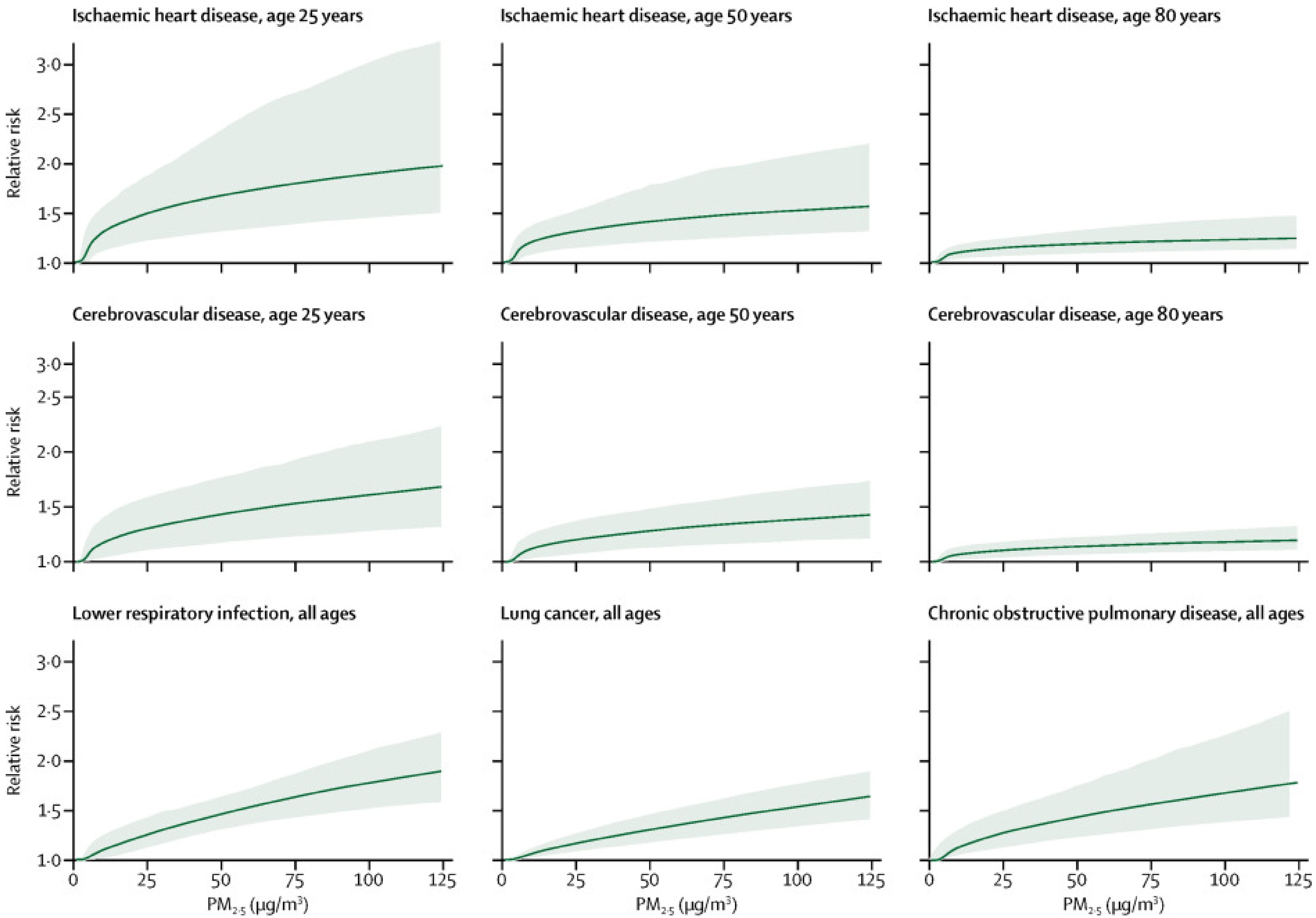
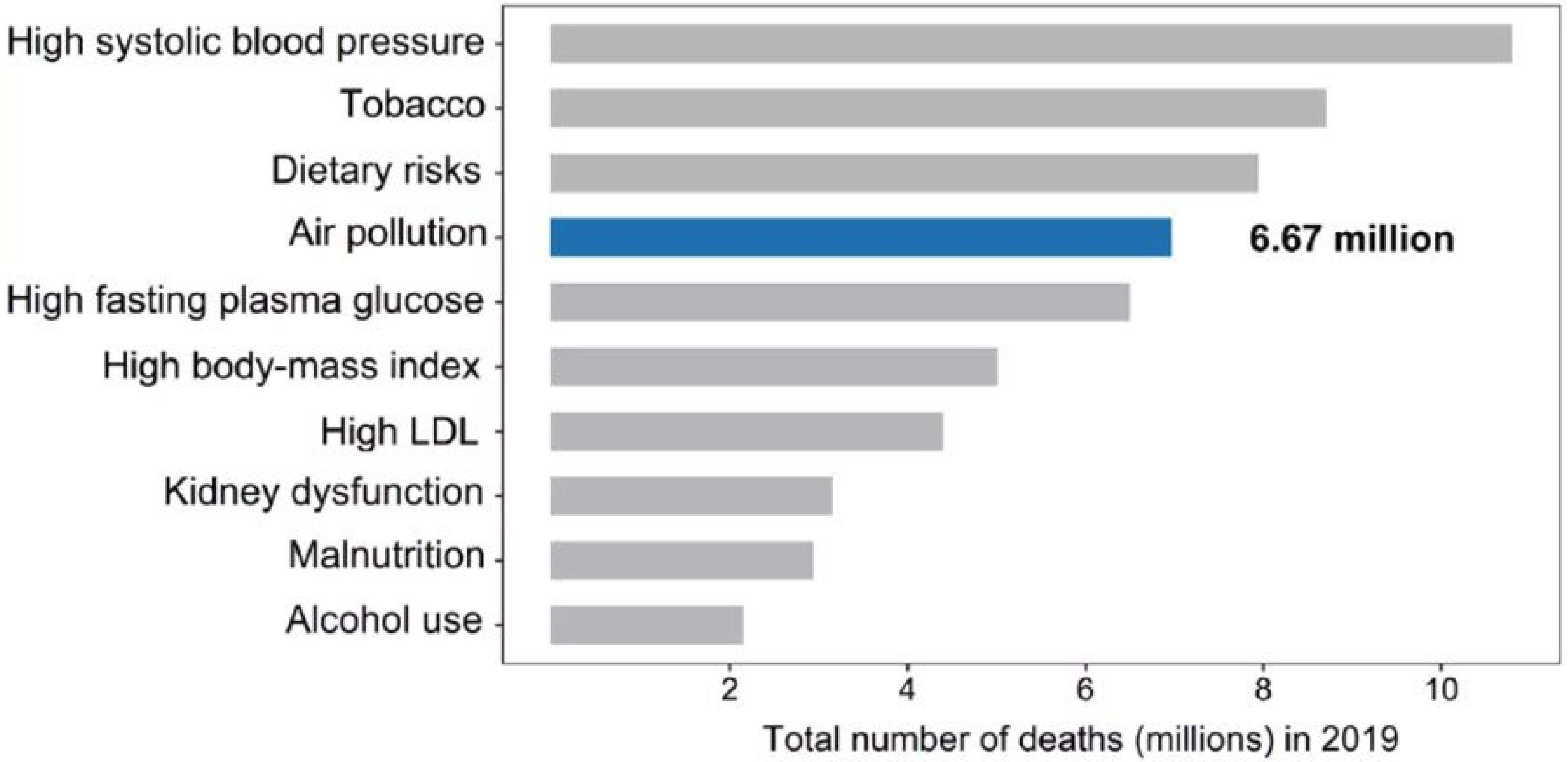


Air pollution increases risk of heart, brain, and lung disease

Cohen AJ et al. Lancet, 2017

Air Pollution Causes Premature Deaths

Globally, air pollution is among the leading causes of premature death



Air pollution is identified as the world's fourth leading risk factor for early death in the new report (Credit: State Of Global Air Report).

State of Global Air, 2019. https://www.stateofglobalair.org/health

Ambient vs Household Air Pollution

Ambient air pollution has overtaken household air pollution in terms of attributed disease burden

