

An aerial photograph of a city, likely New York City, showing a dense urban landscape with a river and a large body of water in the foreground. The skyline is visible in the background, with many skyscrapers. The image has a slightly hazy, atmospheric quality.

Clearing the Air:

Do trees affect air quality and human health?

Tom Whitlow Horticulture, Cornell Univ.

Zheming Tong Mechanical and Aerospace Eng. Cornell Univ.

K. Max Zhang Mechanical and Aerospace Eng. Cornell Univ.

Xing Wang Mechanical and Aerospace Eng. Cornell Univ.

Patrick MacRae Horticulture, Cornell Univ.

Gretchen Fenerz-Fox NYC Cornell Coop, Extension

Marcie Pullman Calif. Air Resources Board

Ruby Beil Lorain County Community College

Jacqueline Lu NYC Parks

Juan Anguita UMass

Clearing the Air:

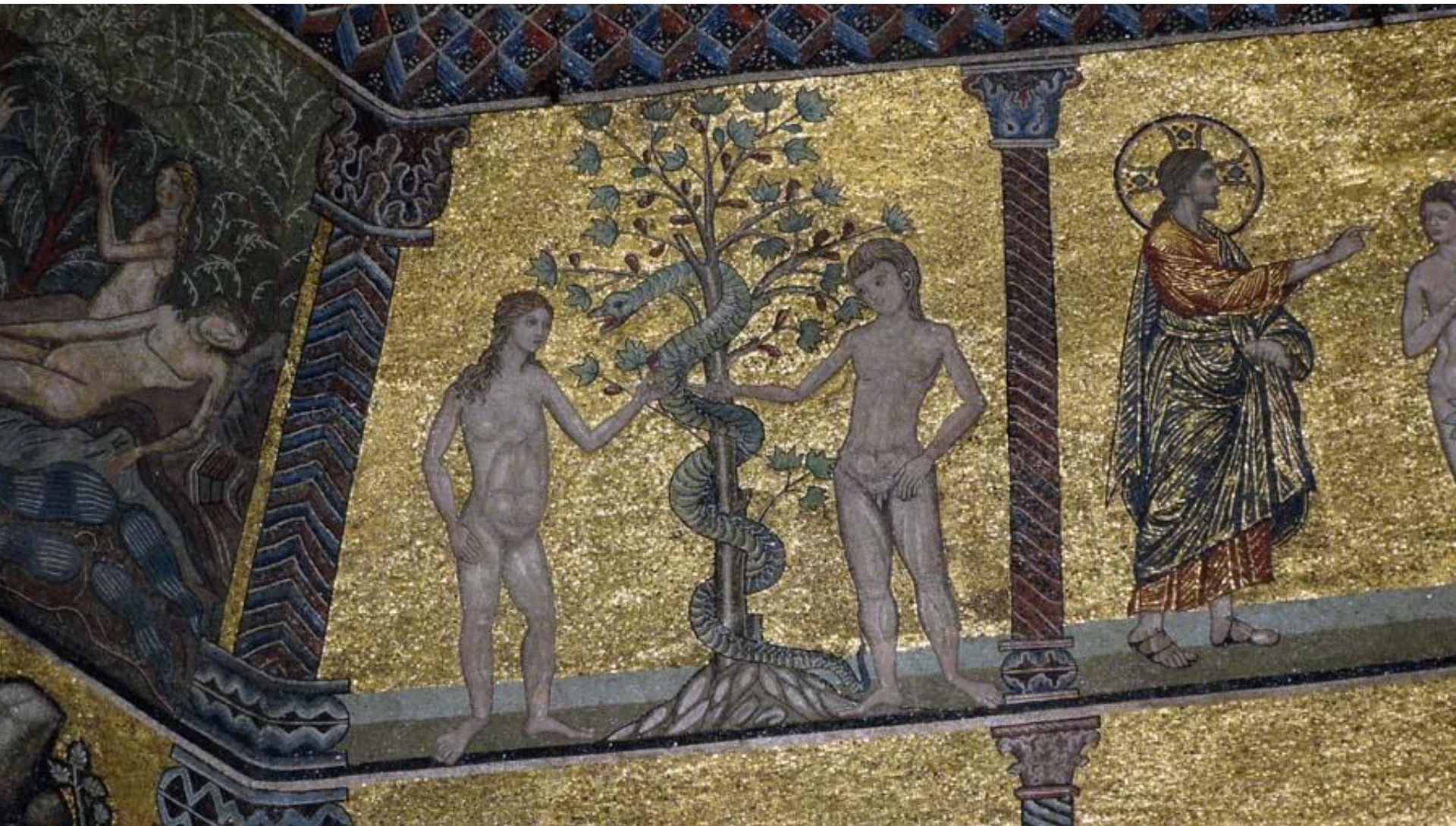
Do trees affect air quality and human health?





Forests and trees are an essential part of the biosphere....

As part of the human story.....



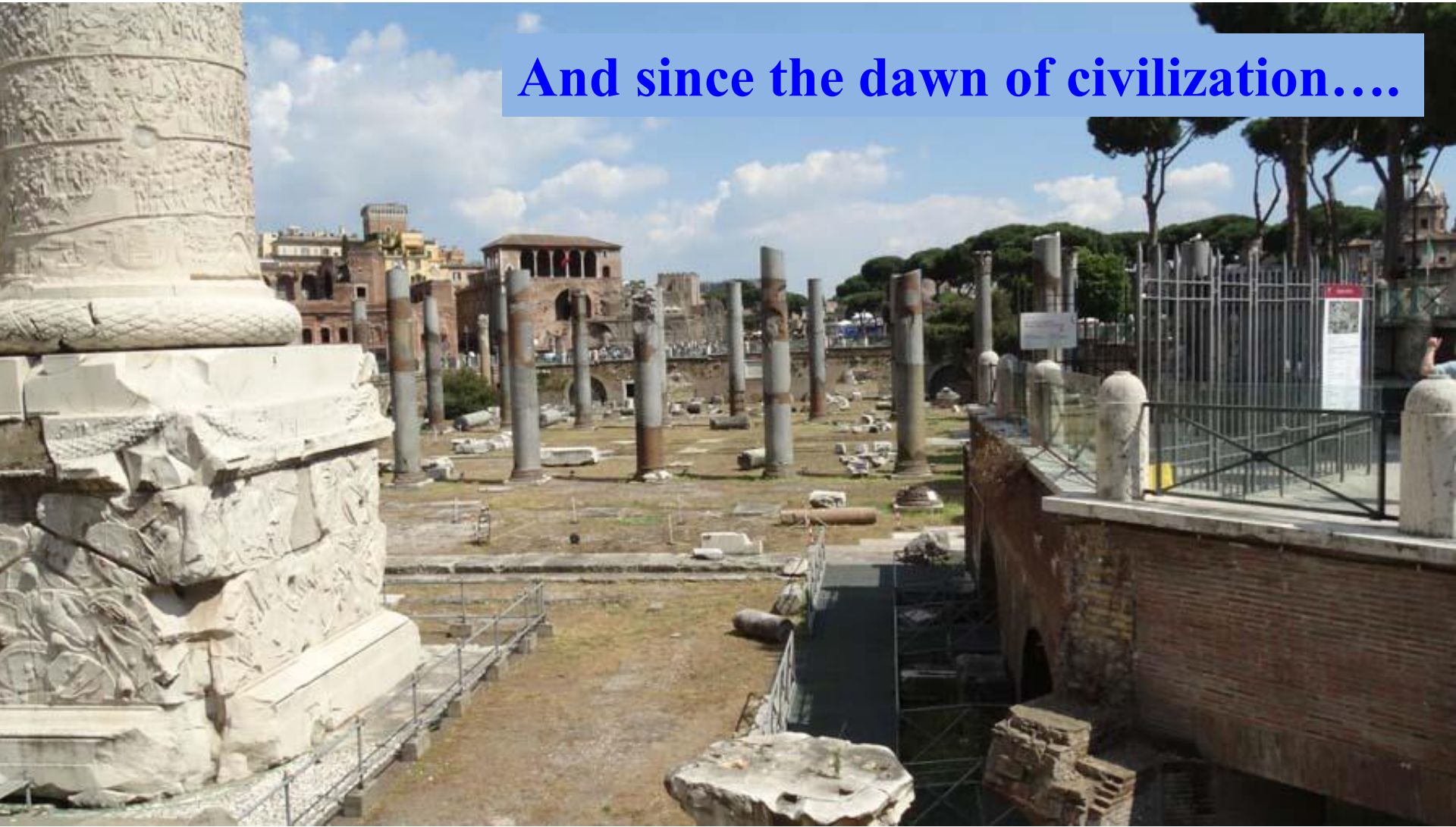
And are essential for human existence.....



.....though we seem to forget this fact

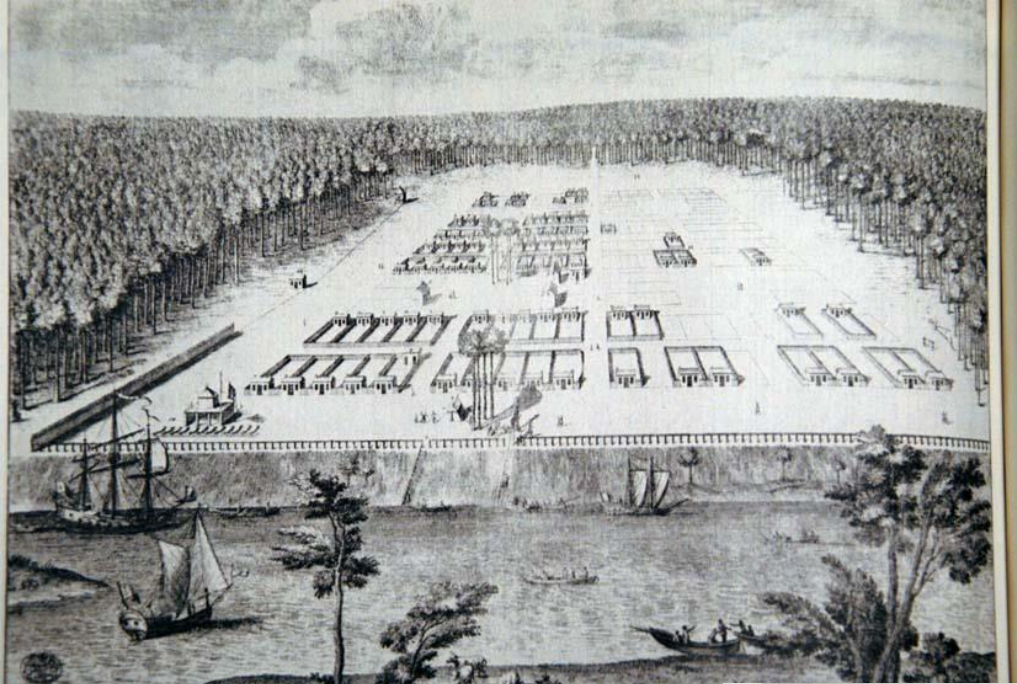


And since the dawn of civilization....



We have marginalized trees.....





To the Hon^{ble} the Trustees for establishing the Colony of Georgia

Savannah, Georgia



Figure 67. View of Plymouth, Massachusetts: 1630

Plymouth, Massachusetts



Manhattan, 1609



Manhattan, 2009

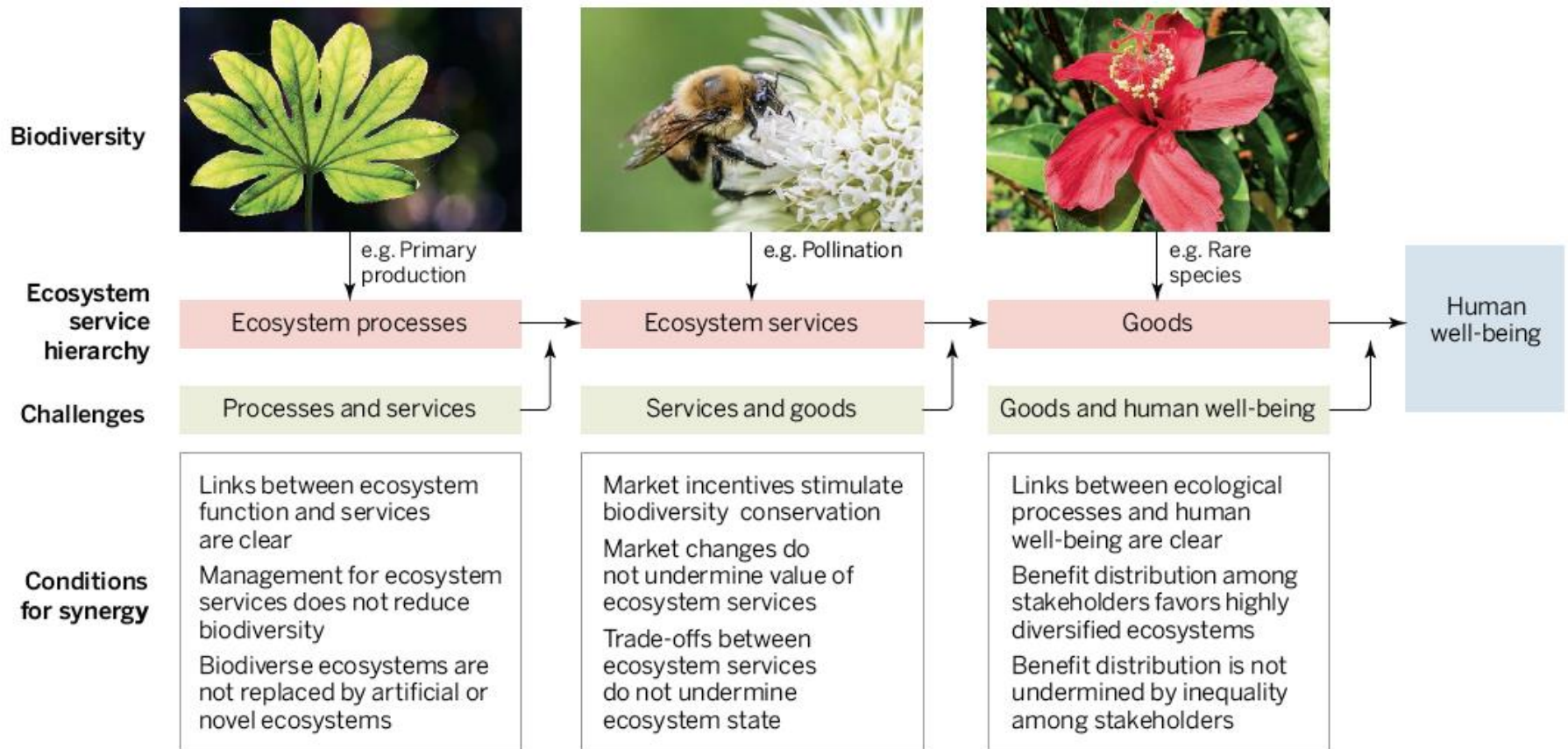
Indeed, we celebrate our built environment.....



