



Trees are Essential:

Growing Human Health and Equity



Return on Investment

Trees and Health Care Expenditures

Brought to you by

Investigators

- Co-PIs: M Kuo, M Browning, S van den Eeden
- D Becker, J Shan, SE Alexeeff, G Thomas Ray, CP Quesenberry

Funding and support

- USDA National Urban & Community Forestry Advisory Council
- University of Illinois at Urbana-Champaign, Kaiser Permanente Northern California, California Urban Forestry Council, and many more
- G Zhang, K O'Craven

Why study health care expenditures?

- A new way to test the greenness-health link
- Health care expenditures are a problem
 - US: astronomical and rising
 - Individuals: 40% of cancer patients deplete entire life savings within two years of diagnosis Gilligan et al, 2018
 - Trees v Health: David and Goliath-squared

Why is g-HCE plausible?

↑ Trees → ↑ Health → ↓ Health care expenditures

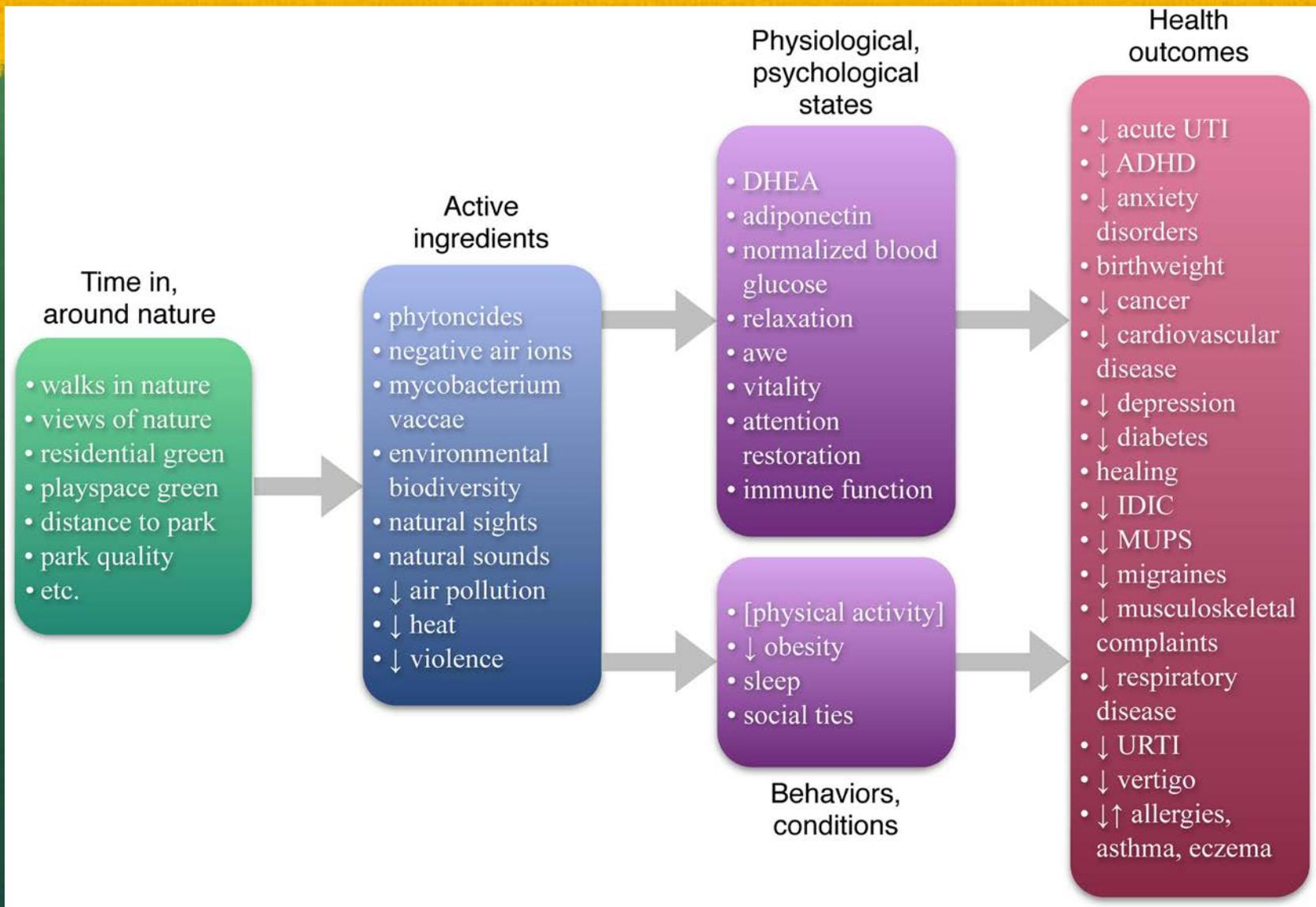
Why is g-HCE plausible?



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Greenness-Health pathways



Why is g-HCE plausible?



g-HCE in Northern California

↑ Trees



↓ Health care expenditures

Two measures:
NDVI, FRAP

Three buffers:
250m, 500m, 1k

g-HCE in Northern California

↑ Trees



↓ Health care expenditures

5.1M Kaiser Permanente members

Five years of records

g-HCE in Northern California

↑ Trees



↓ Health care expenditures

Kaiser Permanente Northern California

24 counties

SF, Oakland, SJ, Sacramento metropolitan areas

Northern Central Valley

Are health care costs lower in neighborhoods with more trees?

- Two greenness measures
- Three buffer sizes

	NDVI	%Tree canopy
250m		
500m		
1k		

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Are health care costs lower when we take other factors into account?

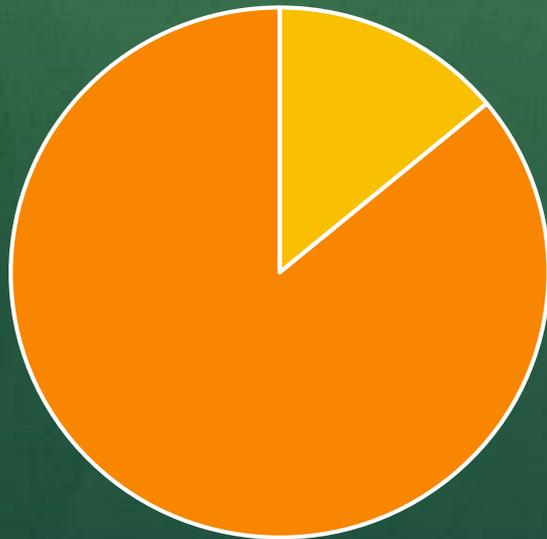
- age, sex, race/ethnicity
- Neighborhood Deprivation Index, education, household income, housing density, population density, and PM_{2.5}