A All ages

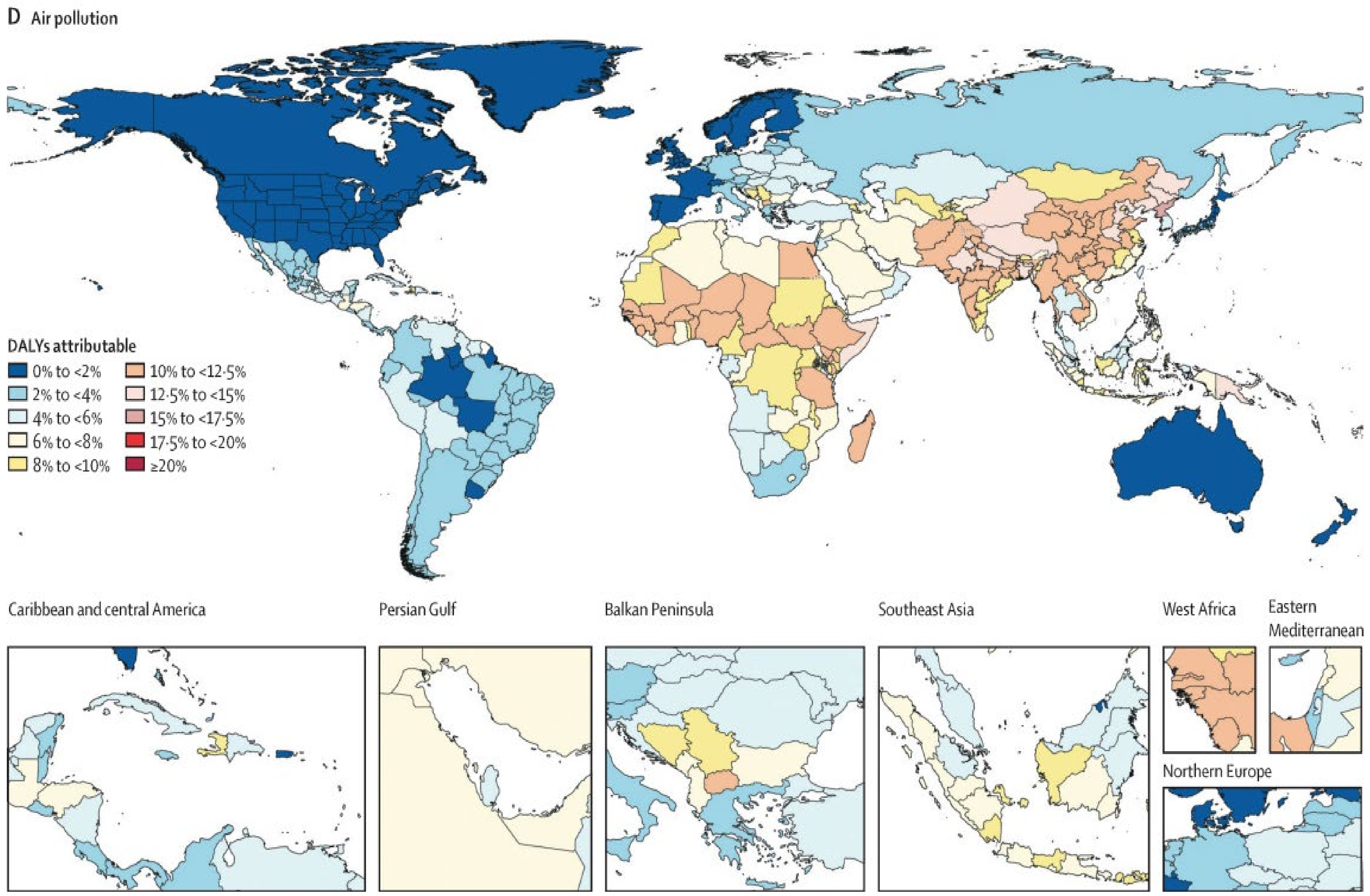
Leading risks 1990	Percentage of DALYs 1990	Leading risks 2019	Percentage of DALYs 2019
1 Child wasting	11·4 (9·5 to 13·6)	1 High systolic blood pressure	9·3 (8·2 to 10·5)
2 Low birthweight	10·6 (9·9 to 11·4)	2 Smoking	7·9 (7·2 to 8·6)
3 Short gestation	8·7 (8·1 to 9·5)	3 High fasting plasma glucose	6·8 (5·8 to 8·0)
4 Household air pollution	8·0 (6·2 to 10·0)	4 Low birthweight	6·3 (5·5 to 7·3)
5 Smoking	6·2 (5·8 to 6·6)	5 High body-mass index	6·3 (4·2 to 8·6)
6 Unsafe water	6·2 (4·7 to 7·6)	6 Short gestation	5·5 (4·7 to 6·3)
7 High systolic blood pressure	5·9 (5·3 to 6·5)	7 Ambient particulate matter	4·7 (3·8 to 5·5)
8 Child underweight	4·9 (3·9 to 6·3)	8 High LDL cholesterol	3·9 (3·2 to 4·7)
9 Unsafe sanitation	4·6 (3·7 to 5·6)	9 Alcohol use	3·7 (3·3 to 4·1)
10 Handwashing	3·2 (2·3 to 4·0)	10 Household air pollution	3·6 (2·7 to 4·6)
11 High fasting plasma glucose	3·0 (2·5 to 3·5)	11 Child wasting	3·3 (2·6 to 4·1)
13 Ambient particulate matter	2·7 (1·8 to 3·8)	13 Unsafe water	2·6 (1·9 to 3·3)
14 High LDL cholesterol	2·7 (2·2 to 3·2)	17 Unsafe sanitation	1·6 (1·3 to 2·1)
15 Alcohol use	2·6 (2·3 to 2·9)	19 Handwashing	1·3 (0·9 to 1·8)
16 High body-mass index	2·6 (1·5 to 4·0)	22 Child underweight	1·1 (0·9 to 1·4)

GBD 2019 Risk Factor Collaborators. Lancet, 2020

Discussion Question!

Why do physicians in the United States ask about your sugar and lipid level, smoking history, blood pressure, and weight but not your air pollution exposure?

Global Distribution of Air Pollution Impact

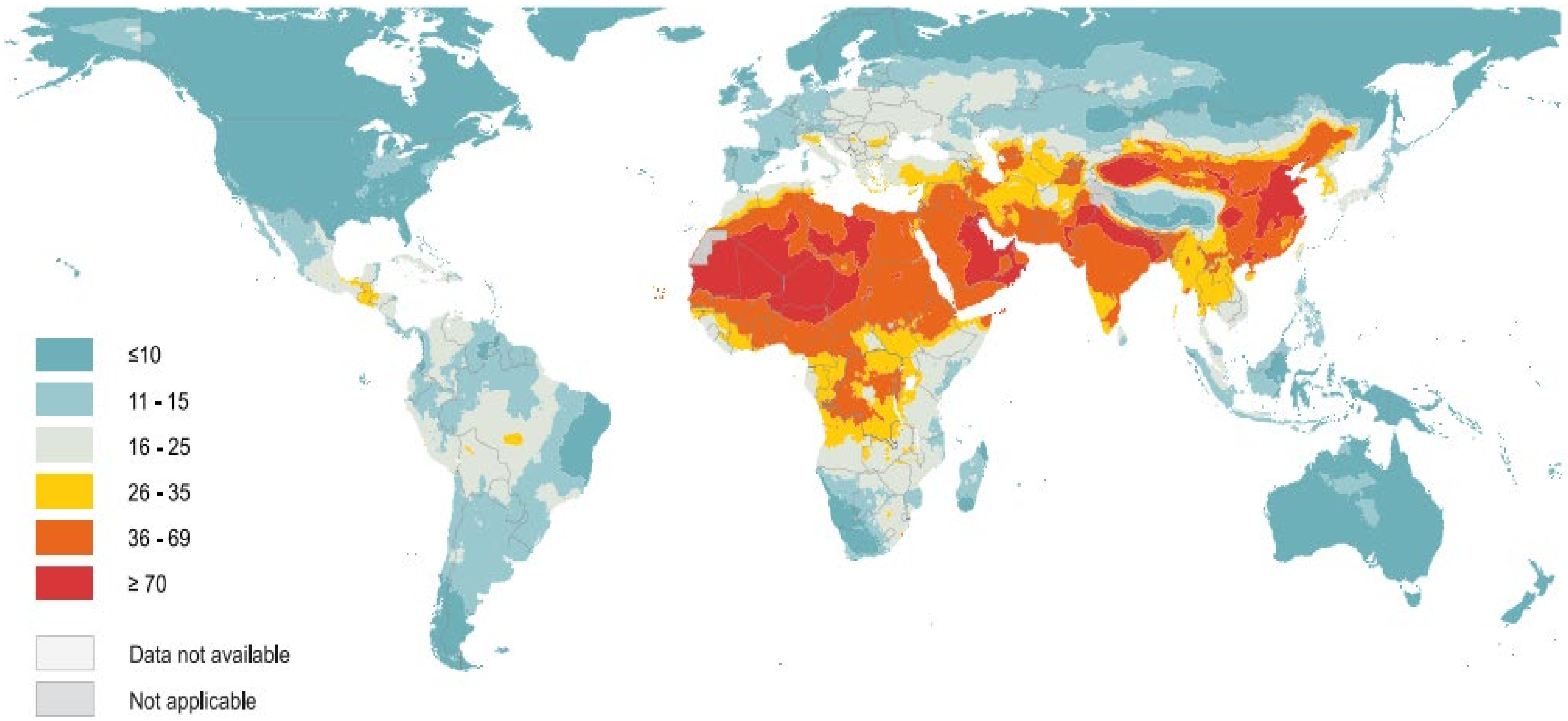


Much of the impact of air pollution has affected Africa and South Asia

WHO, 2022. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

Global Distribution of Air Pollutants

Figure 9: Global map of modelled annual median concentration of $PM_{2.5}$, in µg/m³