Indeed, we celebrate our built environment.....



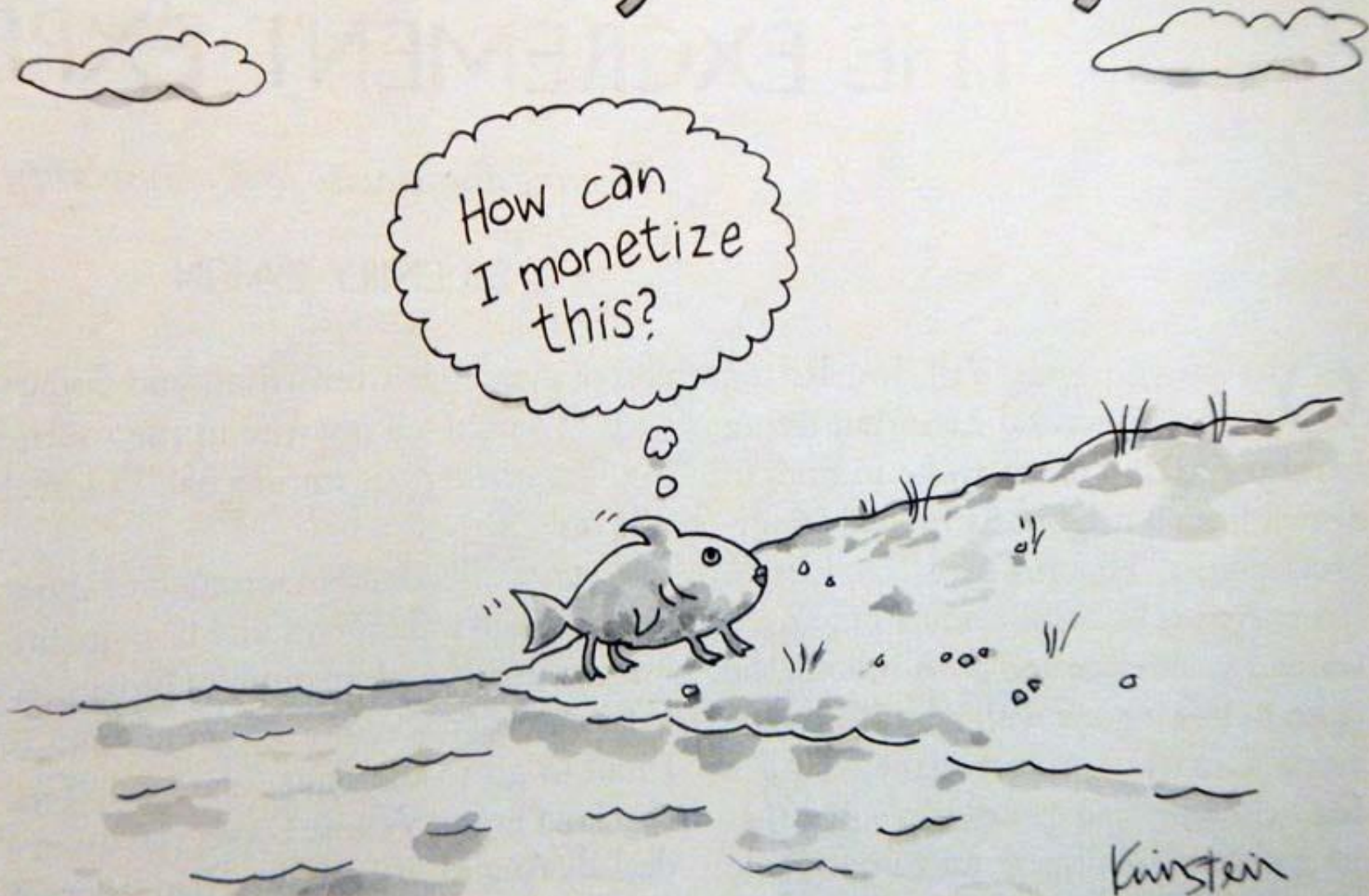
“Without nature, finally, no people.” (E. O. Wilson)



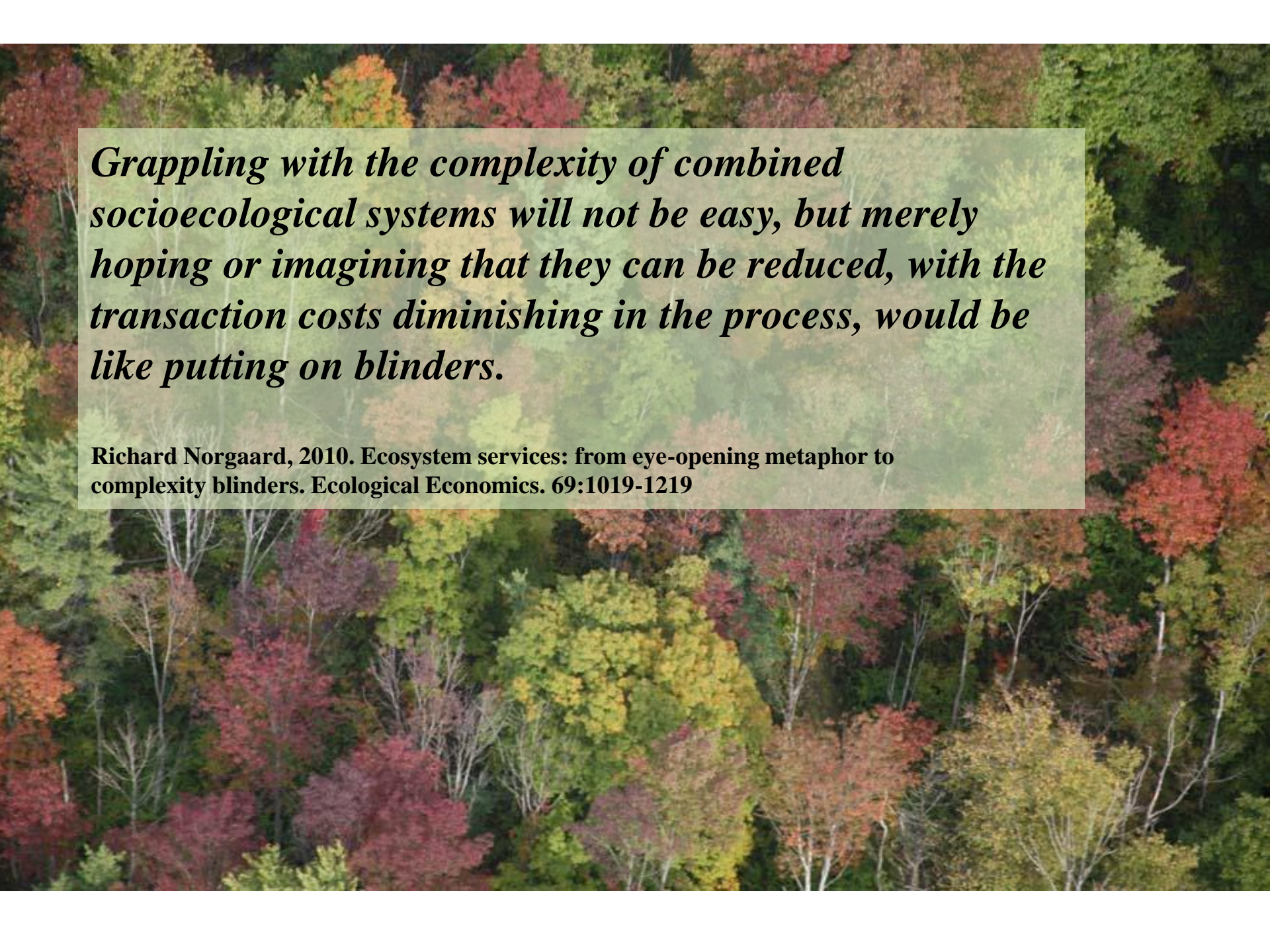
Finding synergies. Biodiversity can regulate fundamental ecosystem processes and ecosystem services, as well as constitute goods that contribute to human welfare (4). Challenges to the creation of synergies between ecosystem services and conservation arise in relationships among ecosystem processes, services, goods, and human well-being. These challenges define the conditions under which synergies arise or can be created.

A growing realization that humans depend on the biosphere.....

Intelligent Design



How can we make nature compete in the urban economy?



Grappling with the complexity of combined socioecological systems will not be easy, but merely hoping or imagining that they can be reduced, with the transaction costs diminishing in the process, would be like putting on blinders.

Richard Norgaard, 2010. Ecosystem services: from eye-opening metaphor to complexity blinders. Ecological Economics. 69:1019-1219

Pitfalls with monetizing pollution mitigation

Distortion: Turns small numbers into large numbers
Loses sight of primary environmental currencies

Distraction: Real problem lies with the sources of pollution
Conveys false sense of progress

Confusion: Conflicting means objectives

Impediment: Interferes with translation of science
into effective policy and practice

Air pollution is a widely acknowledged problem

Health & Science

The deadly toll of air pollution

The deadly toll

Breathing dirty air is a real killer. New findings from the World Health Organization show that air pollution was responsible for more than 7 million global deaths in 2012, making it the world's top 1 environmental health risk. More than a third of those deaths occurred in Asia, where rapid industrial development in countries like Japan, China, and India has contributed significantly to the problem. The stark figures were included in a WHO report that also reveals a significant link between exposure to air pollution and cardiovascular diseases. And the dangers extend beyond urban populations to rural



Hikers in Provo
Where people are happiest
to be happy? Then consider moving
Utah. That's the community

come. New research from the National Oceanic and Atmospheric Administration found that exposure to crude oil can cause heart defects in fish embryos—abnormalities that will likely kill many of developing fish and shorten the lives of others. The study looked at bluefin and yellowfin tuna embryos, key commercial and ecological species. "You mess up the heart, you mess up the ability of species like this to survive," says the study's lead author, environmental toxicologist Fernando G. Fernandez. The April 2010 accident tells CNN.com. The April 10 accident, which unleashed some 4 million barrels of oil into the Gulf, coincided with spawning season, when fragile embryos were being flushed out by the waves.

students watched video of the \$100 (telling the truth). Le correctly identified the then took an "impl designed to measure tions made between ideas. Students m liars to words like truth-tellers to w suggests that se tively triggers deception." Th Science, also m "significantly than men, sup

8 NEWS



Blighted beauty
plates



Paris
City of gloom: Paris is smothered in smog. An unusually windless weather pattern has trapped pollutants over the city for more than a week, causing smog as bad as that seen in Beijing. Authorities made public transportation free and instituted a partial driving ban that allowed only cars with odd-numbered plates on the roads, but lifted the unpopular ban after just one day, saying the pollution had dropped somewhat. Smog suddenly for later this month, as candidates scrambled to put out proposals for reducing traffic and planting trees.

Morélia, Mexico
children for

a, Mexico
children for parts: A mem

The world at a glance

Paris
City of gloom: Paris is smothered in smog. An unusually windless weather pattern has trapped pollutants over the city for more than a week, causing smog as bad as that seen in Beijing. Authorities made public transportation free and instituted a partial driving ban that allowed only cars with blue stickers to circulate. The ban lifted the unpopular ban on taxis and dropped somewhat the number of vehicles on the road.

Belgrade
Milosevic
has reinvigorated
won a last-minute
week to
of strong
Vucic, 44, who
which an
an anti-c
that coul
with 26
said. "M
apprehen
hat lion

NEW YORK, N. Y.

SEXUAL DIMORPHISM OF HYPER-
TENSIVE EGGS AND LARVAE

Recent studies on the biology of *Coccopharyngina*, a parasite of leucine scales, have shown that the form of the eggs that develop into females differs in shape from those that develop into females. The differentiation occurs during oviposition.

JOSE L. RODRIGUEZ

CANDORVILLE

TO A MAN IS WITNESS
HE THINKS "MY GOD,
JUST SAW A UNICORN."