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- age, sex, race/ethnicity
- Neighborhood Deprivation Index, education, household income, housing density, population density, and PM_{2.5}

YES

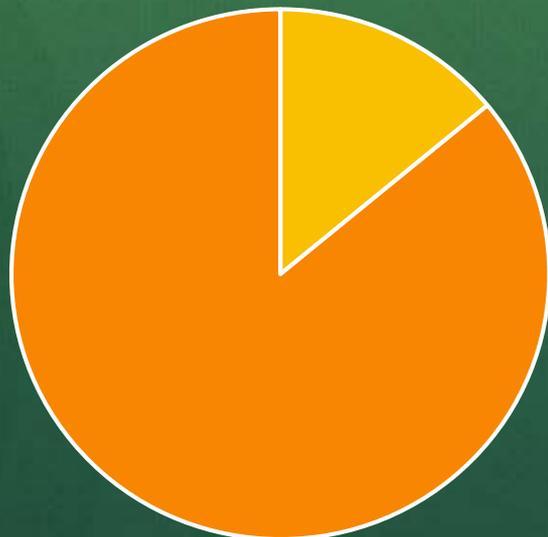
How much lower?
What are the % savings?



■ Savings ■ ■ ■

Greenness	Expenditures
highest	← Compare
9th	
8th	
7th	
6th	
5th	
4th	
3rd	
2nd	
lowest	← Compare

How much lower?
What are the % savings?