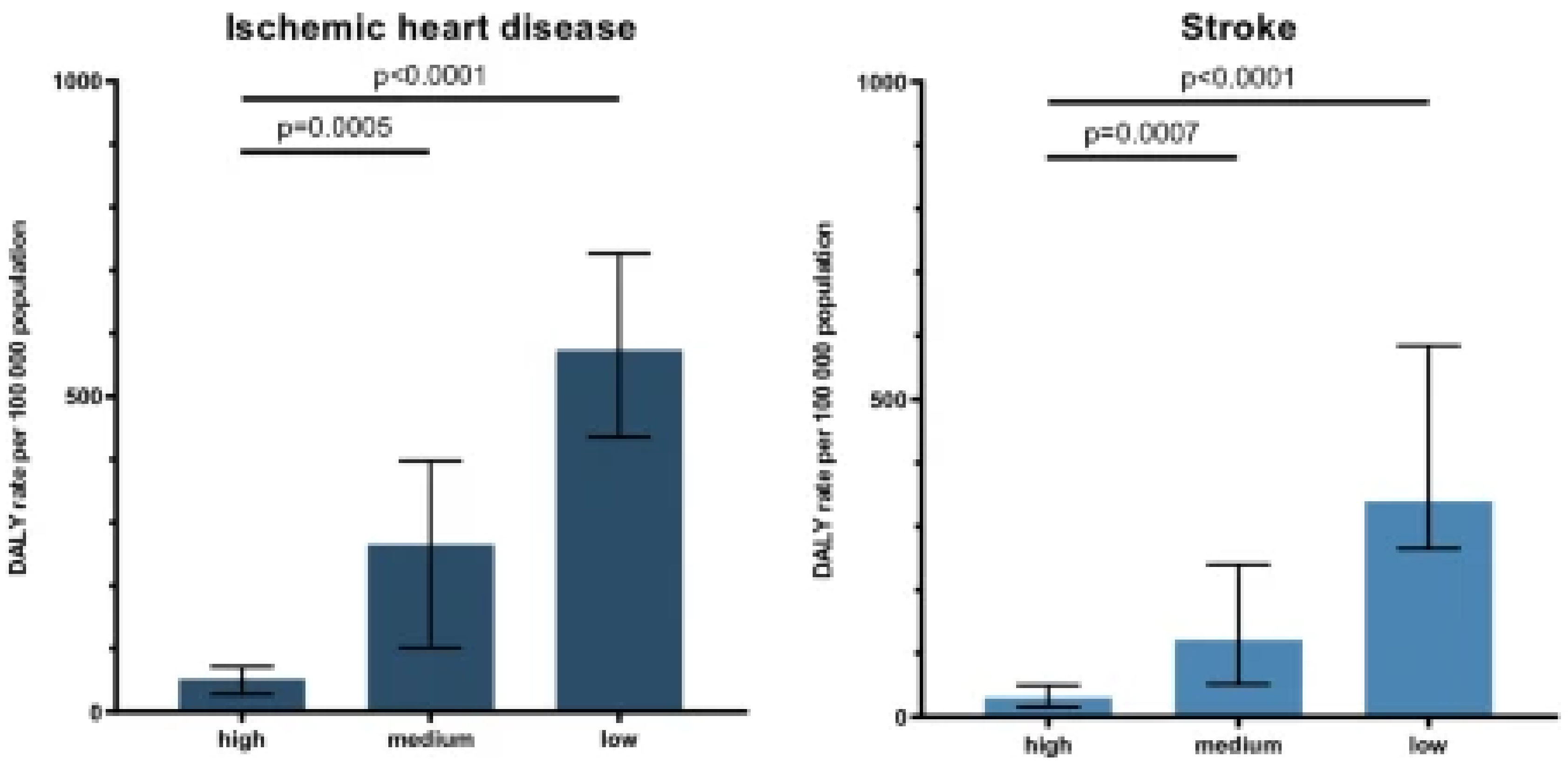


$PM_{2.5}$: Fine particulate matter of 2.5 microns or less.

Unsurprisingly, these parts of the world also have higher levels of air pollutants

WHO, 2016. https://iris.who.int/bitstream/handle/10665/250141/9789241511353-eng.pdf?sequence=1&isAllowed=y

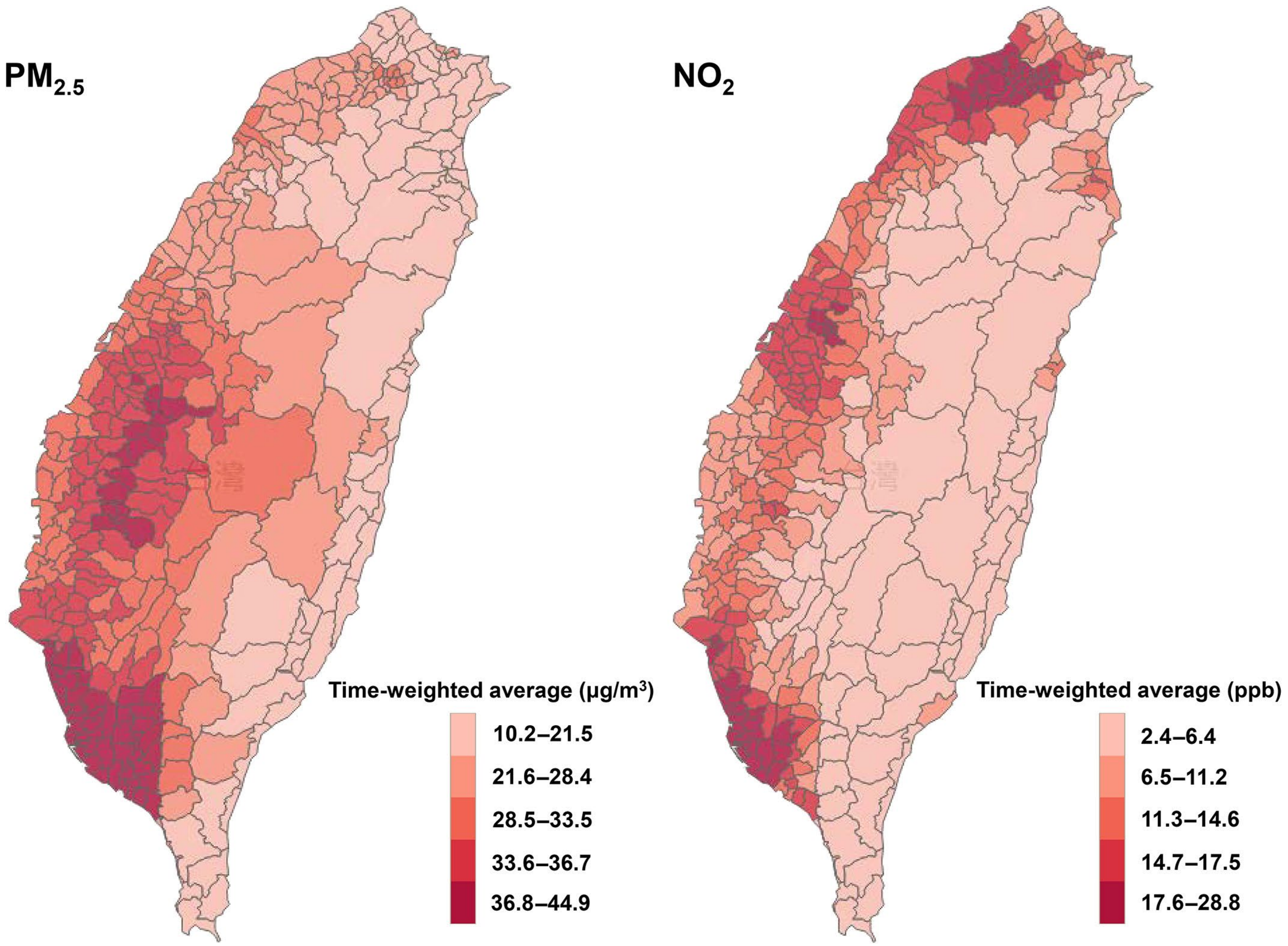
Socio-Demographic Index and Air Pollution



In Europe, countries with a low socio-demographic index had a DALY rate 11 times higher for heart and brain disease compared to those with a high socio-demographic index

Juginovi A et al. SR, 2021

Geographic Location and Air Pollution



In Taiwan, there was a dose-response association between long term exposure to PM2.5 and lung adenocarcinoma in women