BUT WHEN A MAN IS
WITNESSED WITNESSING
A UNICORN, THAT SECOND
WITNESS ADDS
BUT SKETCHES

DO YOU KNOW WHY MANKIND
NO LONGER BELIEVES IN
THE SUPERNATURAL?
ROSENCRANTZ

IT'S BECAUSE
EARTH IS NOW
FILLED WITH
7 BILLION
"SECOND"

DARRIN BEL
TYRONE,
I STILL
DON'T

2222

THE WIZARD OF ID

SIRE, THE PEASANTS WANT YOU TO DO SOMETHING ABOUT AIR QUALITY

BRANT PARKER

THAT'S WHY I
BROUGHT THIS
CHUNK OF IT FOR
OUR SCIENTISTS
TO STUDY

BRANT PARKER

And we often accept its negative consequences



~~AIR QUALITY~~
~~ACTION DAY~~
~~TODAY~~

Manhattan Bridge

LOWER RDWY Canal St WEST ALL TRUCKS 5AM - 10AM MON - FRI	UPPER RDWY Canal St EAST ♦ HOV 2+ & BUSES 6AM - 10AM MON - FRI OTHER TIMES ALL TRAFFIC
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But look! A tree does grow in Brooklyn!



Pitfall 1: Distortion

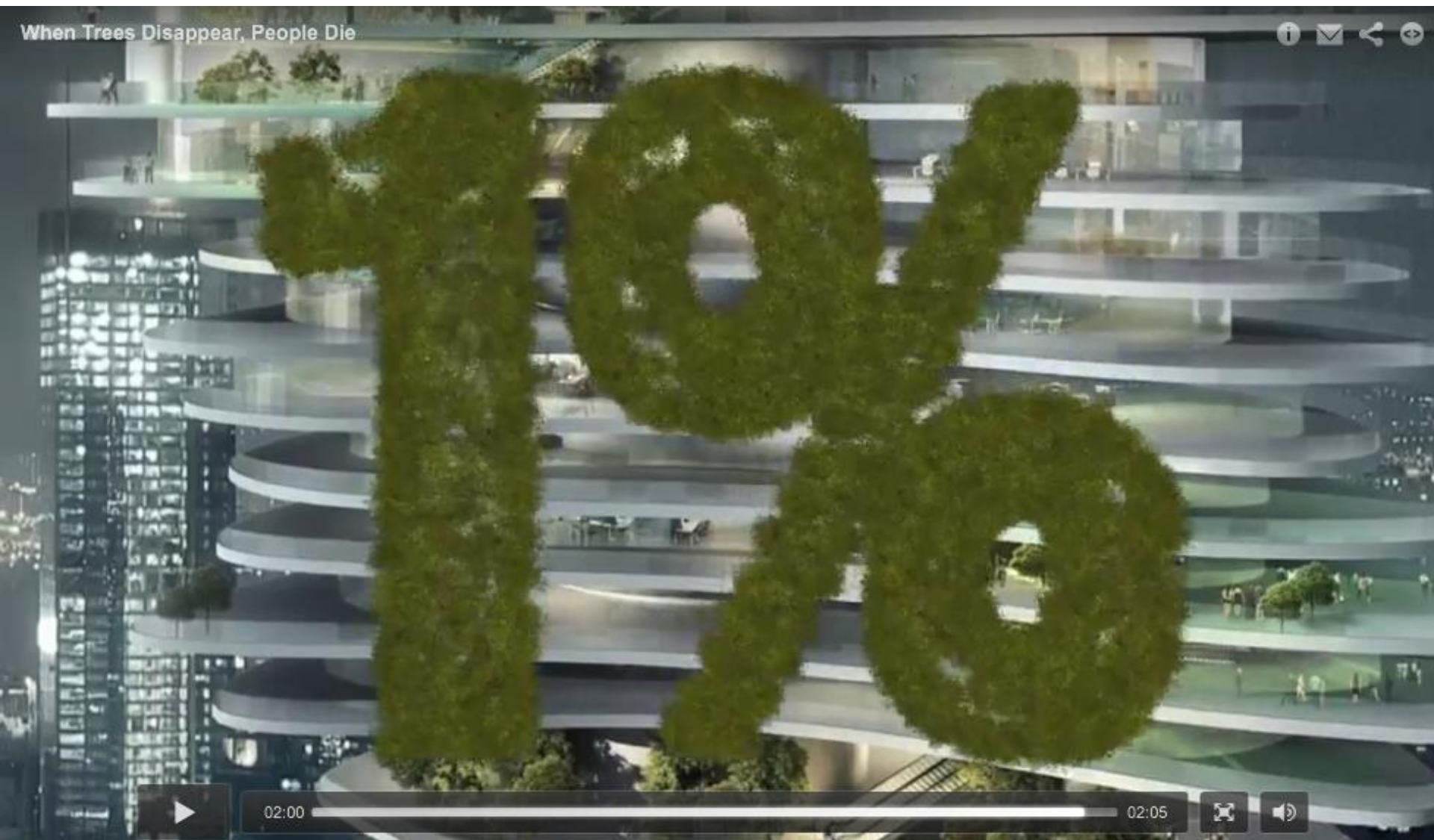


Are trees part of the solution?

A disappointingly small part.



A disappointingly small part.



What to do? Turn small numbers into BIG numbers!

% reduction X mortality rate X population X value of human life =

When Trees Disappear, People Die



\$7,000,000,000

Play



00:57

02:05



!!??

When Trees Disappear, People Die



Is this what the science says?

What is the appropriate community response?

\$7,000,000,000

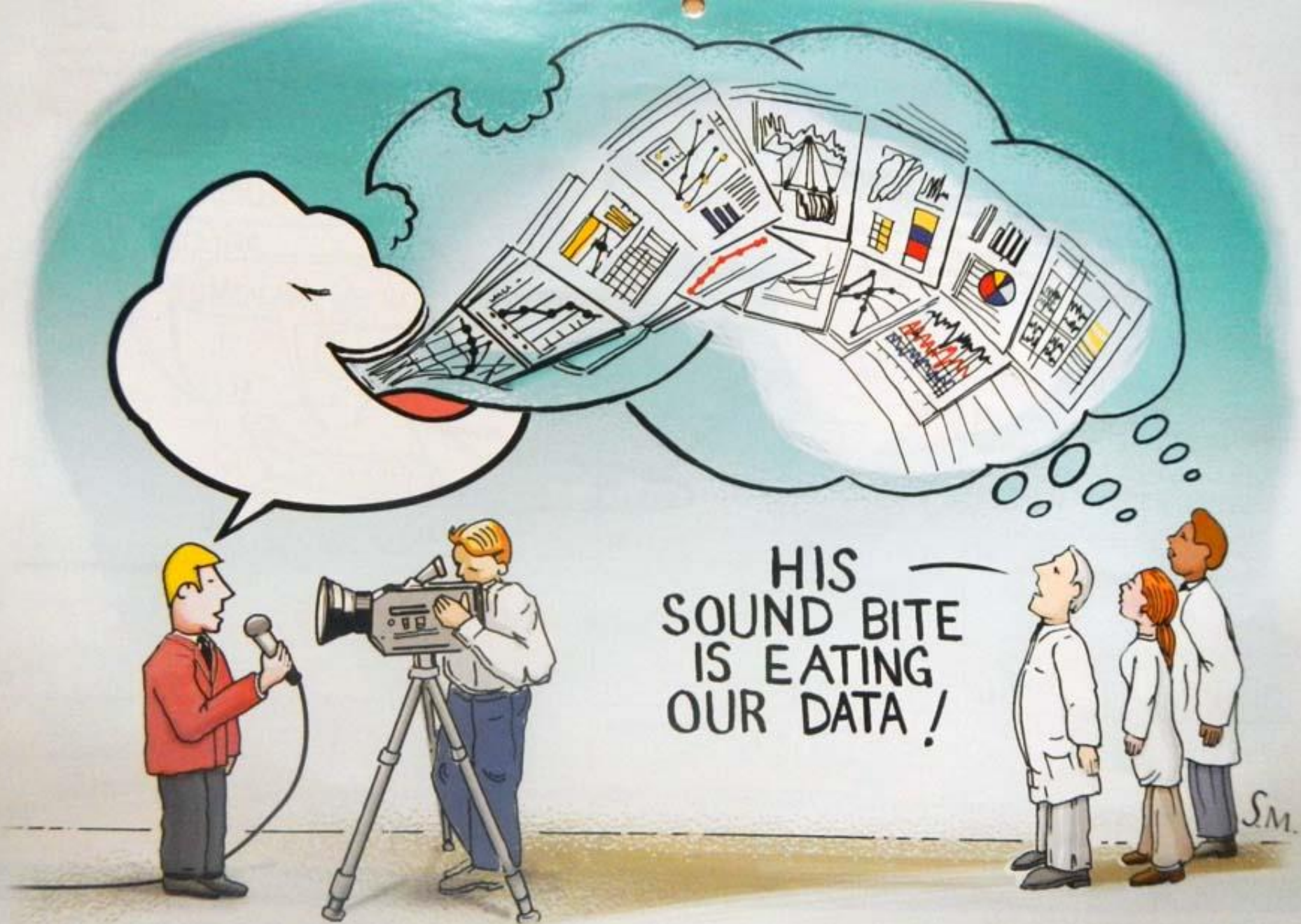
Play



00:57

02:05





Beijing

Pollution acknowledged: The smog suffocating Beijing has gotten so bad that Chinese media this week conceded that something must be done. Visibility in the city is so poor that flights have been canceled and some highways closed, and the level of particulates in the air soared to 35 times the World Health Organization's safety limit. In a dramatic break with precedent, television news programs and state newspapers called for better environmental protection. China's new leaders "appear to be sending a signal that they want to allow more criticism on the environment," said Liu Jianqiang, editor of *China Dialogue*. "Leaders are aware that the people can wait 20 years or more for democracy, but they can't wait that long for clean air."



Haze cloaks the Forbidden City.

Tehran

The other side of the story: Offended by the accolades for Ben Ali, Iran is making its own movie about the

Pitfall 2: Distraction from real solutions

MONDAY, NOVEMBER 10, 2014

ITHACAJOURNAL.COM • 18



TECH
Things will not be perfect. We are aiming for a strong consumer experience, and it will be better.
 Health and Human Services Secretary Sylvia M. Burwell, on the Nov. 15 second round of the HealthCare.gov. Browsing started Sunday.

HEALTH
There will be weight loss, but weight regain will occur when the device is removed.
 Dr. Mitchell Rodin, chief of obesity surgery for Lenox Hill Hospital in New York City, on a new clinical trial of bariatric surgery for obese patients that can trigger weight loss without invasive surgery.

WEATHER
Once it gets its momentum going, it's going to keep going south.
 Steve Klemm of the National Weather Service's predictions center, on a high-pressure system that by Wednesday will bring 70-degree temperatures to Texas and Oklahoma.

Nation & World Watch

From Gannett and wire reports.

► Seattle: American freed by NKorea wanted pizza

Kenneth Bae's sister says the American freed from two years of captivity in North Korea had pizza with family and supporters for his first meal after returning to the United States.

Terri Chung spoke to the media Sunday outside her Seattle church. Bae and Matthew Miller landed Saturday night at a Washington state military base after a top U.S. intelligence official secured their release.

Chung says Bae, who has had health issues, was in "better shape" than his family expected. She says Bae had been in the hospital in North Korea for about six weeks before his return.

► Washington: Higher bar set for HealthCare.gov

Computer woes are possible as HealthCare.gov's second open enrollment season begins Saturday.

There's a bright jolt to the rebuilt website, so version 2.0 of President Barack Obama's health insurance overhaul represents another chance to win over a skeptical public.

But the risks include an unproven system for those renewing coverage and a tax hit that could sting millions of people.

The Obama administration cannot afford a repeat of last year's online meltdown. Congress will be entirely in Republican hands, and GOP lawmakers will be itching to build the case for repeal.

► Germany: Nation marks 25 years since wall fell



A fruit vendor waits for customers Sunday in Huiyuan district, where the venue for the upcoming Asia-Pacific Economic Cooperation summit is located in Beijing. For a 10-day period, only half the city's cars can hit the roads each day in order to reduce smog for world leaders visiting on Monday and Tuesday.