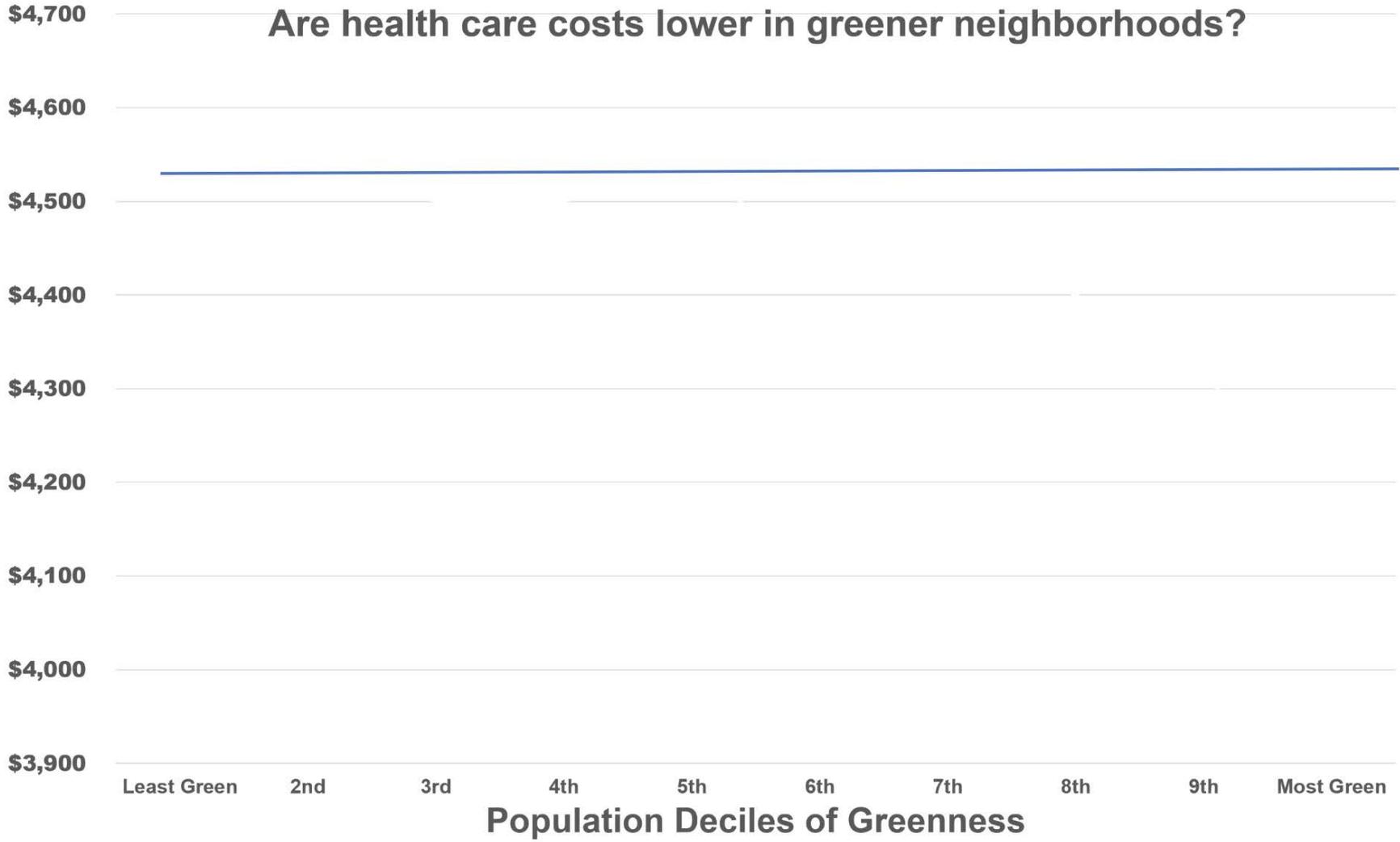


■ Savings ■ ■ ■

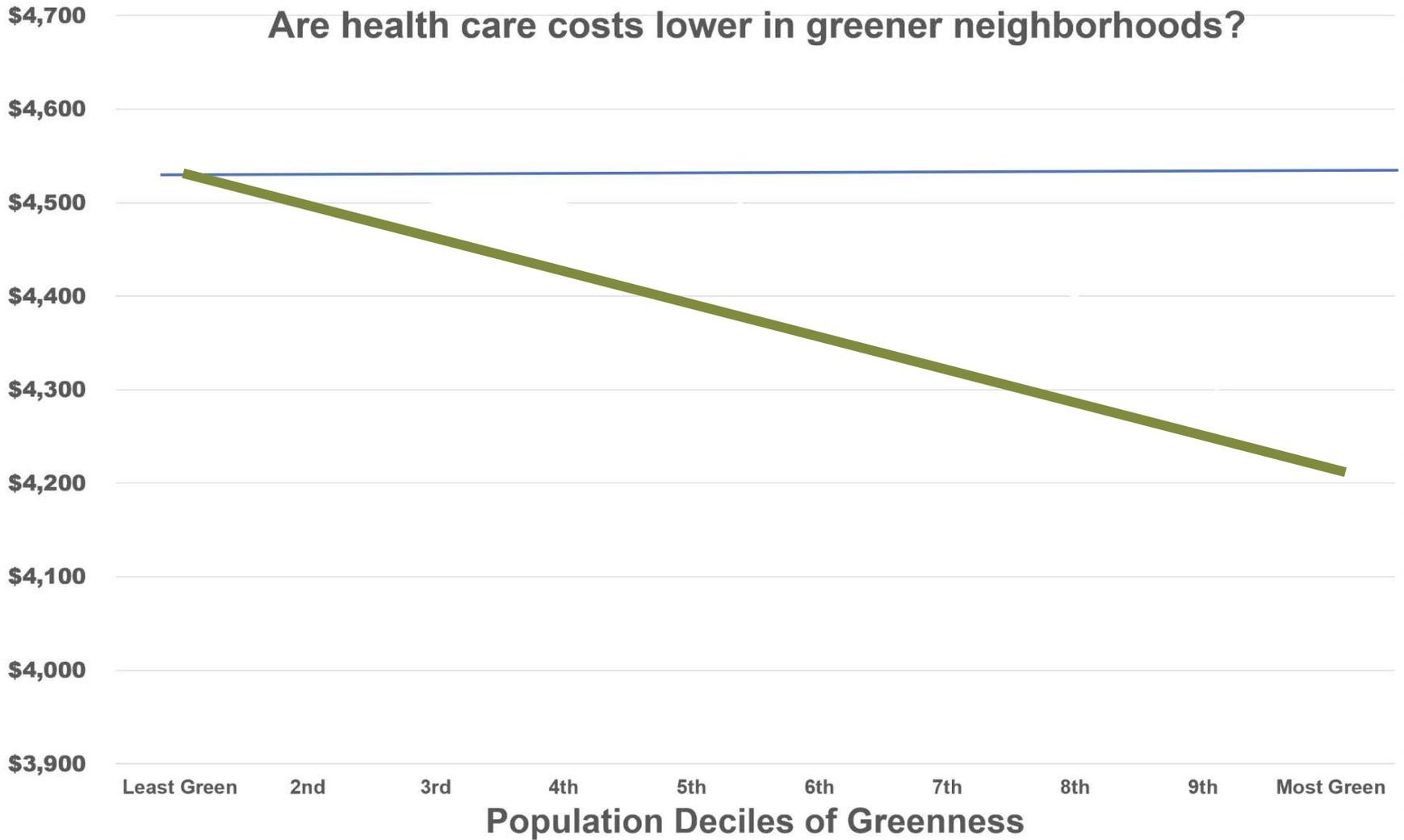
\$165 million for the highest decile

Greenness	Expenditures
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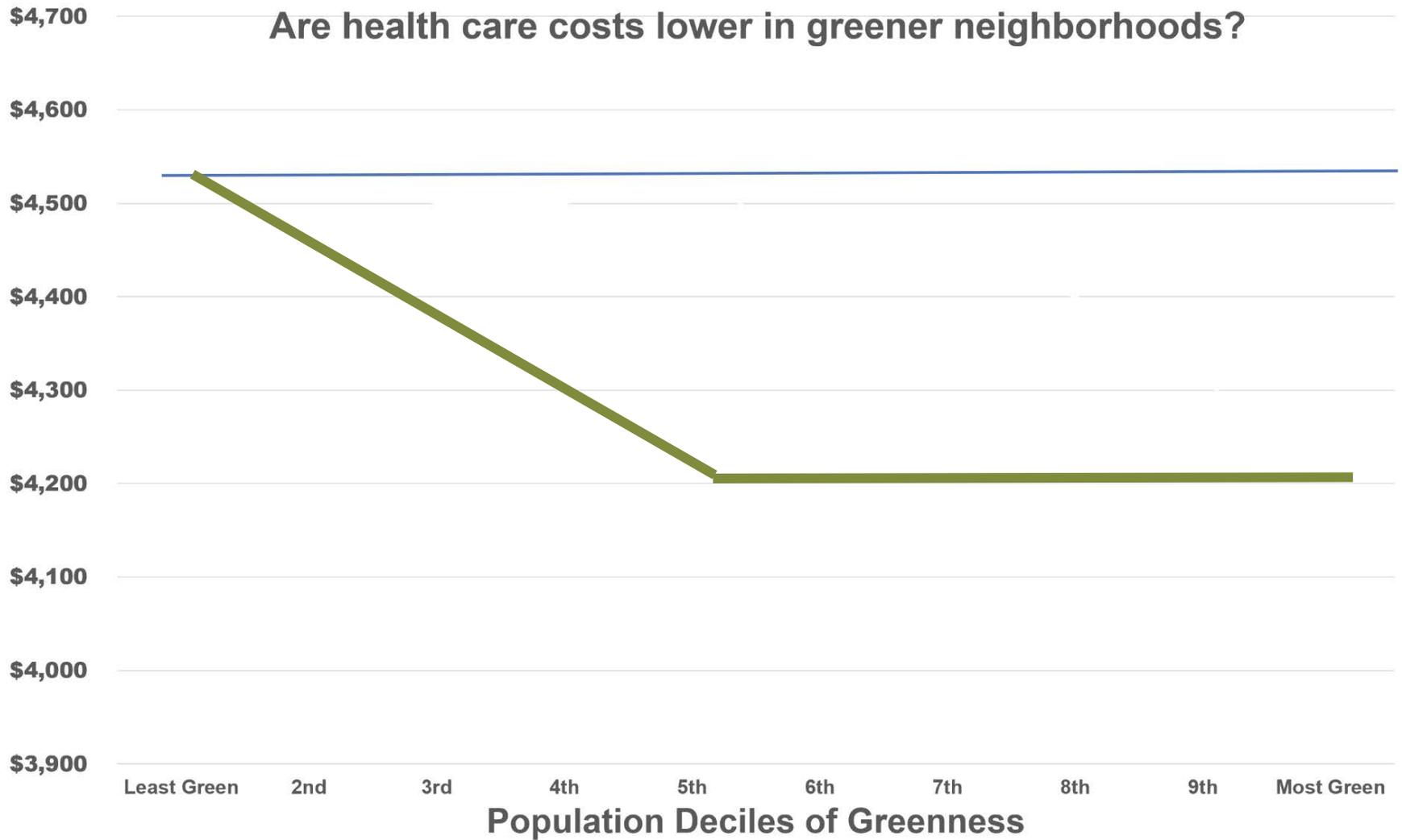
Are health care costs lower in greener neighborhoods?