Yang S et al. R, 2022

Wild Fires and Hospitalization

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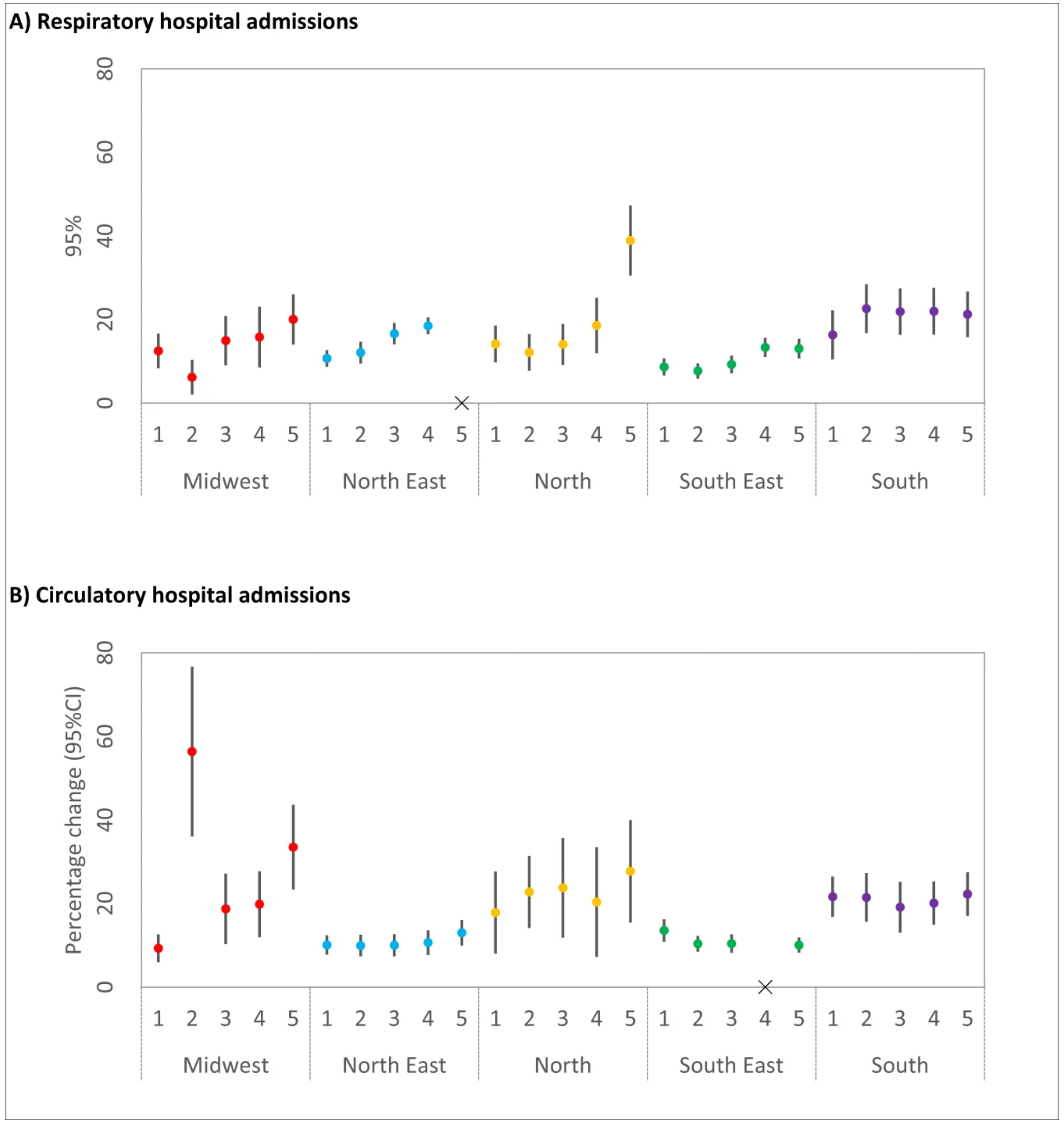
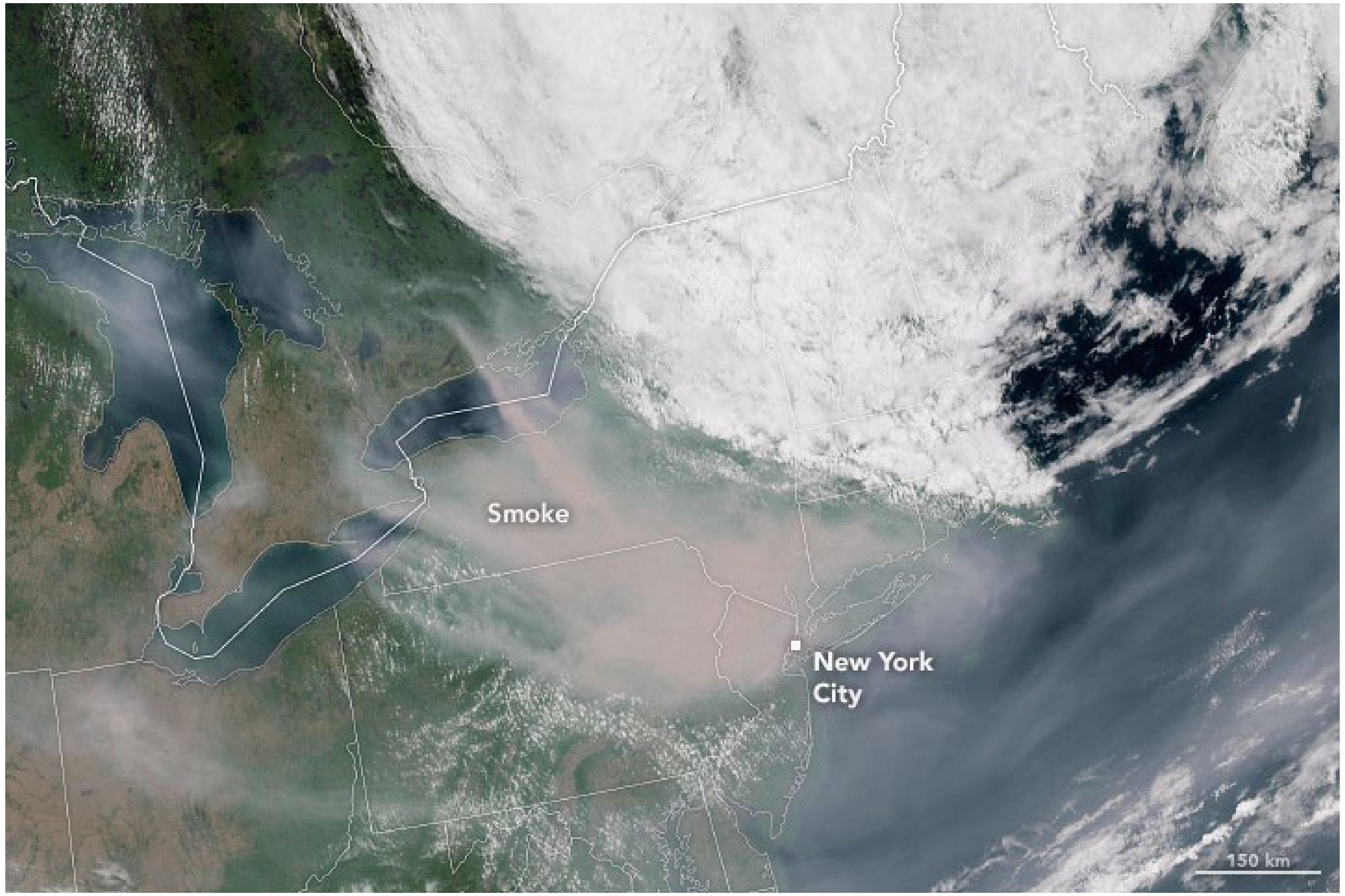
In Brazil, risk of hospitalization increases in the days after exposure to wildfire-related PM2.5



Requia WJ et al. NC, 2021

Wild Fires and Emergency Room Visits

In the US, ED visits for asthma increased in the wake of the smog from wildfires in Canada

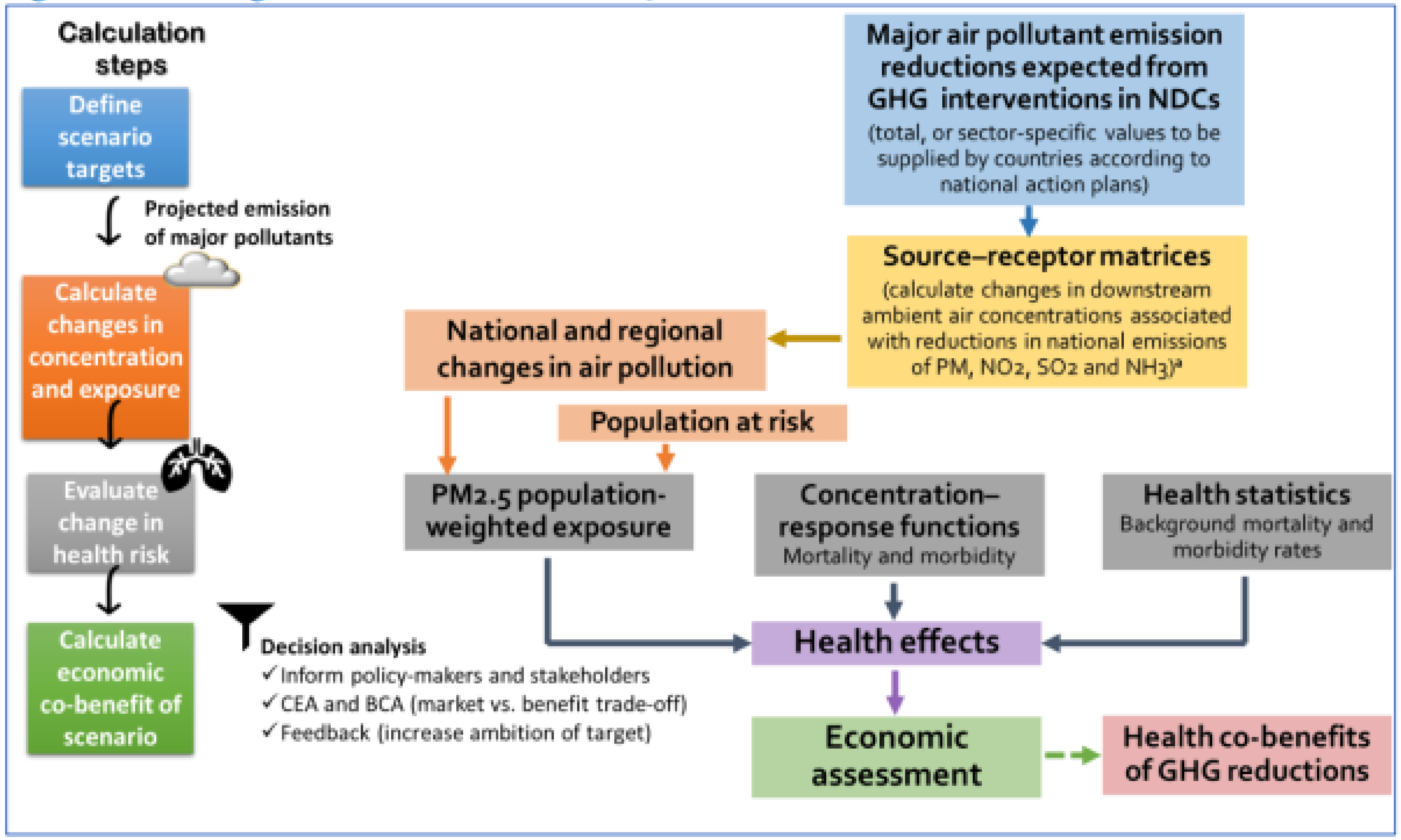


NASA, 2023. https://earthobservatory.nasa.gov/images/151433/smoke-smothers-the-northeast

Framework for Climate Change Policy and Health

Conversely, improving air quality can lead to downstream positive health outcomes and reduced healthcare costs