Ahead of summit, Beijing shuts down to reduce smog

whose son's kindergarten shut and China, whose economic CHINA, JAPAN

Sources of Air Pollution


Long distance transport: Continental + Regional



City scale sources

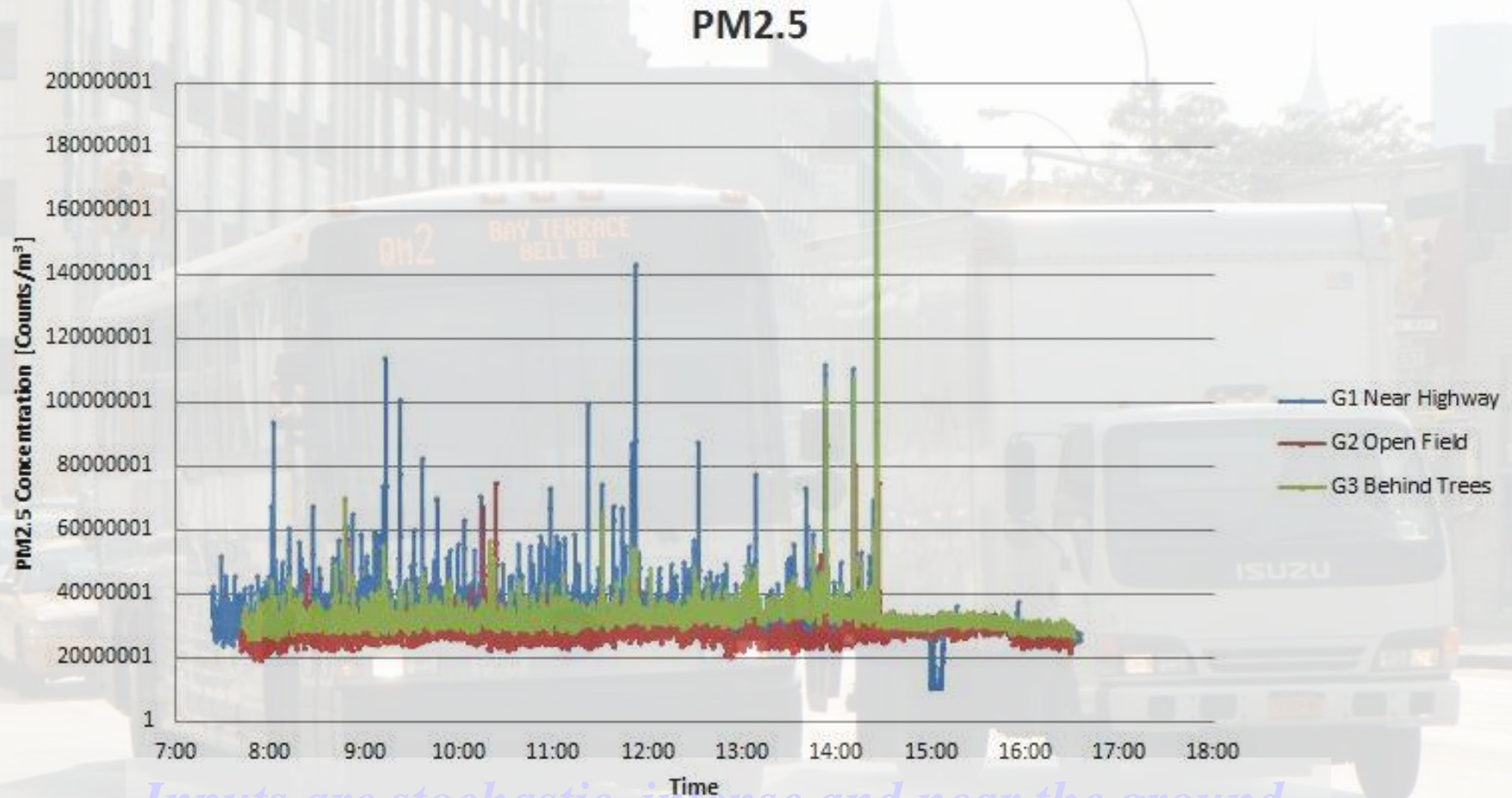


Local, mobile



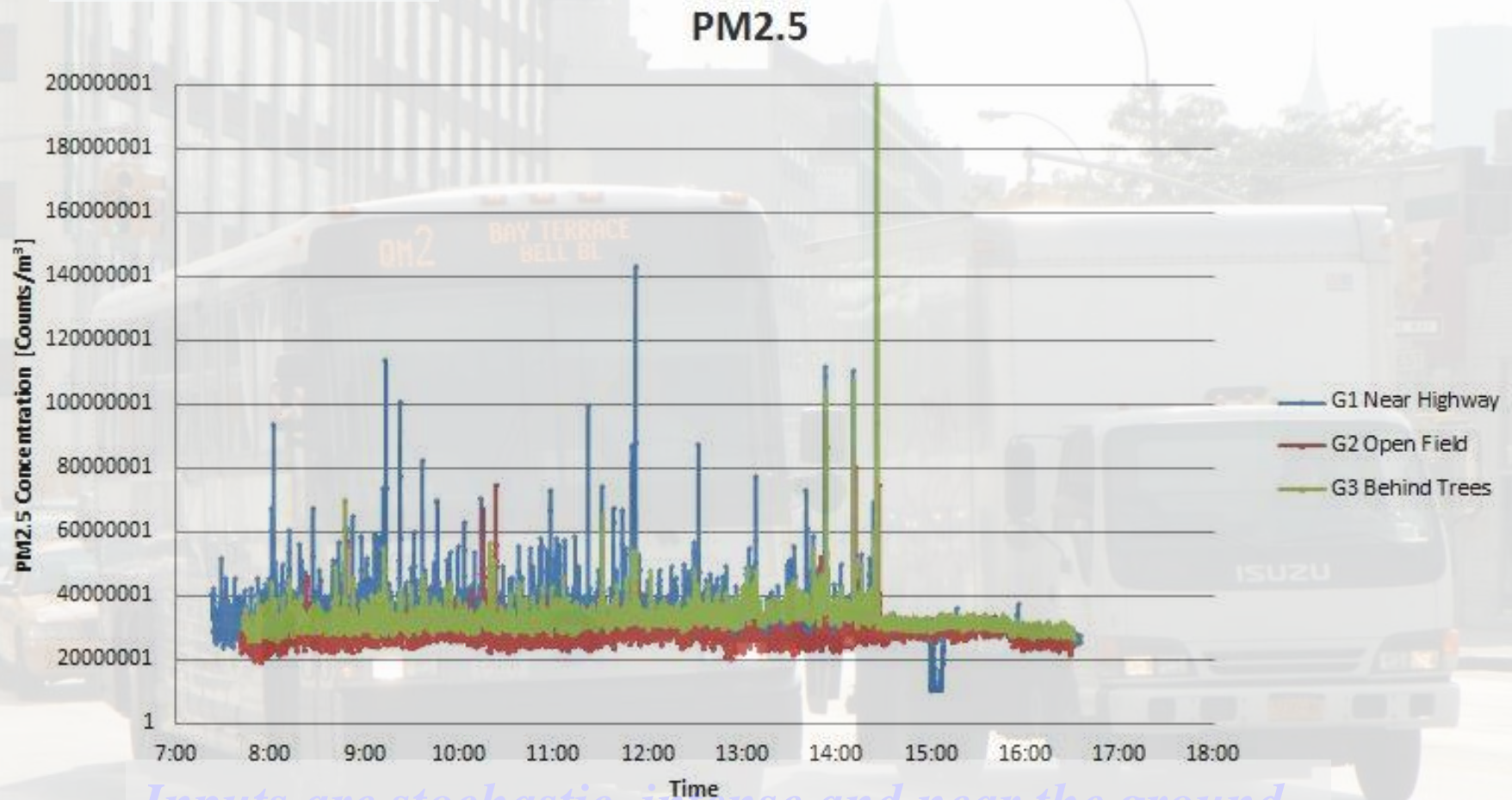
Inputs are stochastic, intense and near the ground
Disproportionate impact on local conditions
Small scale is where exposure occurs!
It is easy to miss this key point.

Local, mobile

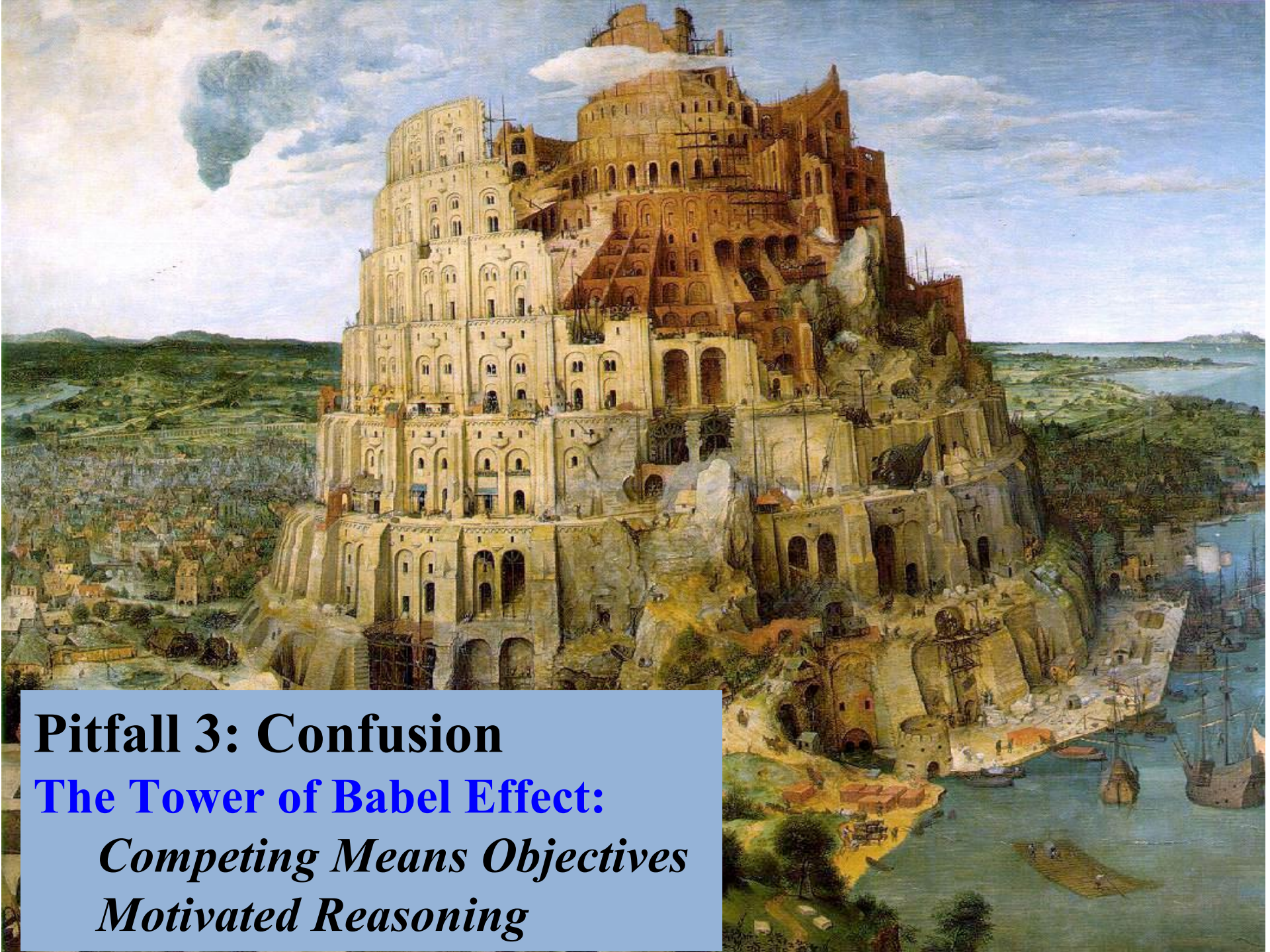


Inputs are stochastic, intense and near the ground
Disproportionate impact on local conditions
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It is easy to miss this key point.

Local, mobile



Inputs are stochastic, intense and near the ground
Disproportionate impact on local conditions
Small scale is where exposure occurs!
Models miss this key point.



Pitfall 3: Confusion

The Tower of Babel Effect:

*Competing Means Objectives
Motivated Reasoning*

...poring over evidence in minute detail and holding


"Not by a long shot."

THE WEEK

Did President Obama commit an act of imperial hubris on immigration, or was he simply following the humane lead of Presidents Reagan and George H.W. Bush? Did police officer Darren Wilson get away with murder, or did Michael Brown force the cop's hand by attacking him? How lovely it would be if we all could judge such questions coolly and rationally, on the basis of evidence. Alas, virtually all of us respond to emotionally loaded issues in a visceral way, and then reason backward to the conclusion that *feels* right because it buttresses what we already believe. The stronger people's political and moral values, social scientists have found, the more reflexively they react to any hot-button debate. "Morality binds and blinds," says social psychologist Jonathan Haidt in his superb book, *The Righteous Mind*. "It binds us into ideological teams that fight each other as though the fate of the world depended on our side winning each battle."

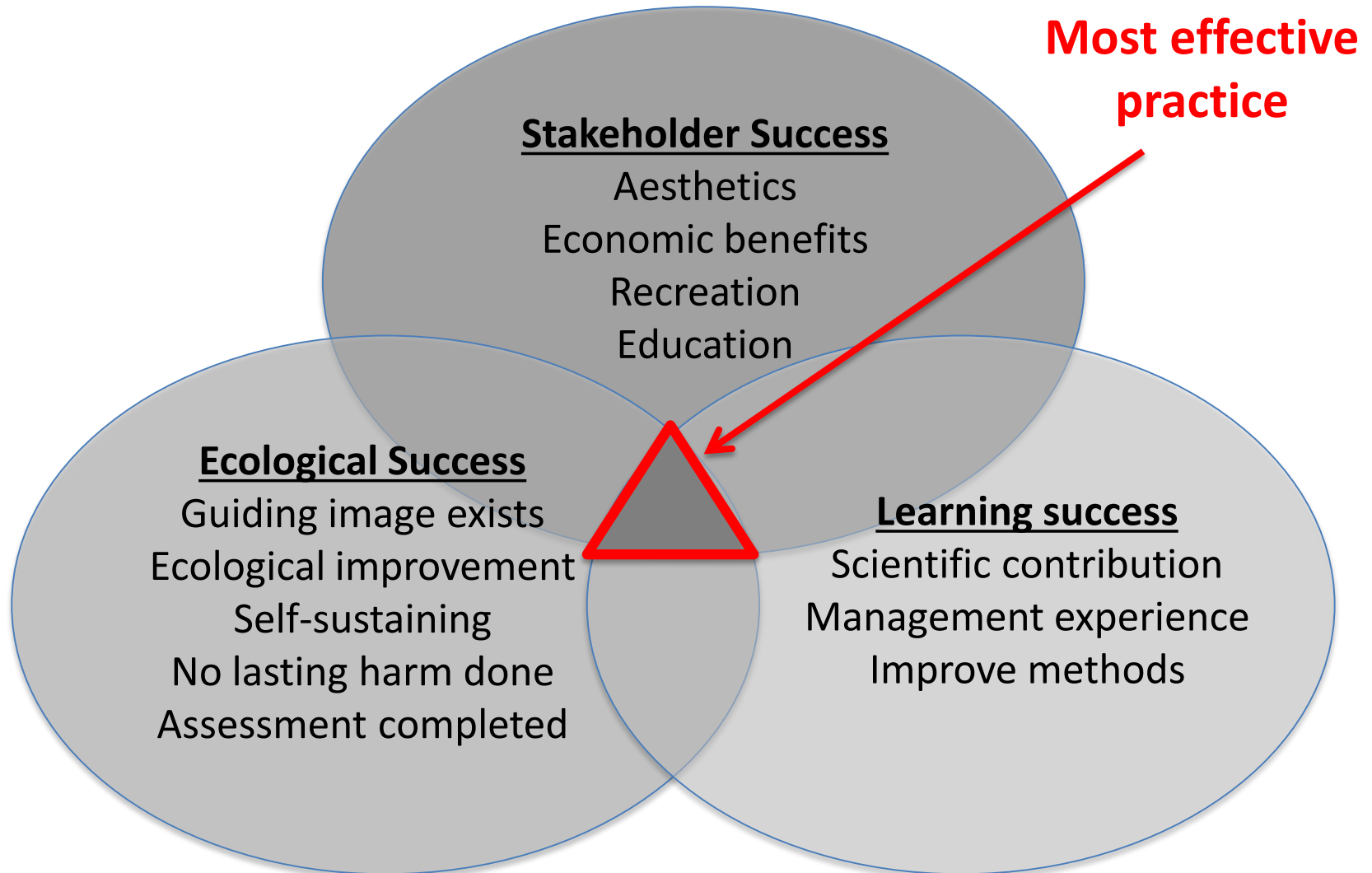
That much, at least, is inarguable. Duke University researchers recently presented self-identified liberals and conservatives with evidence contradicting their views on gun ownership and climate change, respectively. (See Health & Science.) Since neither group liked the policy implications of the evidence, each simply dismissed it as lies. Motivated reasoning, as social psychologists call this phenomenon, is highly rewarding: It wards off the discomfort we feel when our preconceptions are challenged. It binds us further to our "tribe," filling us with the warm glow of impregnable certainty. But as Haidt points out, self-righteous partisanship has a steep cost: "It blinds us to the fact that each team is composed of good people who have something important to say." **William Falk**