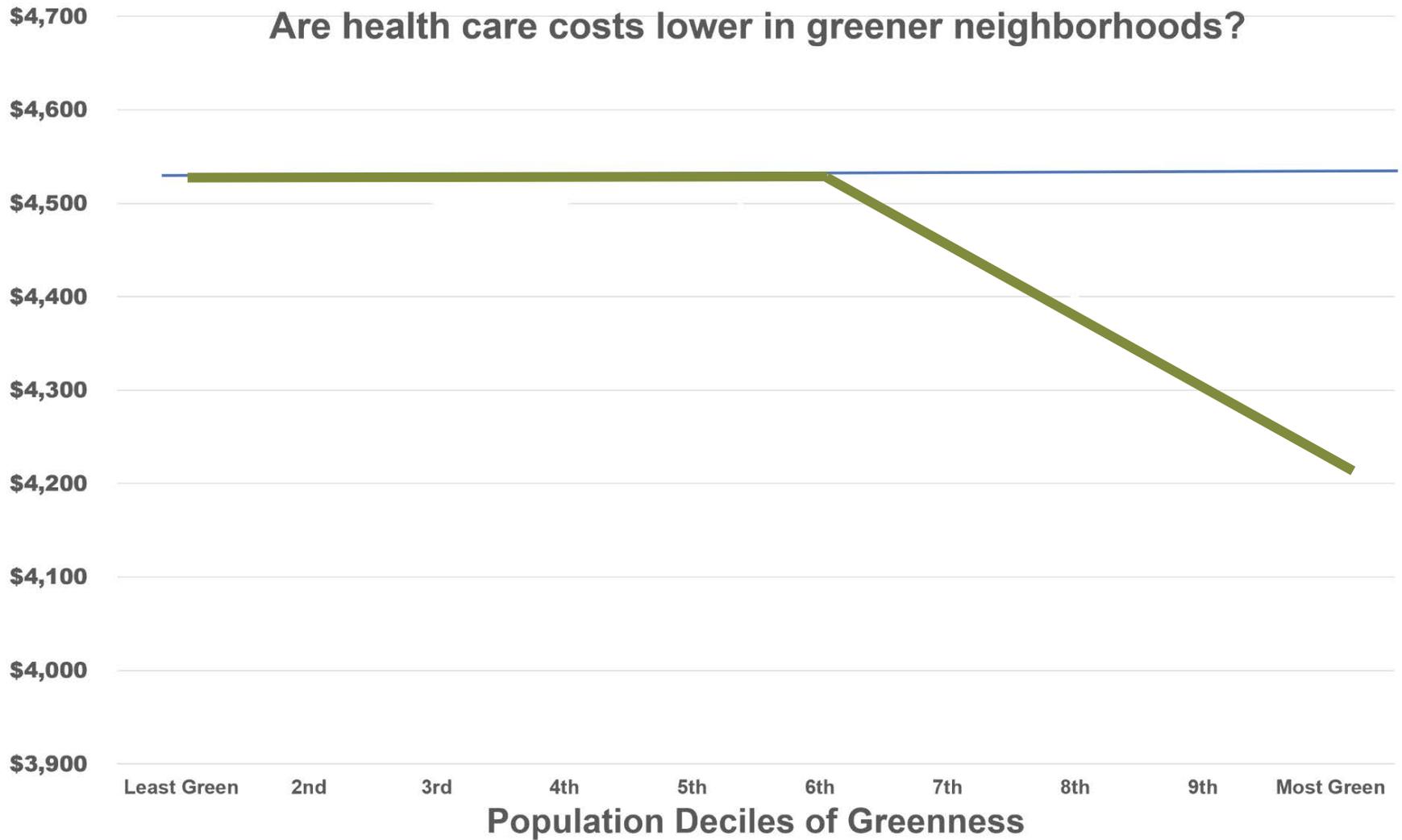
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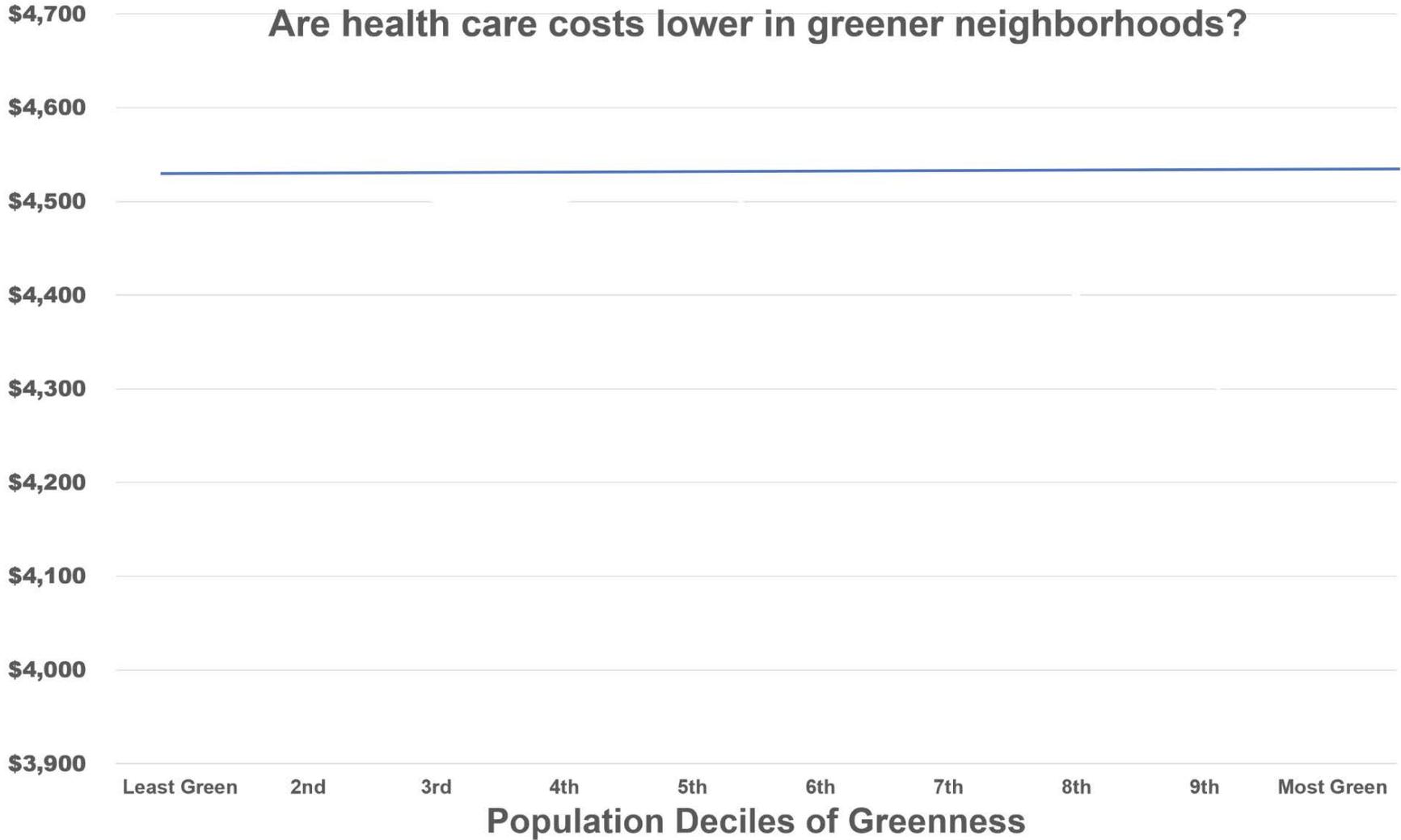
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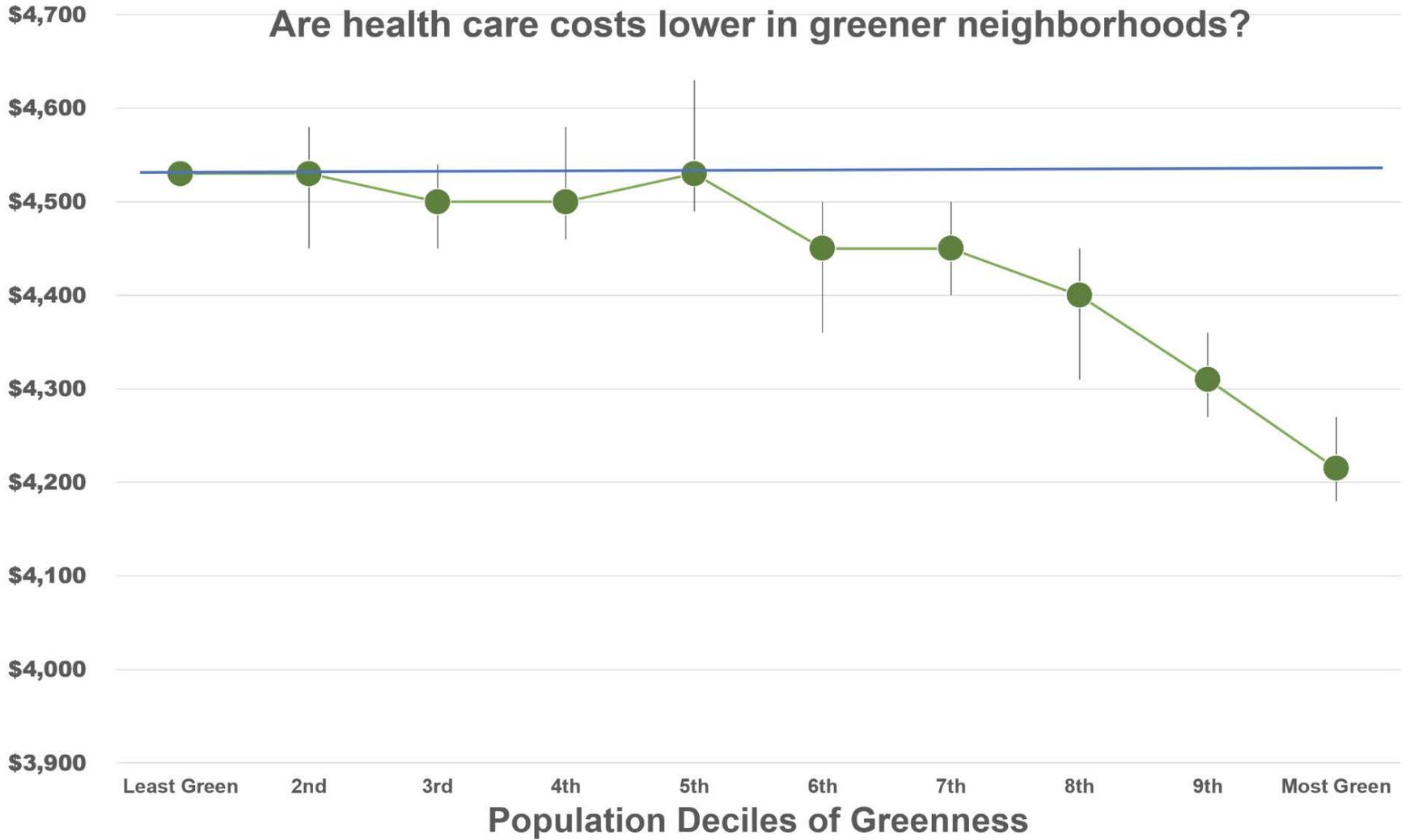
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Explaining the finding