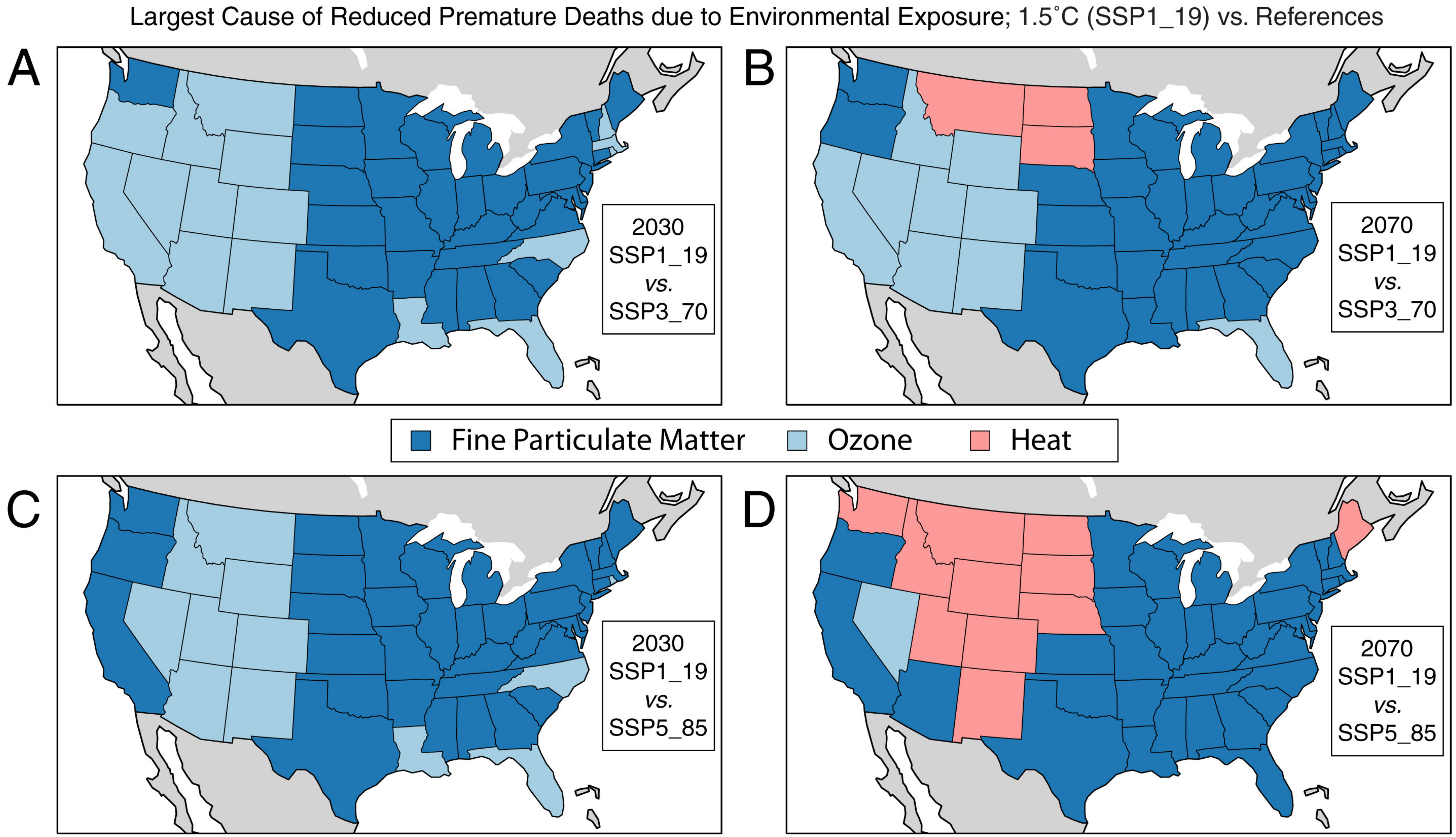
Fig. 2. Methodological framework of CLIMAQ-H



BCA, benefit–cost analysis; CEA, cost–effectiveness analysis; GHG, greenhouse gases
A $PM_{2.5}$ concentration change (relative to BAU in 2030) due to reductions in primary $PM_{2.5}$ emissions and to reductions in precursor emissions of NO_2, SO_2, NH_3 that contribute to formation of secondary $PM_{2.5}$ aerosols.

WHO, 2023. https://www.who.int/europe/publications/i/item/9789289060196

Impact of Climate Change Mitigation



Aggressive climate change mitigation policies can have immediate effects on premature deaths due to air pollution

Shindell D et al. PNAS, 2021.

Climate Change Mitigation of Trees

Table 4
Reduction in number of incidences and associated monetary value ($) for various health effects due to pollutant reduction from trees.

Pollutant	Adverse health Effect	Conterminous US		Urban areas		Rural areas	
		No. Inc[a]	Value	No. Inc[a]	Value	No. Inc[a]	Value
NO_2	Asthma Exacerbation	271,402	21,772,000	214,236	17,178,000	57,166	4,594,000
	Hospital Admissions	640	16,037,000	470	11,823,000	170	4,214,000
	Acute Respiratory Symptoms	18,179	565,000	14,666	455,000	3513	110,000
	Emergency Room Visits	238	100,000	185	78,000	53	22,000
	Total		38,473,000		29,534,000		8,939,000
O_3	Mortality	275	2,137,630,000	185	1,439,586,000	90	698,044,000
	Acute Respiratory Symptoms	481,275	41,143,000	345,581	29,543,000	135,695	11,600,000
	Hospital Admissions	1977	20,326,000	1776	13,852,000	201	6,474,000
	School Loss Days	202,399	19,874,000	146,939	14,428,000	55,460	5,446,000
	Emergency Room Visits	231	97,000	167	70,000	63	26,000
	Total		2,219,069,000		1,497,479,000		721,590,000
$PM_{2.5}$	Mortality	577	4,488,013,000	394	3,062,289,000	183	1,425,724,000
	Chronic Bronchitis	149	41,706,000	106	29,720,000	43	11,987,000
	Acute Respiratory Symptoms	169,701	16,634,000	122,484	12,006,000	47,216	4,628,000
	Acute Myocardial Infarction	125	11,219,000	85	7,629,000	40	3,590,000
	Asthma Exacerbation	137,298	11,161,000	98,467	8,005,000	38,831	3,157,000
	Work Loss Days	28,815	4,758,000	20,836	3,602,000	7979	1,157,000
	Hospital Admissions, Cardiovascular	71	2,705,000	49	1,876,000	22	829,000
	Hospital Admissions, Respiratory	58	1,850,000	39	1,246,000	19	604,000
	Lower Respiratory Symptoms	3900	202,000	2809	146,000	1091	57,000
	Upper Respiratory Symptoms	3168	142,000	2284	103,000	883	40,000
	Emergency Room Visits	203	84,000	150	62,000	53	22,000
	Acute Bronchitis	320	28,000	231	20,000	89	8000
	Total		4,578,503,000		3,126,703,000		1,451,800,000
SO_2	Acute Respiratory Symptoms	2865	90,000	2042	64,000	823	26,000
	Asthma Exacerbation	25,334	1,998,000	17,680	1,393,000	7654	605,000
	Emergency Room Visits	111	46,000	81	34,000	30	12,000
	Hospital Admissions	174	5,322,000	112	3,432,000	62	1,891,000
	Total		7,457,000		4,923,000		2,534,000

[a] reduction in number of incidences.

Trees can mitigate health costs through promoting poor health outcomes by improving air quality

Nowak DJ et al. EP, 2014.

Part Two:

Trees the Charm

i-Tree – Measuring Stick for Impact of Trees

Project Phases

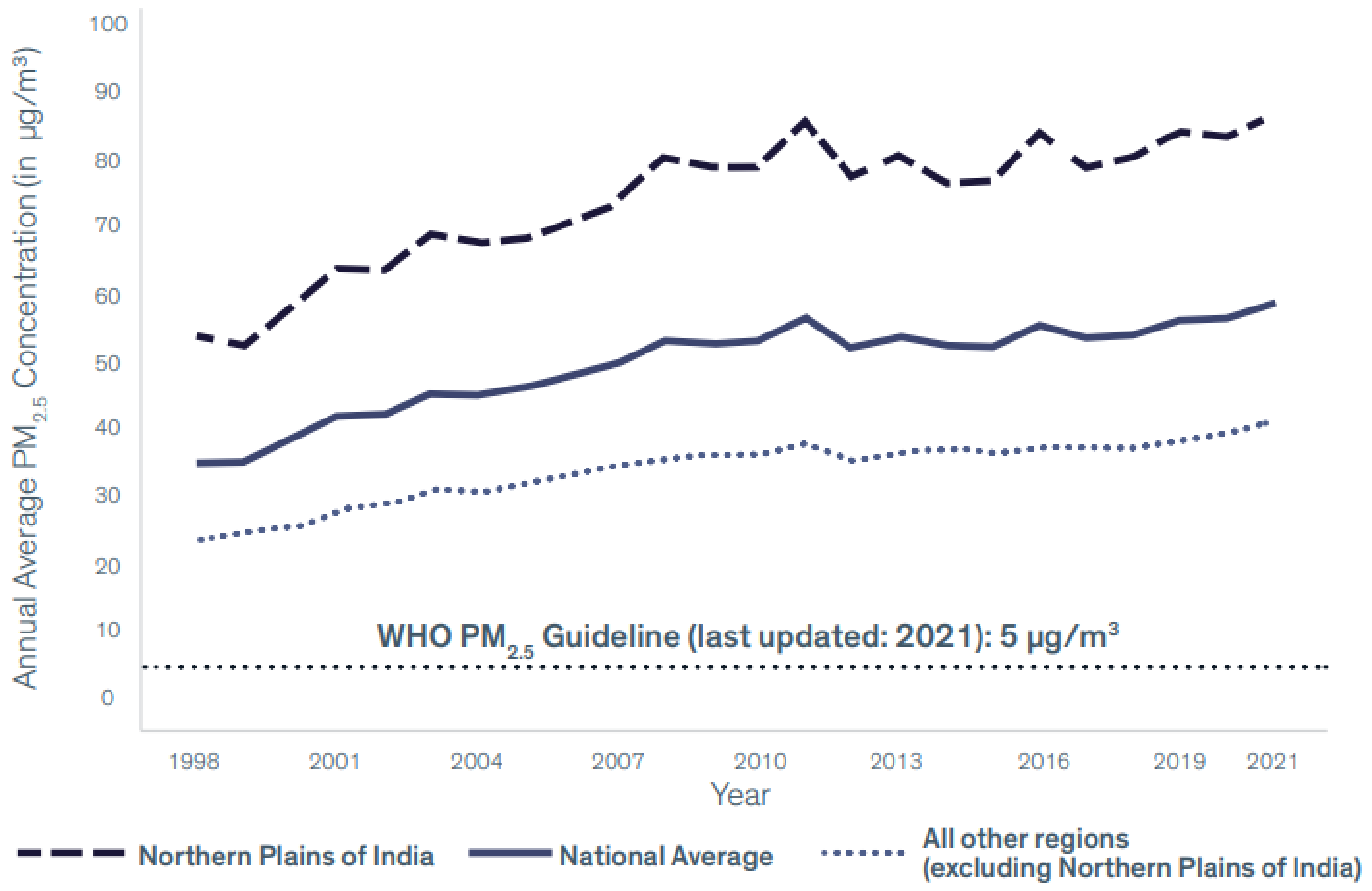
Phase 1 – Trees and Air Quality

Phase 2 – Air Quality and Health

Phase 3 – Tree Coverage Scenarios

Air Pollution in India

Figure 4 · Annual average $PM_{2.5}$ concentrations in India, 1998-2021



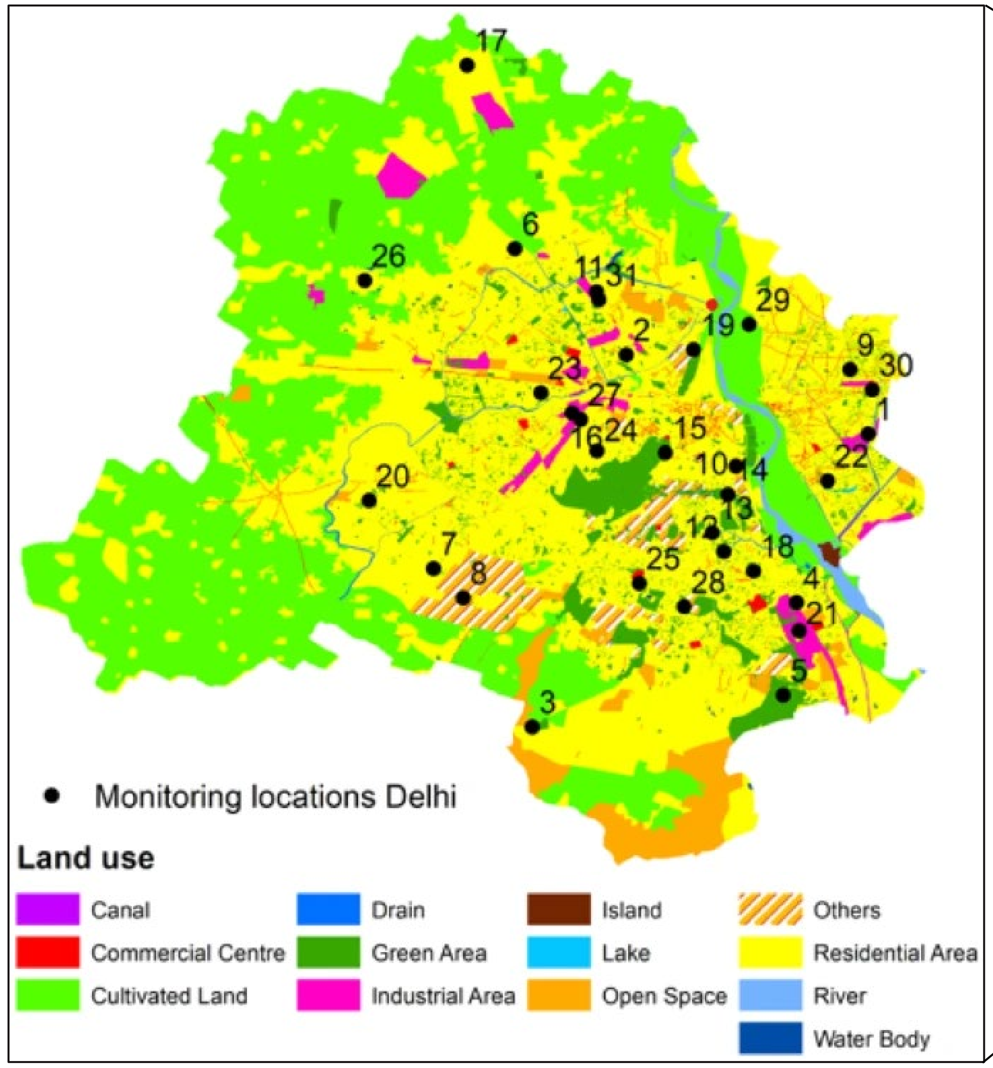
India has the second to worst levels of air pollution in the world especially in the Northern Plains

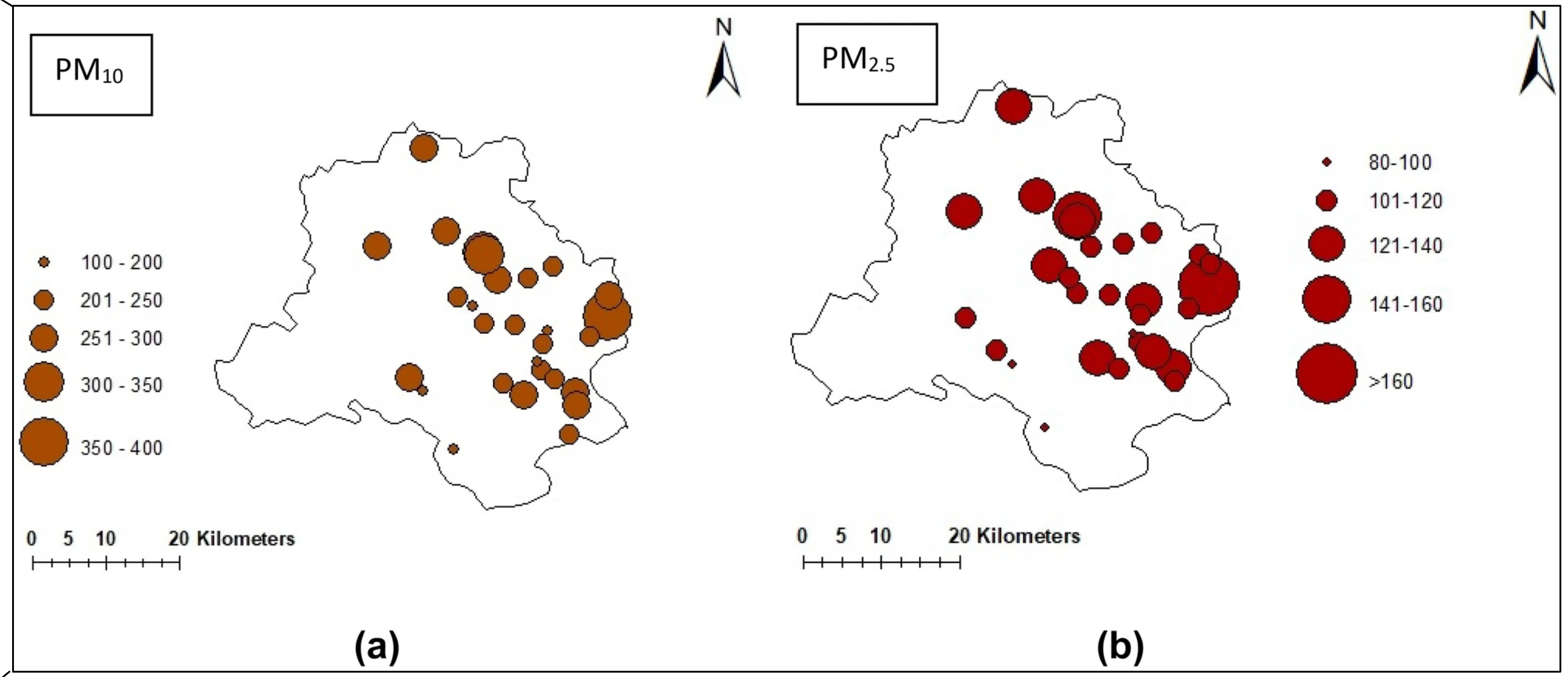
AQLI, 2023. https://aqli.epic.uchicago.edu/wp-content/uploads/2023/08/India-FactSheet-2023_Final.pdf