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**What is the question?
What is the real goal?**

**Save lives?
Plant more trees?
Increase your budget allocation?**



Intersection is a small target and often missed

Palmer, M. A., E. S. Bernhardt et al, 2005. Standards for ecologically successful river restoration. *Journal of Applied Ecology* 42:208-217.

Pitfall 4: Impeded progress



OUTCOME

Right

Wrong

Right

1
RR

Desired state

2

RW

Incomplete understanding?

Mis-application?

*But can lead to adaptation:
learn from mistakes*

Wrong

3
WR

Dumb luck!

Impedes progress

4

WW

Why do the wrong thing?!

Perversity in system?

Impedes progress

INFORMED
APPROACH

INFORMED
APPROACH

Right

Wrong



Truth emerges more
readily from error
than from confusion.

2

RANDOM ERROR!

Incomplete understanding?

Mis-application?

*But can lead to adaptation:
learn from mistakes*

3

CONFUSION!

Dumb luck!

Impedes progress

4

CONFUSION!

Why do the wrong thing?

Perversity in system?

Impedes progress

Distortion

+

Distraction

+

Confusion

= Impeded progress

How can we do better?

*Design based on solid understanding,
not slogans and self-justifying models
that cannot yield negative results*

TREES ARE THE ANSWER



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SCHMIDT
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containing

Helfa

*First, ask a question.
What do you want to do?*

TREES ARE THE ANSWER



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company

Helix

Ask the right question.

Accurate perception of cause and effect is crucial.

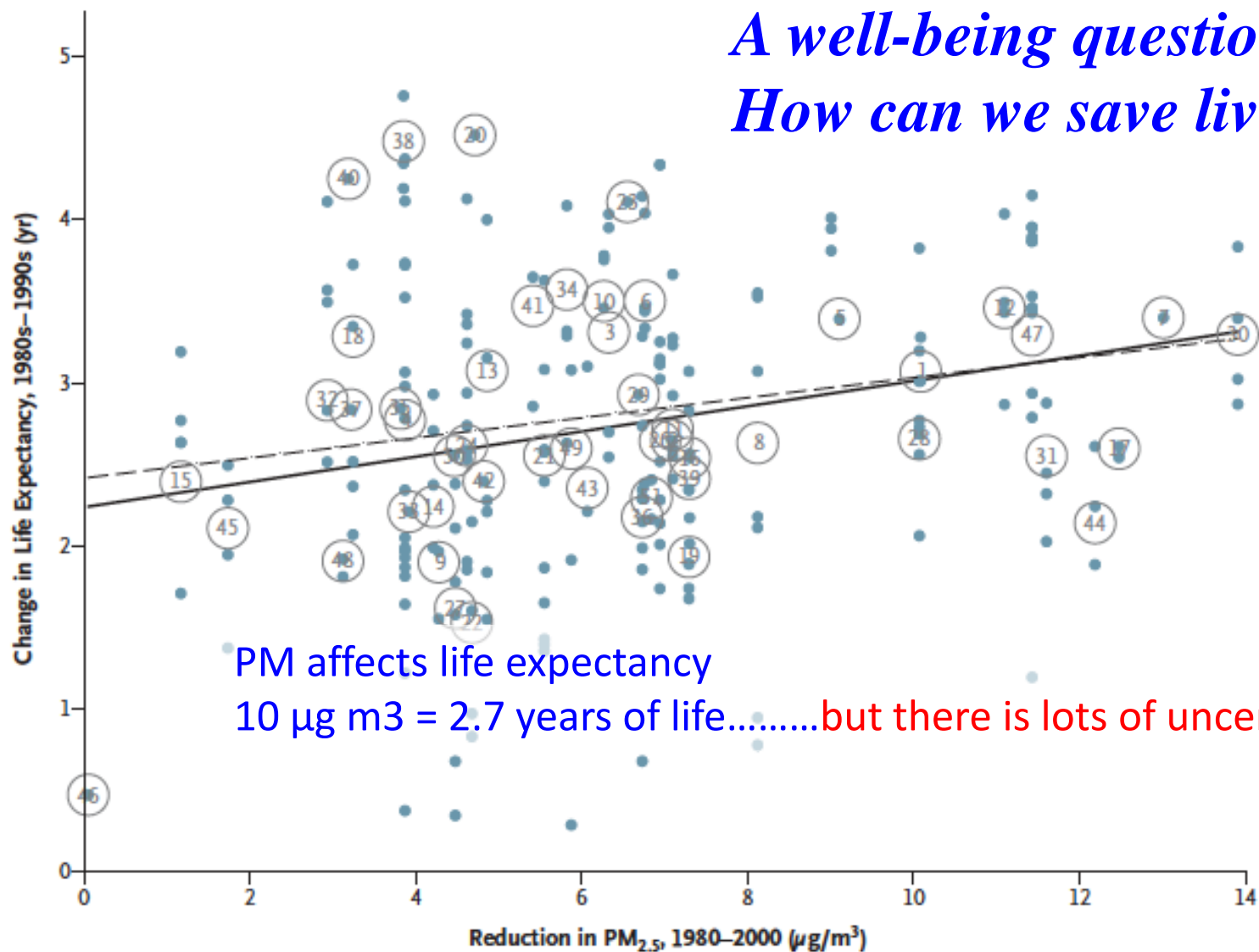
TREES ARE THE ANSWER



J. FRANK
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*A well-being question:
How can we save lives?*



PM affects life expectancy

10 μg m³ = 2.7 years of life.....but there is lots of uncertainty

Figure 4. Changes in Life Expectancy for the 1980s–1990s, Plotted against Reductions in PM_{2.5} Concentrations for 1980–2000.

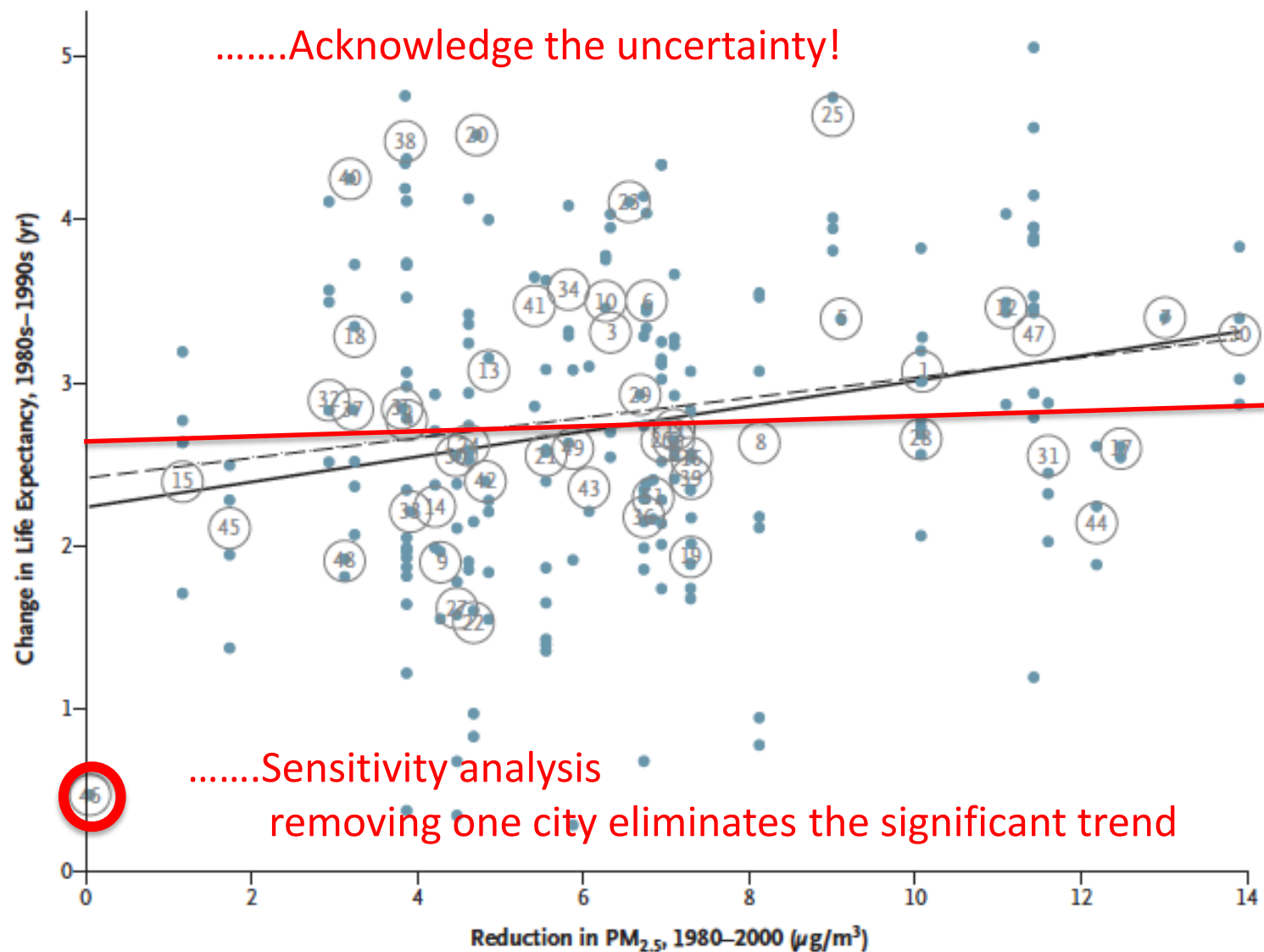


Figure 4. Changes in Life Expectancy for the 1980s–1990s, Plotted against Reductions in $PM_{2.5}$ Concentrations for 1980–2000.

Pope, C. A. III et al, 2009. Fine particulate air pollution and life expectancy in the United States. *New England Jour Med.* 360: 376-386.



A design question:

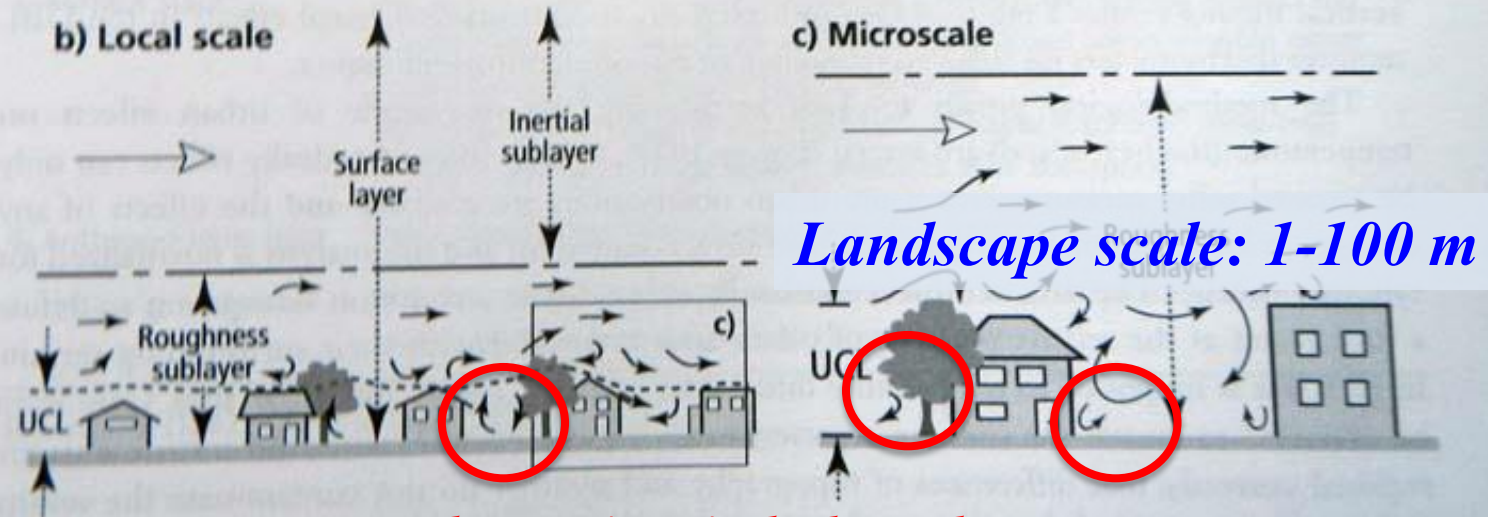
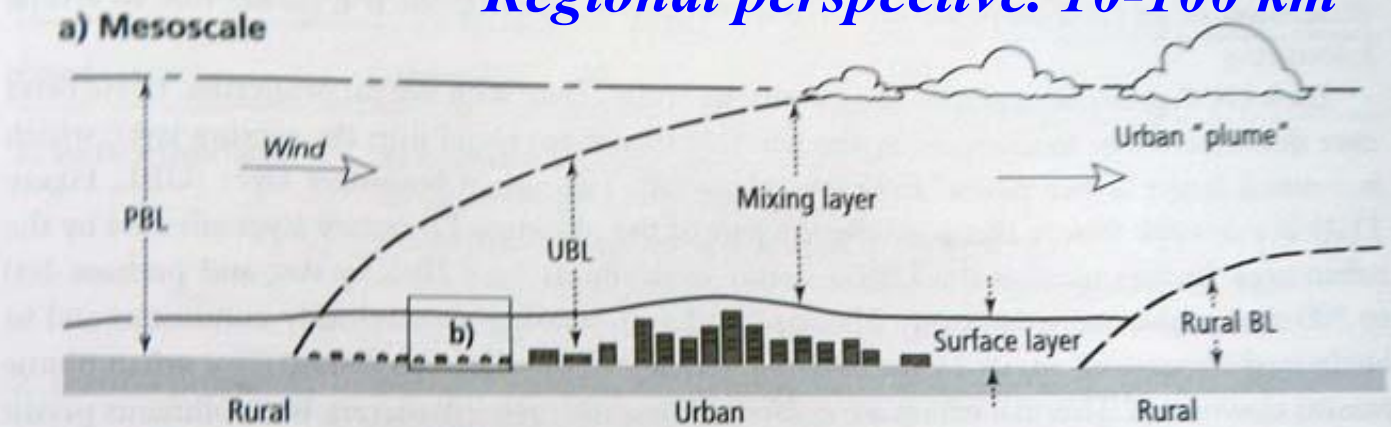


*Where should we locate
trees in relation to a sandbox or nursing home?*

Local inputs may swamp regional inputs

Urban heat islands

Regional perspective. 10-100 km



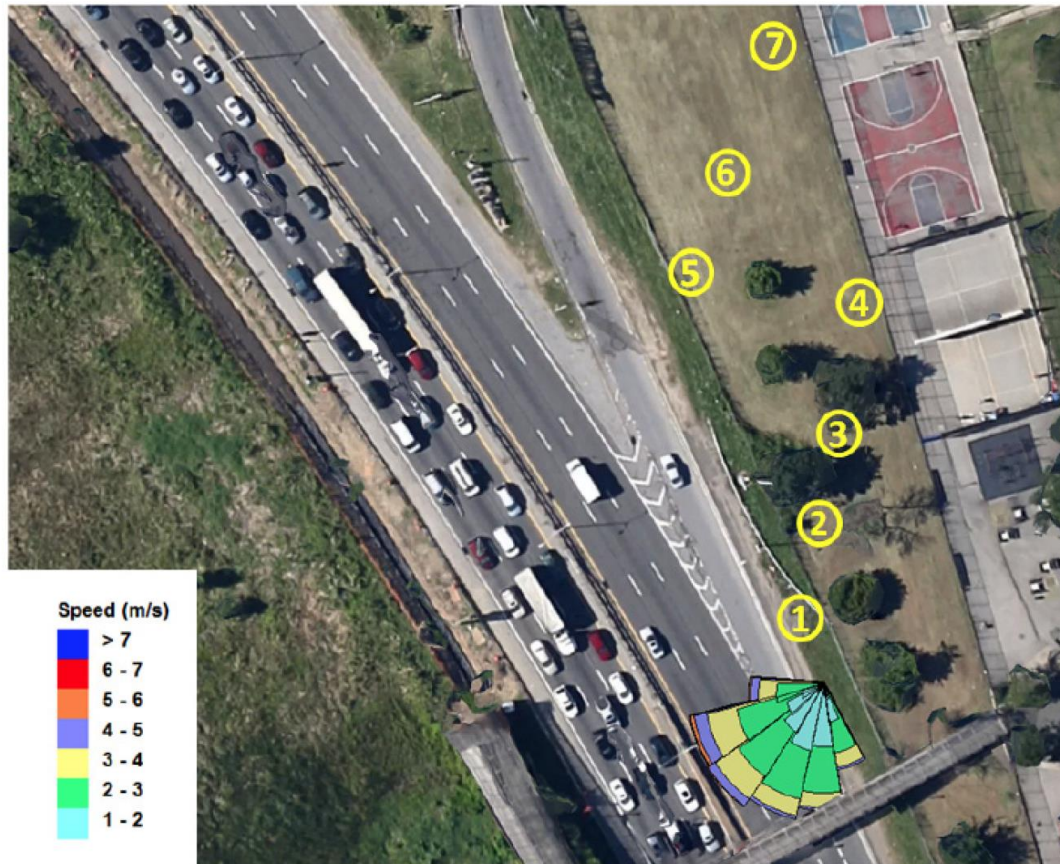
The action is below the canopy

Figure 11.1 A classification of the main scales found in urban climates (source: modified after Oke 1997).

Informative Examples

Van Wyck East

A



Natural Experiments

Downwind transect
Flushing Meadows, Queens

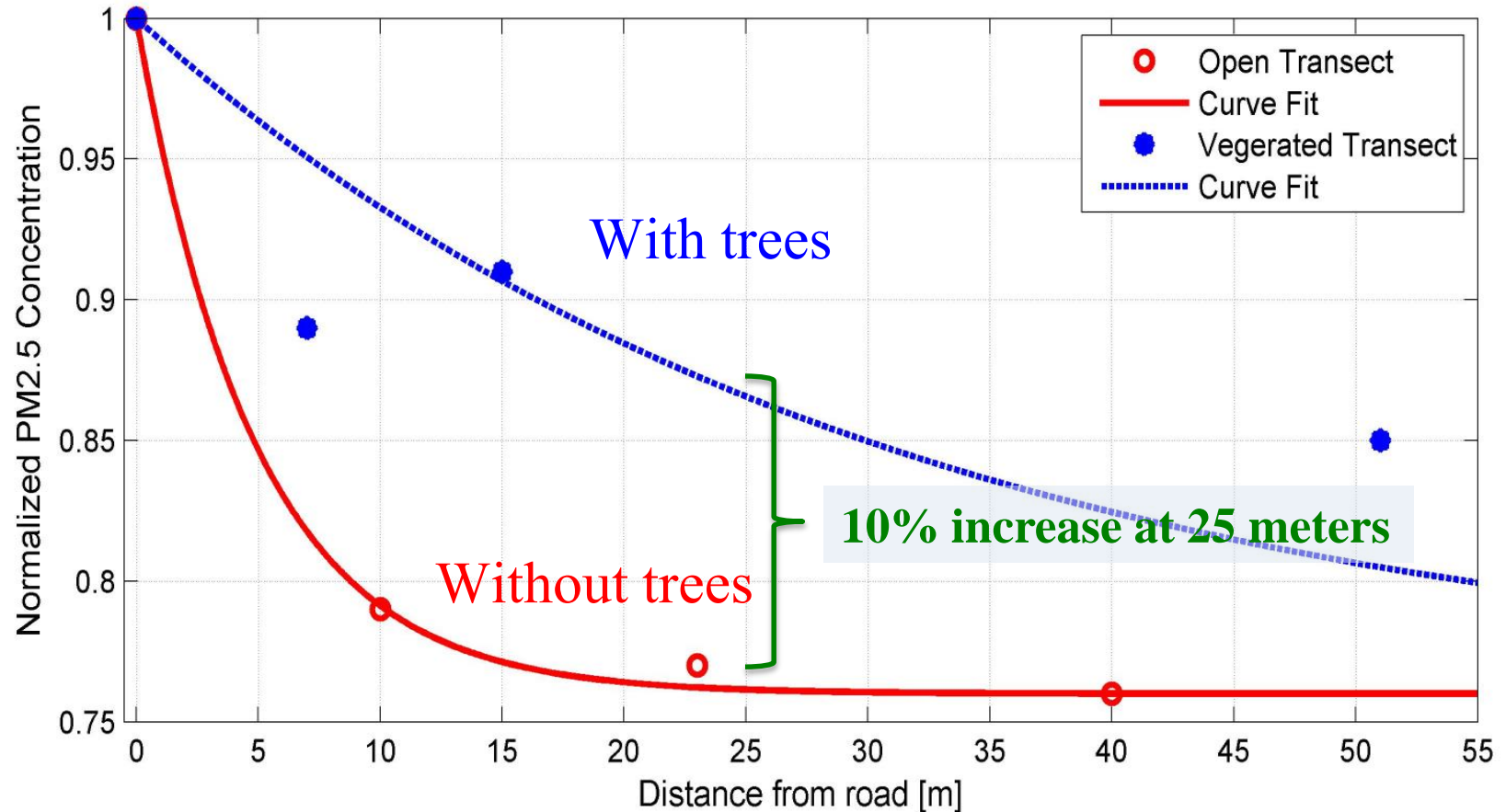
*Do trees make concentration
decline faster or slower?*



???

???

Landscape configuration matters.....



Dispersion overrides deposition effect

10% increase vs. 1% decrease



Which is more useful in landscape design?



Unintended consequences of well-intended, uninformed design



Try this!

lots of PM on filter
or 2 days just filter
rest of C 4622
down alternately
C 1:00
evening
morning
roof
16
hand

PM spikes every time a subway passes



PM spikes every time a subway passes



*An ecological trap!
Implications for Complete Streets?*

Computer Simulations

Road-barrier-canopy Configurations

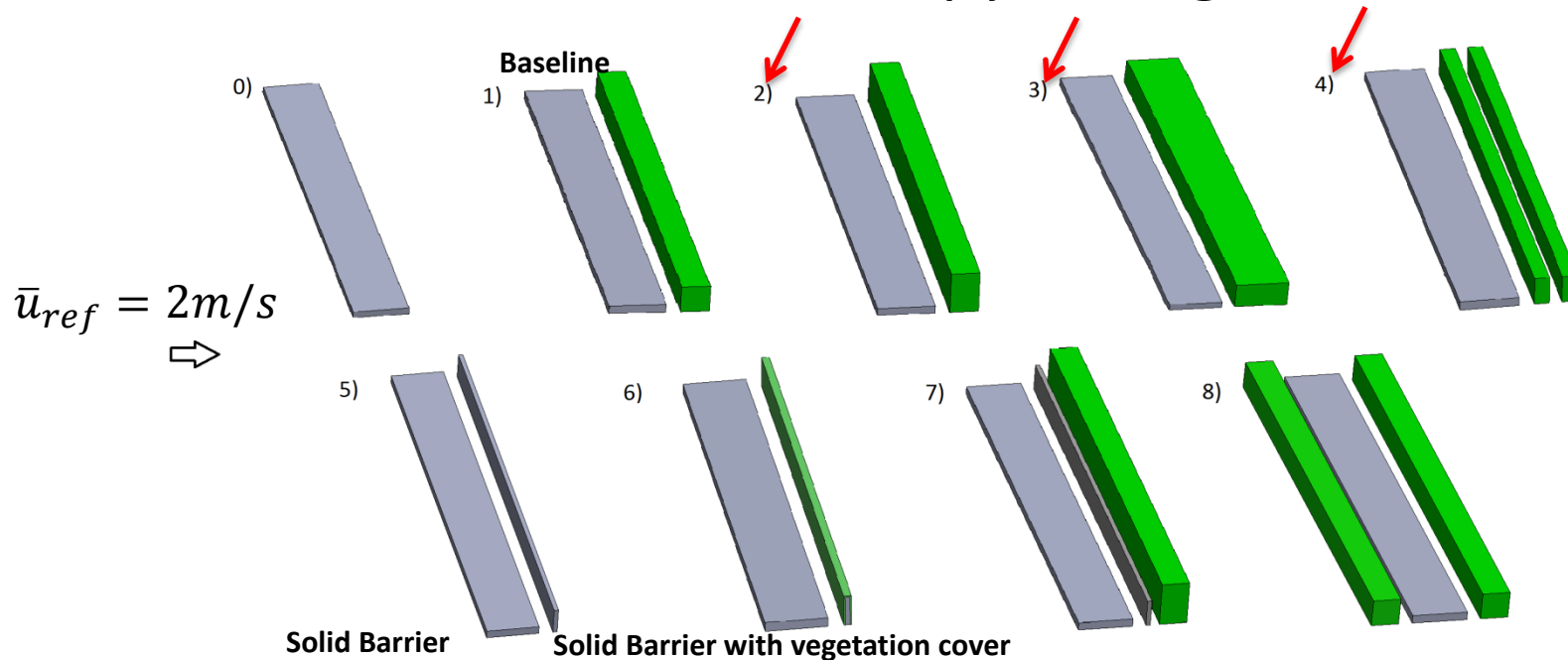
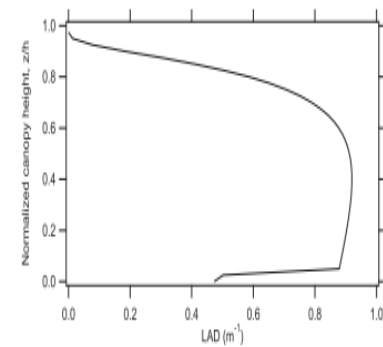


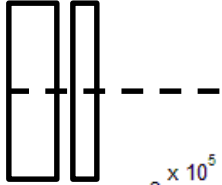
Table 1: Description of tree geometry for all configurations tested; a) case 6 represents a solid barrier with vegetated cover. The thickness of the cover is 25 cm; c) both upwind and downwind vegetation barrier have the same dimensions; e) LAD in the unit of m^2m^{-3} . 1 stands for the baseline LAD profile of conifer trees, and 0.5 is 50% less of the baseline LAD, and 1.5 is 50% more than the baseline LAD. f) $\text{LAD}=0.33 \text{ m}^2\text{m}^{-3}$ is used for the vegetation cover assuming constant cover thickness.