Do trees drive health care expenditures via their impacts on health?

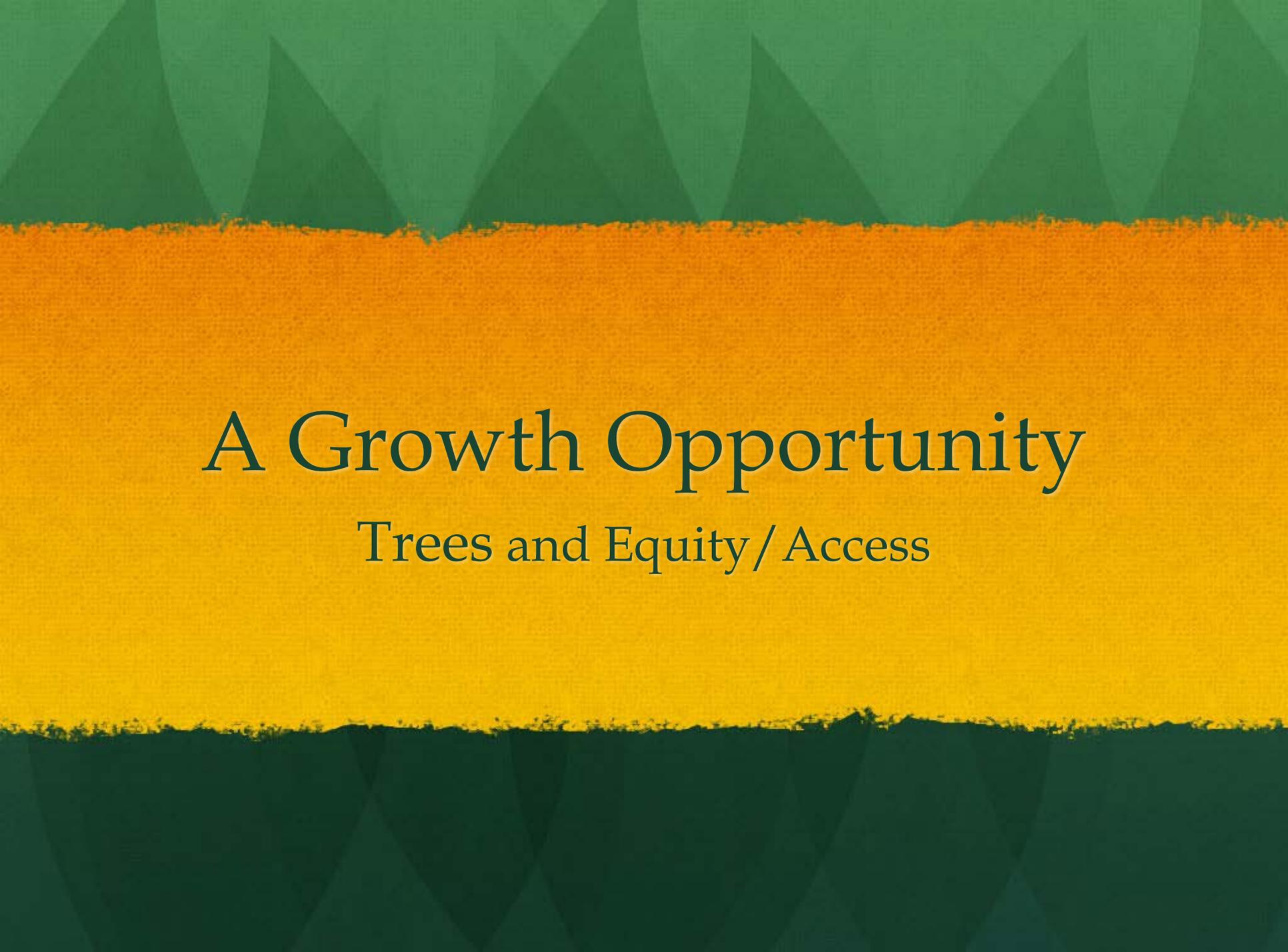


Explaining the finding

Do trees drive health care expenditures via their impacts on health?