The Delhi Context

Study Area and Air Pollution

Air pollution levels in Delhi are constantly measured via multiple stations





Rahman, MH et al. EMA, 2023

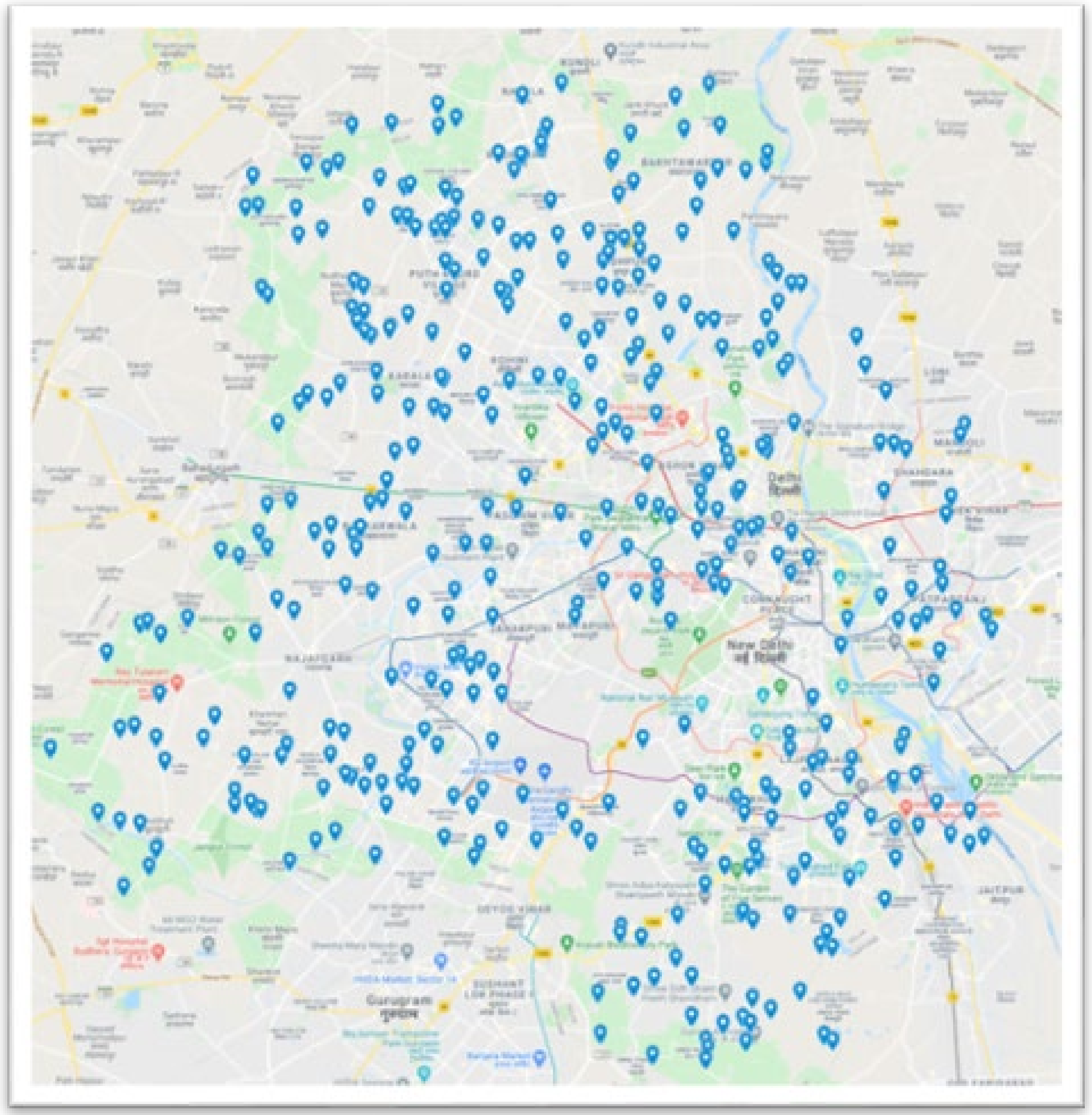
What is i-Tree?

- A software developed by U.S. Forest Service, Davey Tree Expert Company and other partners to **assess the benefits provided by trees** and manage them.
- Can be used to assess benefits of individual trees as well as trees in large scale areas (eg. cities)
- Visit itreetools.org for more information

Impact of Trees on the Environment

Phase 1:

- Data for trees across 400 locations in Delhi was collected using i-Tree.
- Data collection took almost 2 years

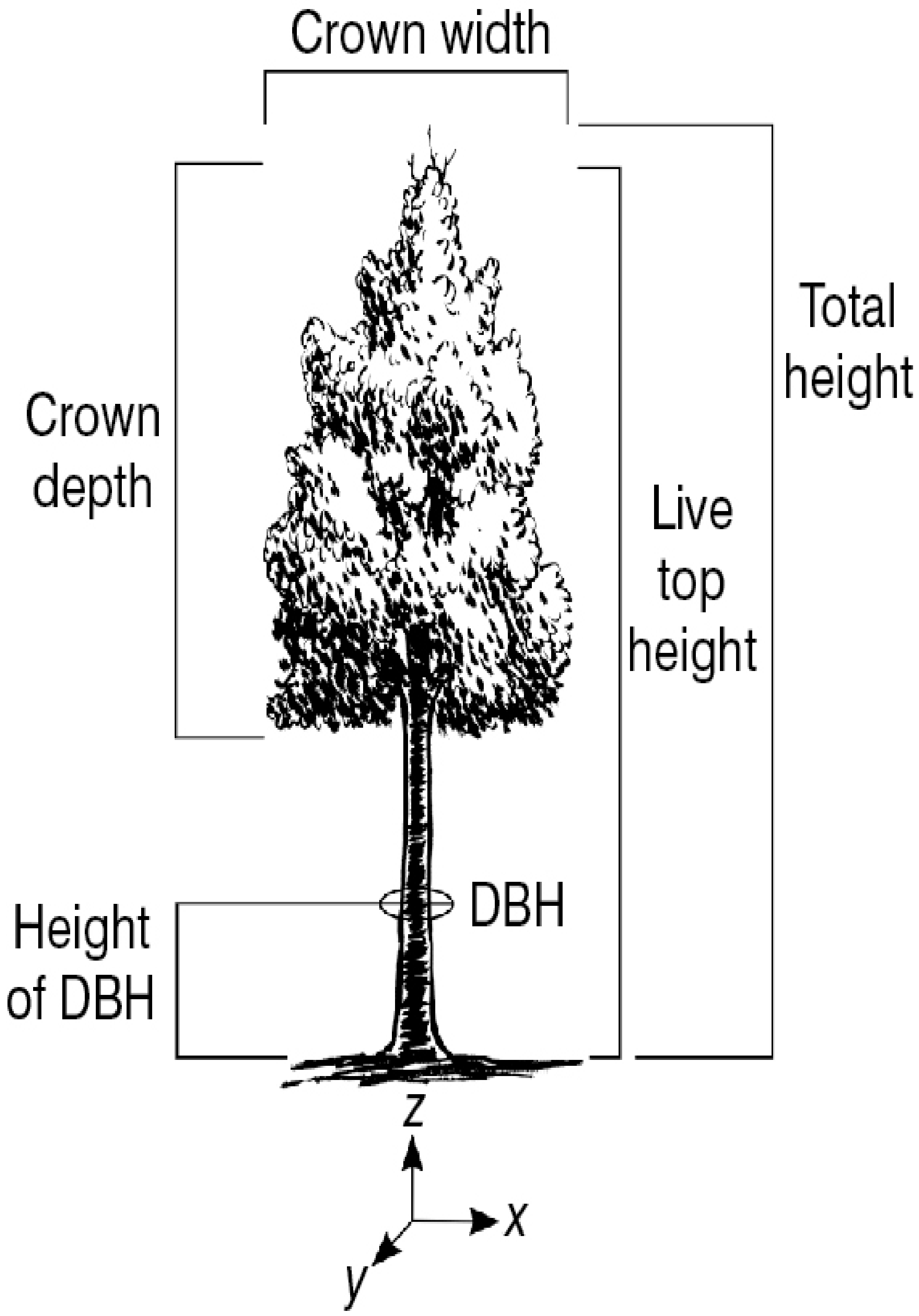


- Data on pollutants absorbed from the air by these trees has been calculated using i-Tree

Tree Variables Collected in the Study

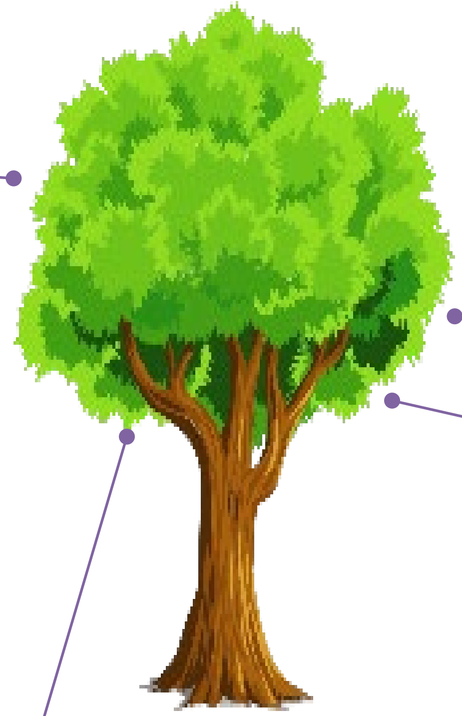
Mandatory variables**
- Tree species
- Diameter at breast height (DBH)

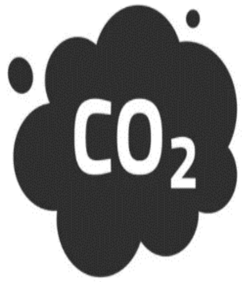
Recommended variables
- Total height
- Crown live top height
- Crown base height
- Crown width (both sides)
- Sunlight Exposure of crown
- Gaps in crown (crown missing)
- Crown Health
- GPS Coordinates



Summary of Results

10,440,000
trees in Delhi
with a **tree cover**
of **8.1%**





- **Carbon Storage : 1.469 million metric tons**
  (equivalent to carbon emissions by almost 1.5 million cars)

- **73.59 thousand metric tons** of **Carbon Sequestration**/year
  (almost 1.5 times the weight of the Titanic)

Avoided runoff 3.471 million cubic meters/year

(equivalent to water in 1400 Olympics size swimming pools)

6.8 million tons/year of **Air Pollution Removal**

(equivalent to weight of1,135 male African elephants)

Oxygen Production of 174 thousand metric tons/year

Air Pollutants Absorbed by Trees

Air pollutants absorbed by the tree available at the following levels:

- Species-wise
- District wise (11 districts in Delhi)
- Month of the year

Air pollutant	Total amount absorbed by all trees in Delhi (kg)
CO	108
NO2	604,237
O3	835,956
PM10	4,837,284
PM2.5	253,116
SO2	282,721
Total	**6,813,422**

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Impact of Air Quality on Health

Phase 2:

- Sources for clinical data in Delhi were identified

BARRIERS

- Global Burden of Disease project (left) does not have detailed information within a city
- Delhi lacks a shared available public health dataset or a standardized electronic medical records system

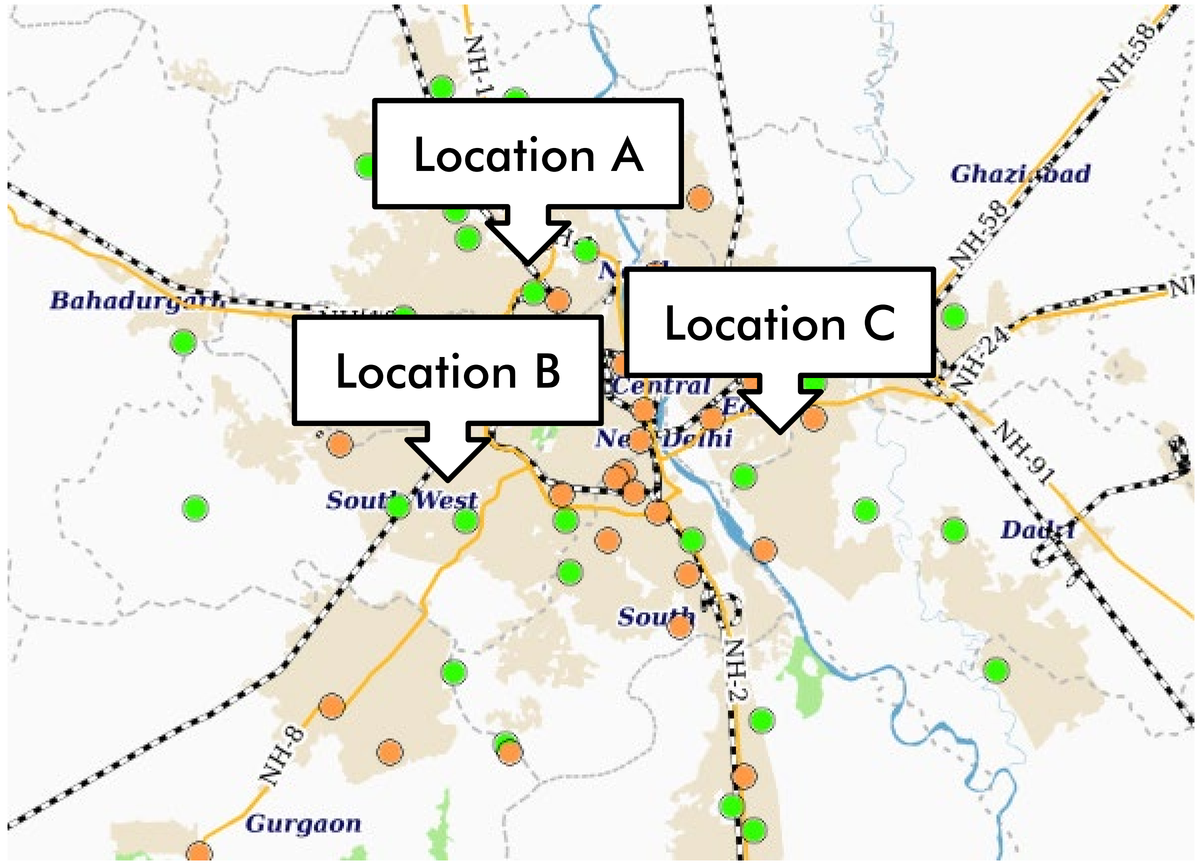
Study and year	Variable	Findings
Siddique *et al.*, 2011[20]	Vehicular air pollution effects in children	Ambient PM10 level was positively correlated with ADHD in children (OR = 2.07; 95% CI, 1.08–3.99)
Rajarathnam *et al.*, 2011[23]	Outdoor air	It was found that every 10 μg/m³ change in PM_{10} was associated with 0.15% increase in total all-natural-cause mortality
Kumar *et al.*, 2008[15]	Indoor air pollution	Indoor SO_2, NO_2 and suspended particulate effects in children matter levels were high in houses with family history of smoking. Indoor air pollution was associated with respiratory function of children
Kulshreshtha *et al.*, 2008[16]	Indoor air	High levels of indoor airborne pollutants during winter were associated with respiratory problems for women and children.
Jayaraman, 2008[13]	Outdoor air	10 μg/m³ rise in pollutant level led to statistically significant relative risks (RR) for respiratory morbidity: 1.033 for O_3, 1.004 for NO_2, 1.006 for RSPM
Nidhi *et al.*, 2007[24]	Outdoor air	The relative risks of hospitalization due to respiratory diseases were 1.07–2.82
Kumar, 2007[19]	Indoor air pollution	Indoor SPM level was also significantly effects in children higher in homes of children with a history of respiratory illness
Agarwal *et al.*, 2006[12]	Outdoor air	SPM (r = 0.474; P <0.01) and RSPM (r = 0.353; P <0.05) showed a significant positive correlation with the number of COPD cases. Winter months had higher risk
Pande *et al.*, 2002[25]	Outdoor air	Emergency room visits for asthma, COAD and acute coronary events increased by 21.30%, 24.90% and 24.30%, respectively, due to higher than acceptable levels of air pollutants

Rizwan S et al. IJCM, 2013.

Overcoming International Barriers

SOLUTION

- Collaborate with local researchers with datasets with clinical respiratory outcomes collected from patients across Delhi and pair with historical air quality data



Reforestation vs Deforestation and Health

Phase 3:

- After determining associations between tree coverage, air quality, and health outcomes in Delhi, we can model the health outcomes of different tree coverage scenarios

Kim H et al. AP, 2021.

Part Three:

Recipe for Success

Impacts of Climate Change on Human Health

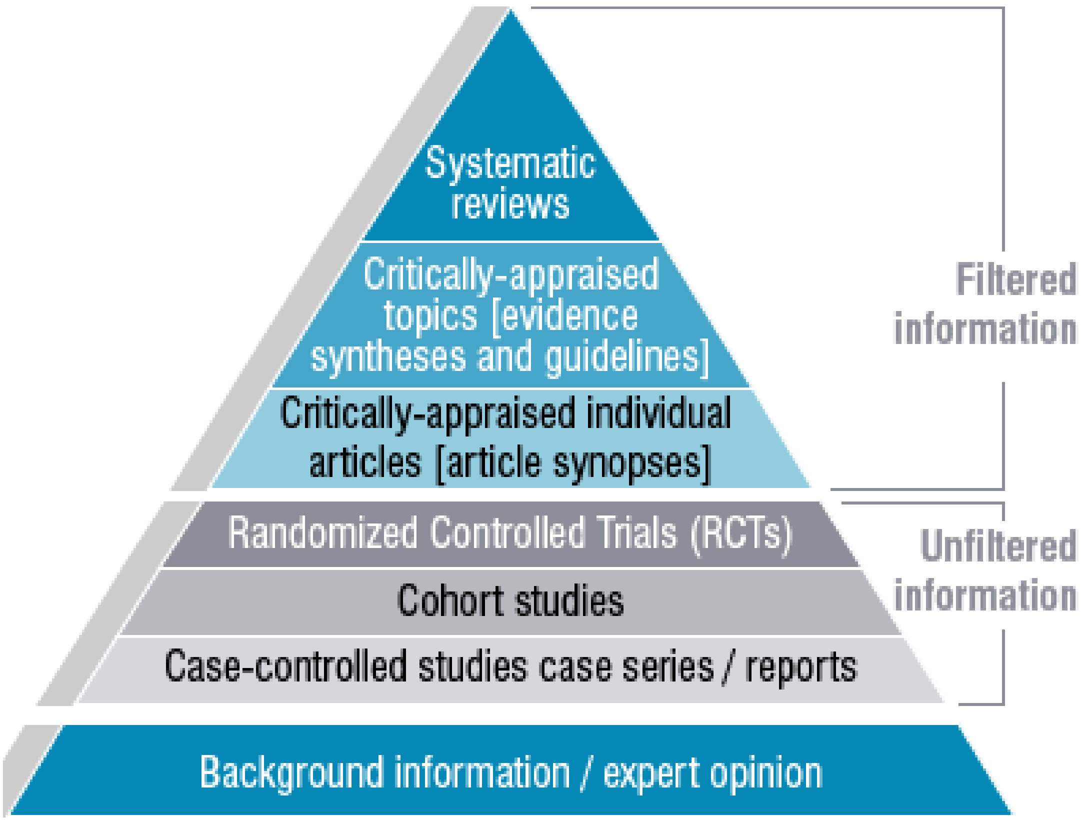
- Temperature-Related Disease and Illness
- Populations of Concern
- Air Quality Impacts
- Extreme Events
- Vector-Borne Disease
- Water-Related Illness
- Food Safety, Nutrition, and Distribution
- Mental Health

Adapted from Crimmins A et al. USGCRP, 2016

Discussion Question!

How would you design a study on the impact of trees on health given the perfect conditions?

Components of a Clinical Study



Population:
- Demographics (e.g., age, sex, race)
- Socioeconomic factors
- Behavior and lifestyle
- Geographic location
- Comorbidities

Intervention vs Control:
- Differences in tree coverage

Outcome:
- Validated clinical tool
- Morbidity and Mortality

UCL. https://canberra.libguides.com/c.php?g=599346&p=4149721

Discussion Question!

For this ideal study, how do you envision physicians and the broader medical community to respond?

Three Levels of Preventative Health

Primary: Prevent the disease
- How can trees mitigate the impact of climate change to prevent illness?

Secondary: Diagnose and stop the disease early
- How can the impact of climate change – or a proxy indicator such as tree coverage – be used as a risk factor for residents of certain areas?

Tertiary: Manage the disease
- How can trees be incorporated into treatment?

Thank you

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