Case #	0	1	2	3	4	5	6 ^a	7 ^b		8 ^c
								Solid	Vegetation	
Height	N/A	6 m	10 m	10 m	6 m	6 m	6 m	6 m	10 m	6 m
Width	N/A	6 m	6 m	12 m	3+3 m	1 m	1 m	1 m	6 m	6 m
LAD ^e	1	0.5, 1, 1.5	1	1	1	1	0.33 ^f	N/A	1, 0.25	1
U	2 m/s	1, 2, 4 m/s	2 m/s	2 m/s	2 m/s	2 m/s	2 m/s	2 m/s	2 m/s	2 m/s
Stability	Unstable	Stable, Unstable, Neutral	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable

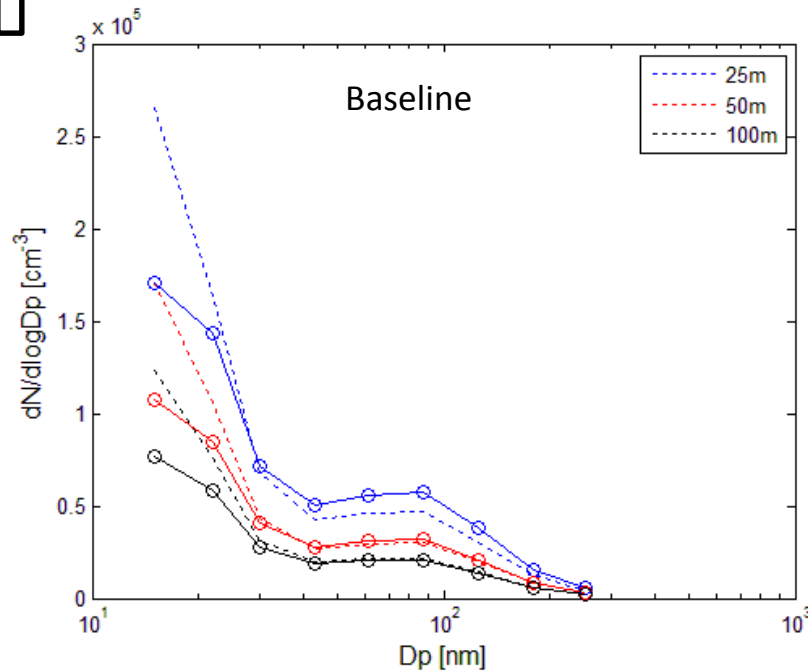
LAD profile of conifer stand



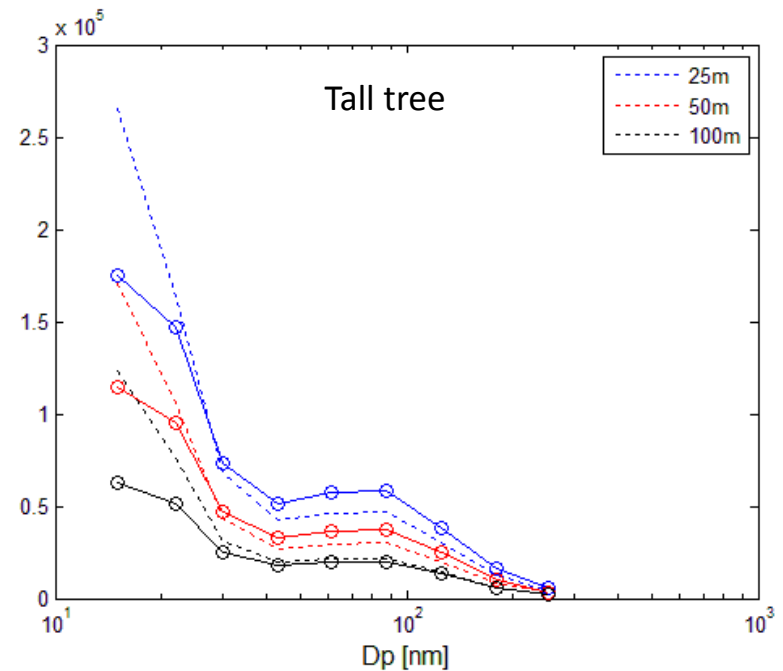
Case 2: 1 Row Tall trees 10 m



Centerline PSD at 3 distances downwind at $z=1.8\text{m}$, dash lines are PSDs from the treeless case as comparison



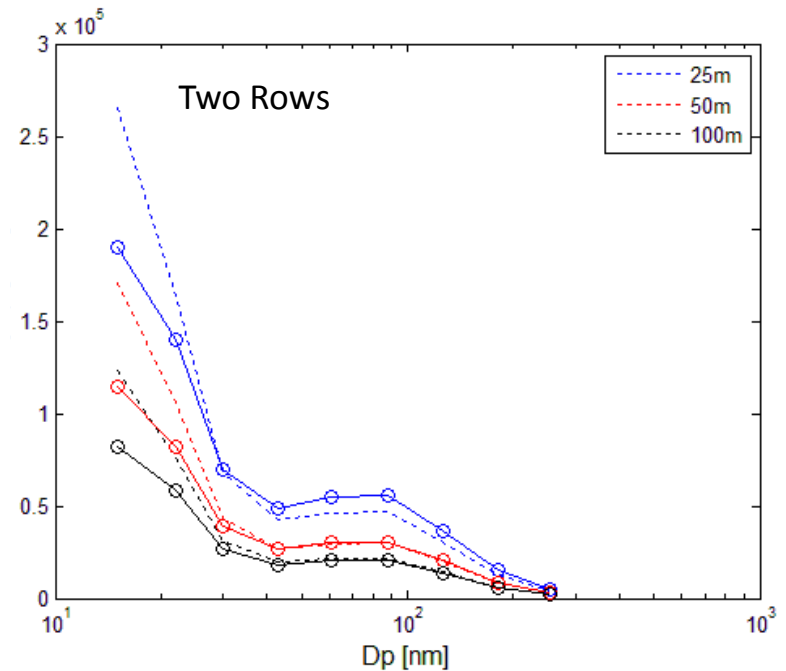
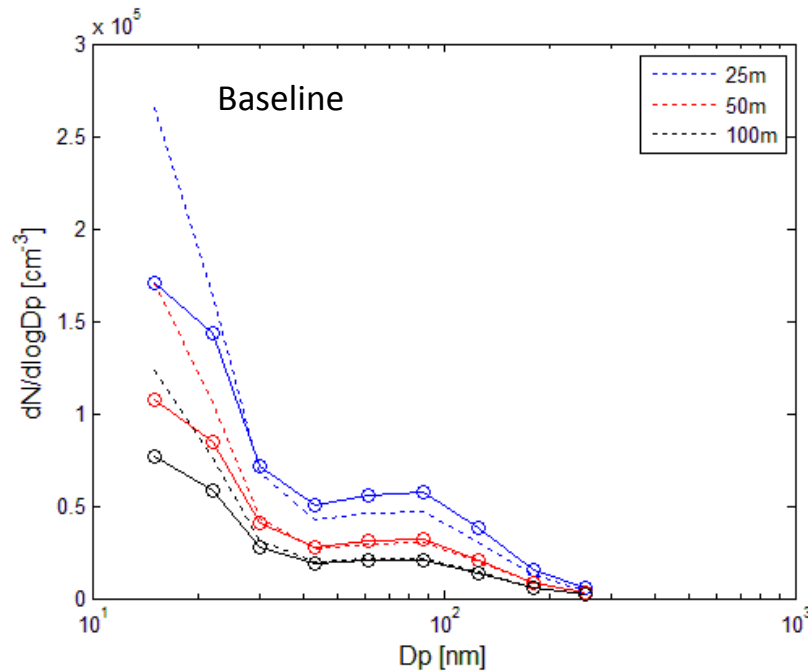
Left=Baseline (case1)



No significant reduction at pedestrian level.

Case 4 PSD: Two Rows of Trees

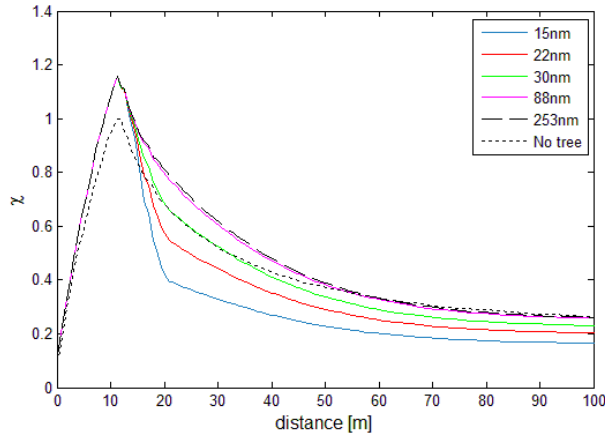
Centerline PSD at 3 distances downwind at $z=1.8\text{m}$



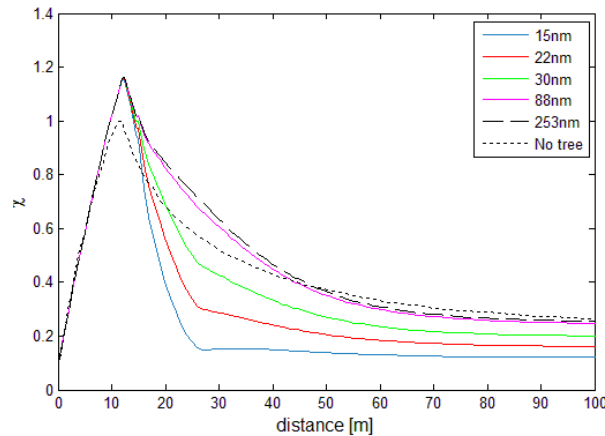
No significant reduction at pedestrian level.

Case 3 PSD: Wide and Dense Stand

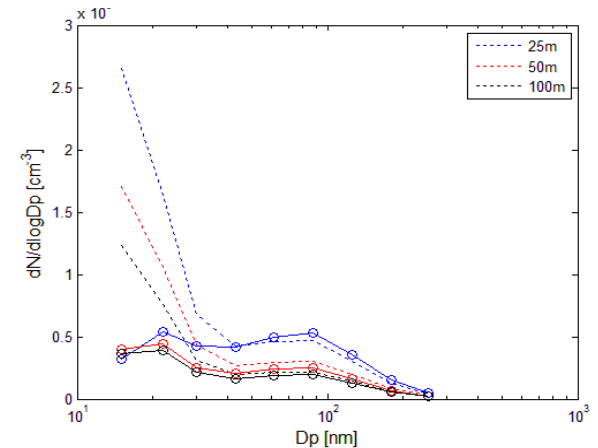
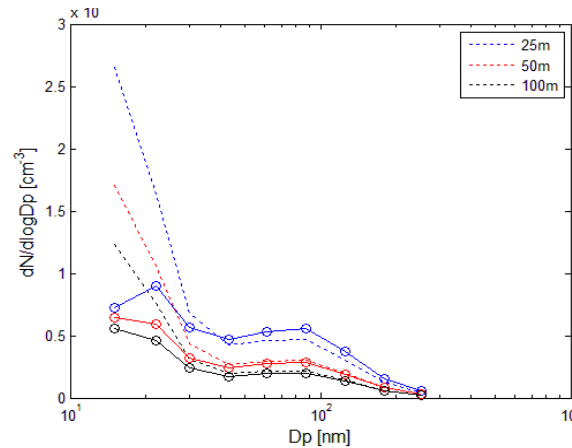
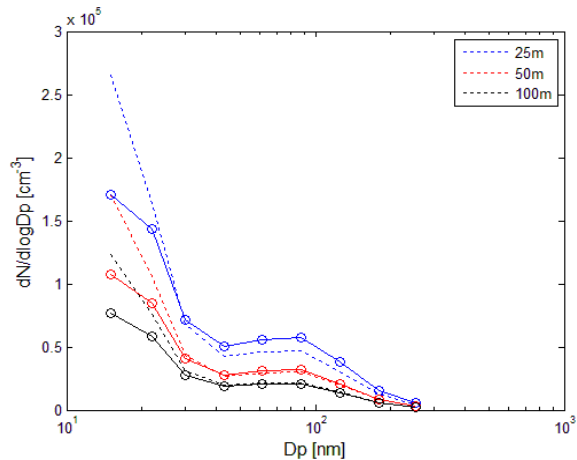
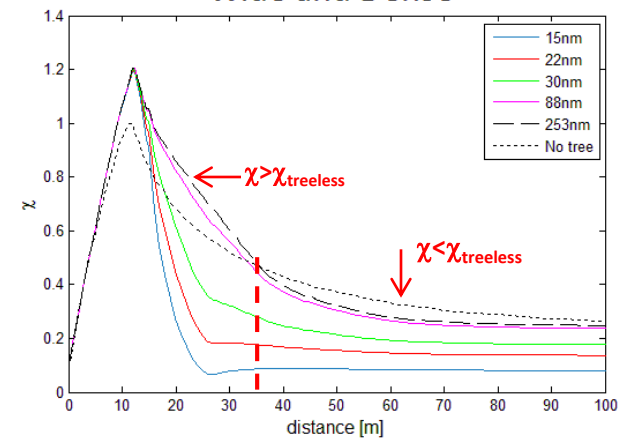
Baseline