Likely

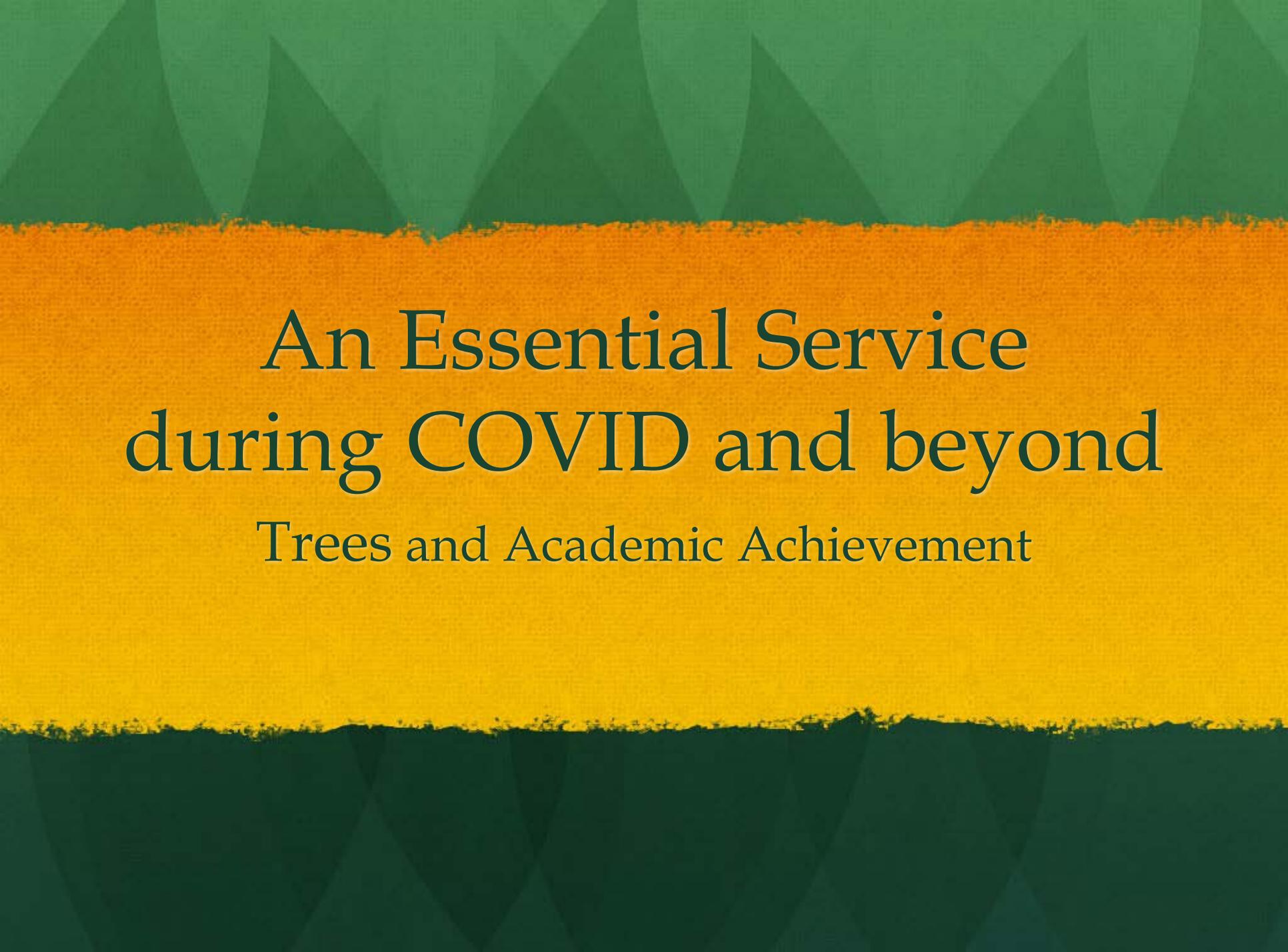


A Growth Opportunity

Trees and Equity/Access

Brought to you by

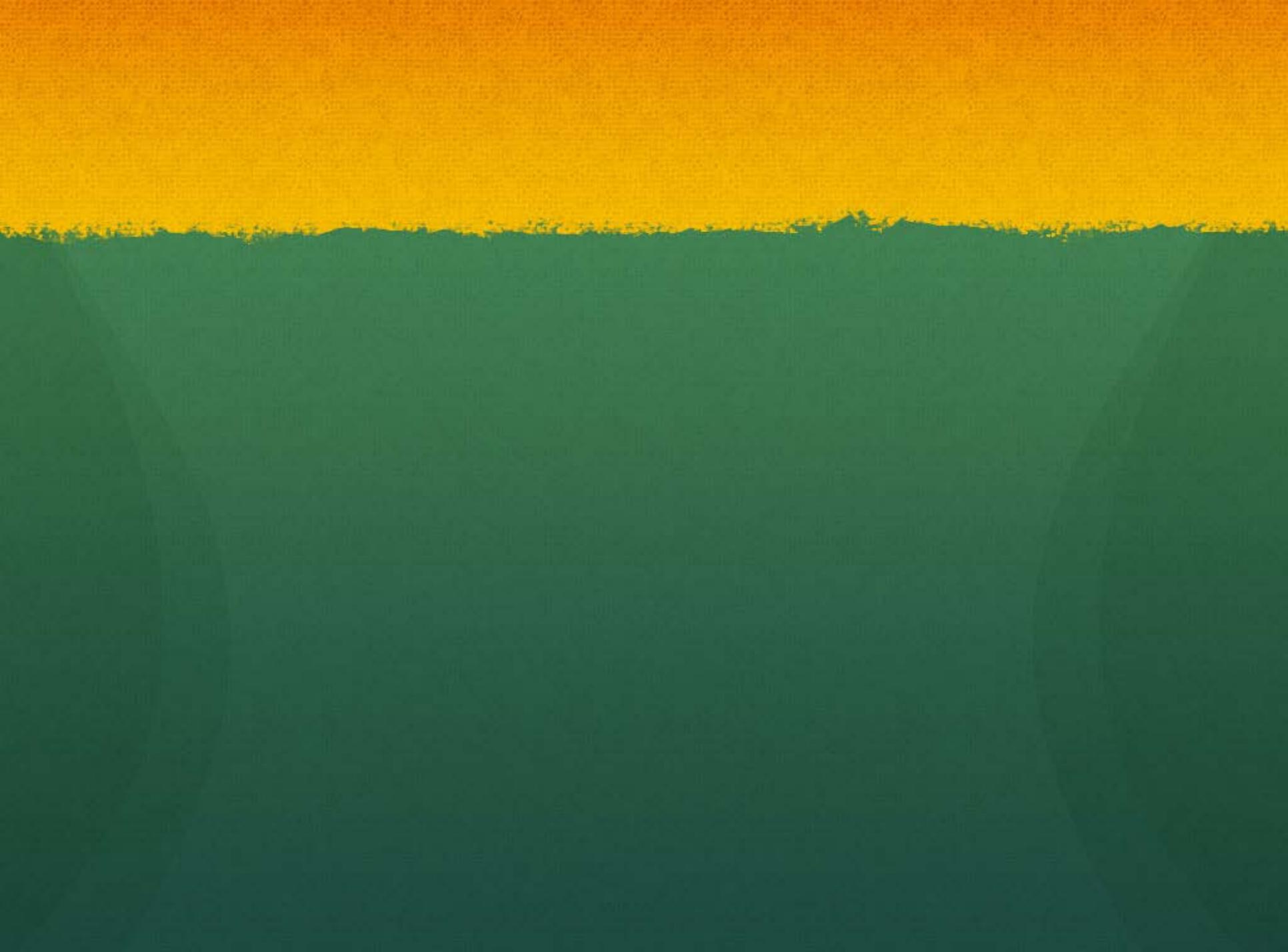
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An Essential Service
during COVID and beyond
Trees and Academic Achievement

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NATURE EXPOSURE

Free play in nature
Nature walks
Camp experiences
Wilderness adventures
Nature center programs
Nature-based preschools
Nature-based curricula
Outdoor classes and schools
Forest schools
Classroom views
Vegetation around early
childhood institutions, schools
and homes
School gardens
Animal-assisted learning

THE LEARNER

- More able to concentrate*
- Less stressed*
- More self-disciplined*
- More engaged
- More physically active, fit

THE LEARNING CONTEXT

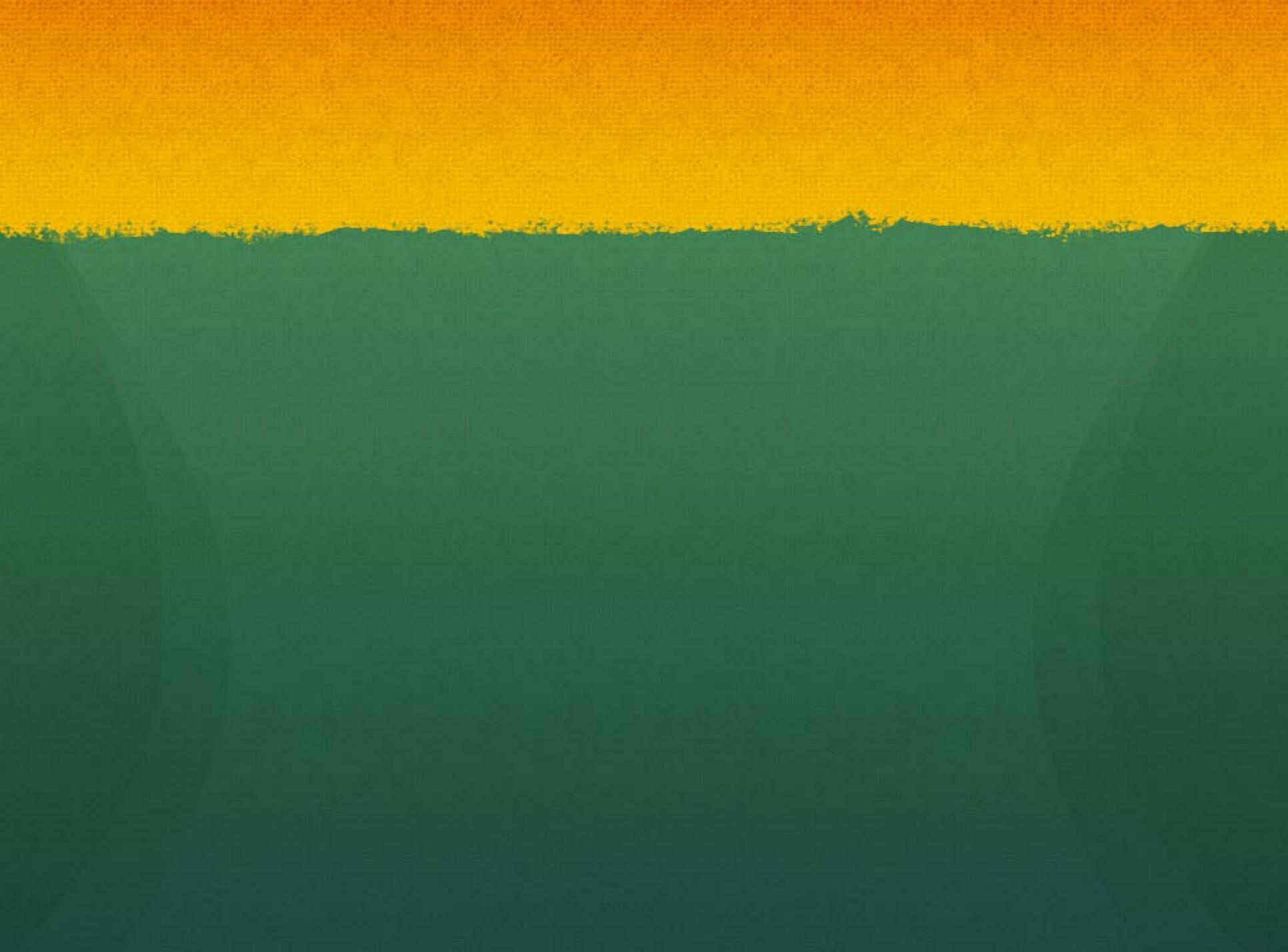
- Calmer, quieter, safer social context
- Warmer, more cooperative social context
- Autonomy and “loose parts”