Wide



Wide and Dense +50% LAD



Centerline PSD at 3 distances downwind at $z=1.8m$, dash lines are PSDs from the treeless case as comparison

Tree buffer must be 35 m (114') wide before the concentration drops below the no tree baseline

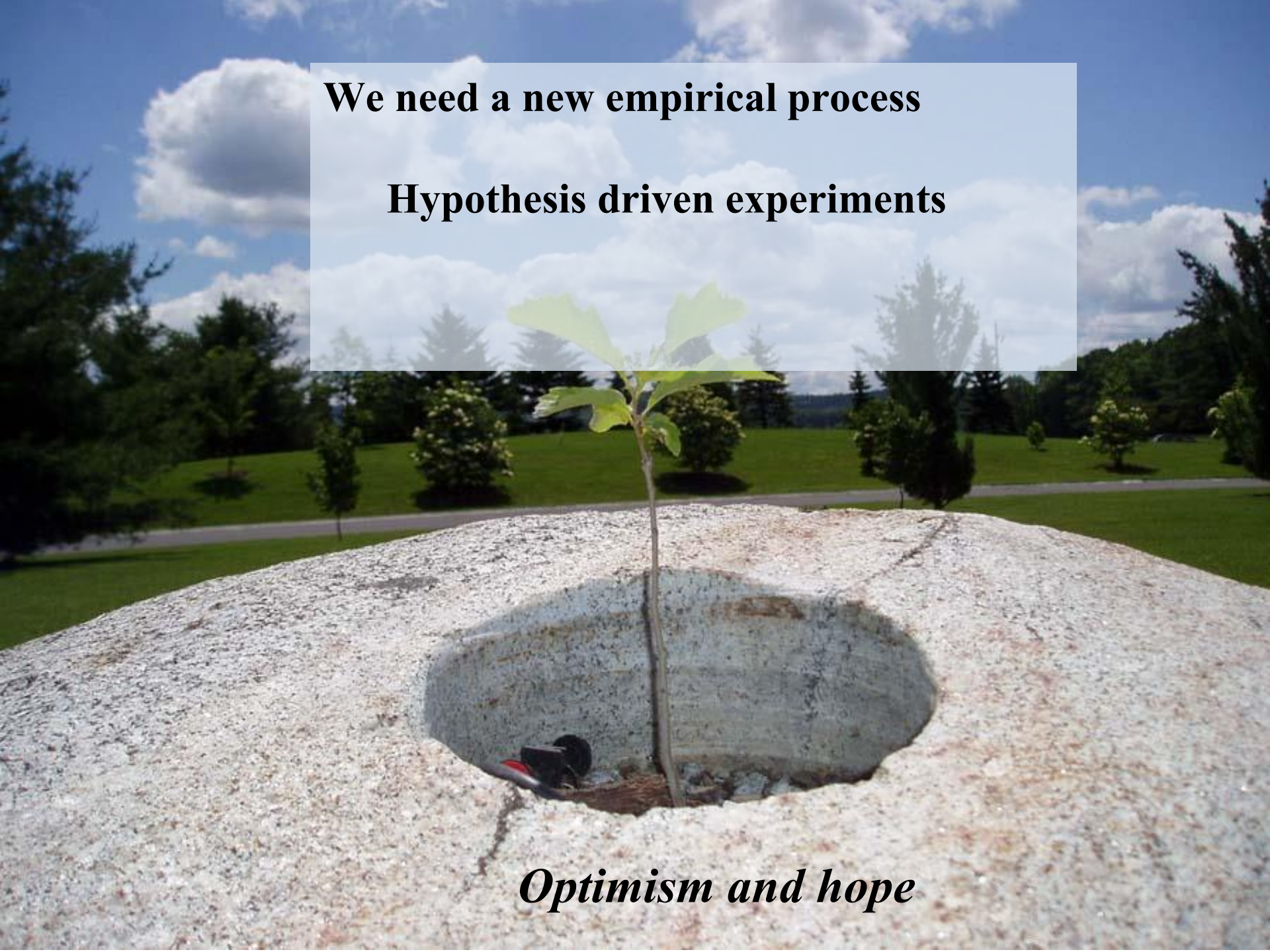


We need a new empirical process



We need a new empirical process

Hypothesis driven experiments



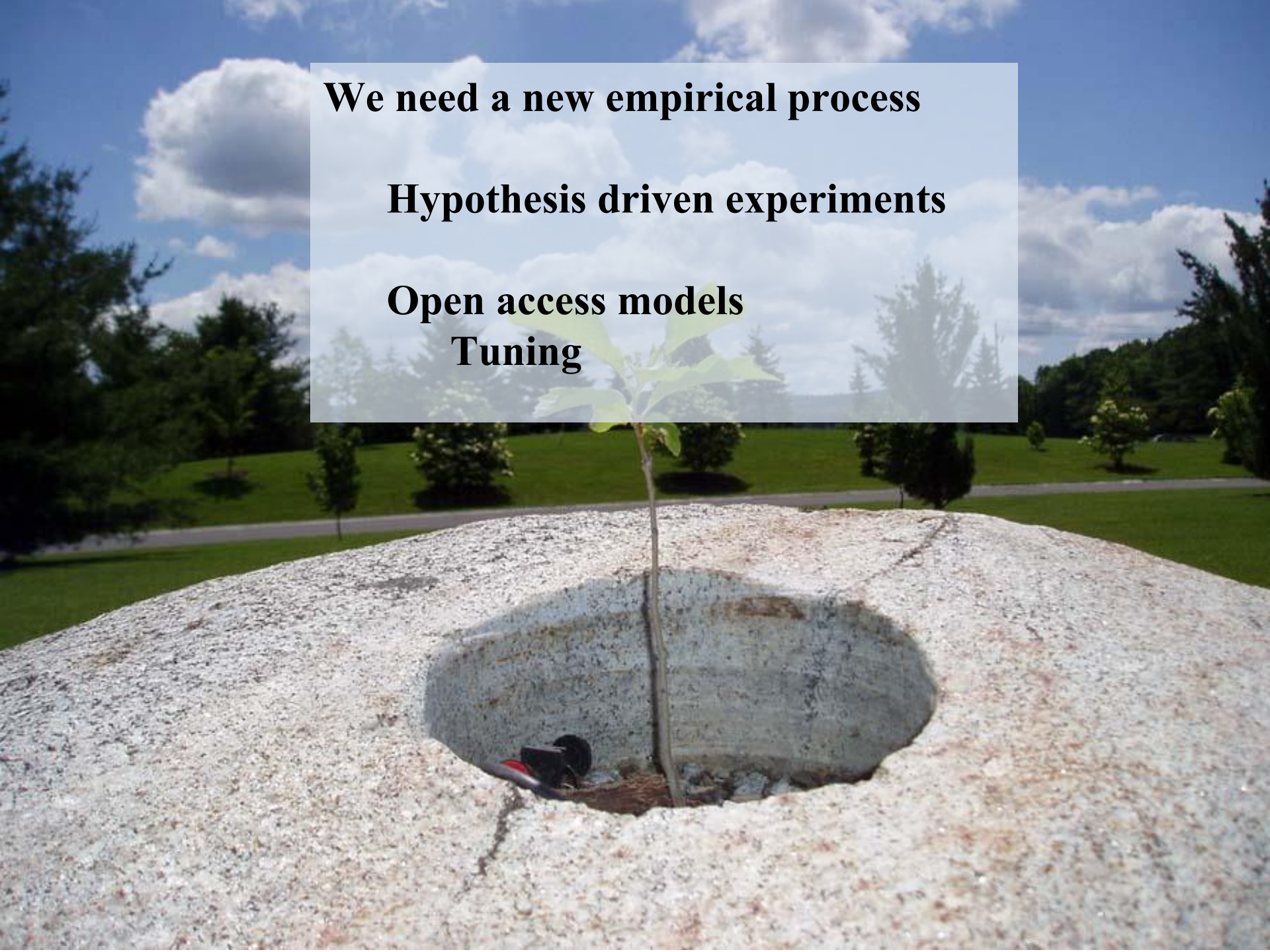
Optimism and hope

We need a new empirical process

Hypothesis driven experiments

Open access models

Tuning





We need a new empirical process

Hypothesis driven experiments

Open access models

Tuning

Ground truthing

Optimism and hope

We need a new empirical process

Hypothesis driven experiments

Open access models

Tuning

Ground truthing

Comparative studies



A young tree with green leaves is growing out of a hole in a concrete surface. The background shows a grassy area with trees and a blue sky with clouds.

We need a new empirical process

Hypothesis driven experiments

Open access models

Tuning

Ground truthing

Comparative studies

In order to achieve

Optimism and hope



We need a new empirical process

Hypothesis driven experiments

Open access models

Tuning

Ground truthing

Comparative studies

In order to achieve

Better understanding

A photograph of a golf course with a large, light-colored rock in the foreground. A small hole has been drilled into the rock, and a young plant with green leaves is growing out of it. The background shows a green lawn, trees, and a blue sky with white clouds.

We need a new empirical process

Hypothesis driven experiments

Open access models

Tuning

Ground truthing

Comparative studies

In order to achieve

Better understanding

Meaningful policies

A photograph of a young plant with green leaves growing out of a hole in a mound of light-colored gravel. In the background, there is a green lawn, several trees, and a blue sky with white clouds.

We need a new empirical process

Hypothesis driven experiments

Open access models

Tuning

Ground truthing

Comparative studies

In order to achieve

Better understanding

Meaningful policies

Effective practices

Do no harm!



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Innovation

URBAN ISSUES

Green Walls Could Cut Street-Canyon Air Pollution

Rows of tall buildings can create a unique urban habitat known as a street canyon. These canyons trap traffic pollutants, limiting their dispersal into the atmospheric boundary layer that extends as high as 2,000 meters above the ground. A new study suggests that vegetation in street canyons may reduce air-pollutant concentrations much more than previously reported and suggests innovative planting configurations to improve city pollution hot spots.¹

Outdoor air pollution is believed to cause an estimated 1.3 million annual deaths worldwide,² as well as an increased risk of respiratory and cardiovascular diseases.³ Plantings are often promoted as a partial solution, because leaves absorb gaseous pollutants through their pores and capture particulate matter on their surfaces.^{4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100} Yet modeling studies of the vegetation across entire cities have estimated that existing green cover reduces air pollution concentrations by less than 1.5%.⁴⁴

For the current study, researchers developed a computer model to calculate how much pollution is captured by vegetation in the much smaller, somewhat isolated space of a street canyon. "We argue that for urban air quality these effects will be much more important because people aren't found five hundred meters up in the atmosphere; they're found down at street level," says lead author Thomas Pugh, a postdoctoral researcher in atmospheric chemistry now at the Karlsruhe Institute of Technology.⁹

The team estimated that street-canyon vegetation may reduce concentrations of two of the most harmful urban air pollutants, nitrogen dioxide (NO₂) and coarse particulate matter (PM₁₀), by as much as 40% and 60% respectively, although average reductions over a year were in the range of 7–30%. Because air lingers in street canyons, it stays in contact with pollutant-scavenging vegetation, Pugh says.

David Nowak, who studies how urban forests affect environmental quality for the U.S. Forest Service, likens the effect to that of an air purifier running in a small, enclosed room as opposed to a large, open space. He points out that the new results are not entirely unexpected—at least one other study showed similar reductions in the air pollutant ozone, although those measurements were made in an urban forest, not a city.⁴⁴

The study is limited by the model's reliance on data with only modest experimental support, including the rates at which plants capture pollutants and air flows in and out of

street canyons, says Pugh. Moreover, experimental research in vegetated street canyons is needed to verify the results. This lack of validation makes Max Zhang, an associate professor of engineering at Cornell University who studies traffic emissions, question the size of the pollutant reductions the paper reports. "I still believe the argument is very good," says Zhang. "I believe there are definitely reductions, but the problem is the magnitude."

Nevertheless, Pugh says city planners may be able to design plantings that significantly improve air quality in highly polluted street canyons. The model results suggest that plants growing vertically on building walls could remove nearly 10 times as much NO₂ and nearly 12 times as much PM₁₀ from street-canyon air as horizontally grown rooftop vegetation. The researchers even propose adding "green billboards" to rooftops to increase the time polluted air spends within a canyon, maximizing its exposure to vegetation.

Whether green billboards or green walls are practical on a large scale remains to be seen. Walter Warriner, community forester for the city of Santa Monica, California, and a board member of the National Urban and Community Forestry Institute, is unaware of any plantings specifically targeted at urban pollution hot spots in the United States. But he says they may soon be possible given advances in air-quality monitoring technology and a recent focus among urban foresters on quantifying environmental benefits.

Trees are a more familiar solution, but although Pugh and colleagues did not directly model how trees capture airborne pollutants,⁹ they predict that in highly polluted street canyons, trees may actually do more harm than good. That's because in those circumstances, trees' ability to capture pollutants may be outweighed by their tendency to trap vehicle emissions near street level, right where people can breathe them in.⁴⁴

"That's not to say you should go and chop down all the trees in busy street canyons," says Pugh, but planners contemplating planting new trees in these settings should proceed with caution to make sure they don't inadvertently increase ground-level pollution while trying to address some other issue, such as rainwater runoff or beautification. Where traffic is lighter, trees offer clear benefits, the researchers write.

Nowak notes that although plants can certainly help reduce urban air pollution, reducing emissions is a more effective, if not



Vertical plantings may be a better option than trees or green roofs for mitigating street-canyon pollution.

necessarily an easy first step. In the worst cases, he says, "We're not going to plant our way out of this problem."

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The last word.....

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