LEARNING OUTCOMES

- **Academic Achievement**
Increased retention of subject matter content*
Higher standardized test scores
Better grades
Better reading, math, writing skills
Higher graduation rates
- **Personal Development**
Better leadership skills
Better communication skills
More resilience
Better critical thinking and problem solving
Better spatial skills
- **Stewardship**
Stronger connection to nature
Stronger environmental values
More pro-environmental behaviors

Could we do this?

- Could we study forest bathing here?
- Might the findings be true here?
- Might the findings have the same impacts on the public and policy?





The study design

Could we?



Could we?



Could we?



Could we?



Could we?

Concentration of volatile substances (phytoncides) in the air of the forest park, calculated as α -pinene (ng/m^3)

Kind of phytoncides	Quercus serrata forest area	Pine forest area
Isoprene	5291.6	9.8
Tricyclene	15.1	18.1
α -Pinene	70.0	241.1
Camphene	12.4	20.3
β -Pinene	18.8	39.8
D-Limonene	10.9	22.2
Bornyl acetate	0.0	11.1

The concentration of phytoncides represents the mean concentrations of each chemical between 9:30 am and 15:30 pm with consecutive sampling.

Could we?

- Multiple, objective measures of immune functioning
- Before, after, day 7, day 30

The background features a central horizontal band of bright yellow. Above and below this band are green areas with a repeating pattern of overlapping, semi-transparent triangles pointing downwards, creating a textured, mountain-like effect.

Findings

Findings

Big, lasting effects

- Double NK cell activity
- Days 7, 30

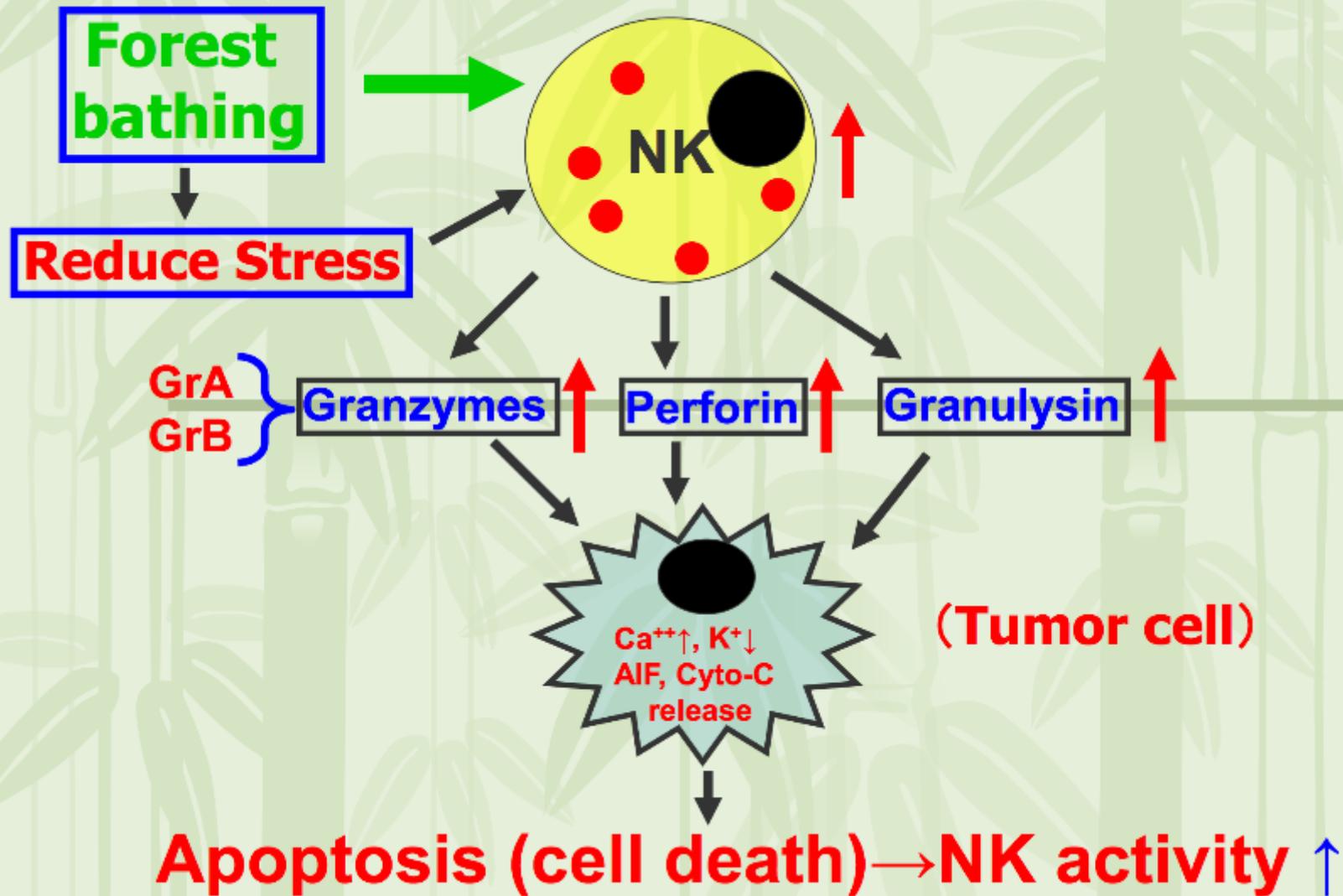
Findings

Urban trips show no effects

Evidence of mechanism

- stress reduction
- phytoncides

Mechanism of forest bathing-induced NK activity





The Impacts

The Impacts

- Self-disseminating findings
- Widely adopted as part of a healthy lifestyle – train rides
- Designated Forest Therapy Bases

Could we do this?

- Can we do this research?
- Could we get similar findings?
- Could we have similar impacts?

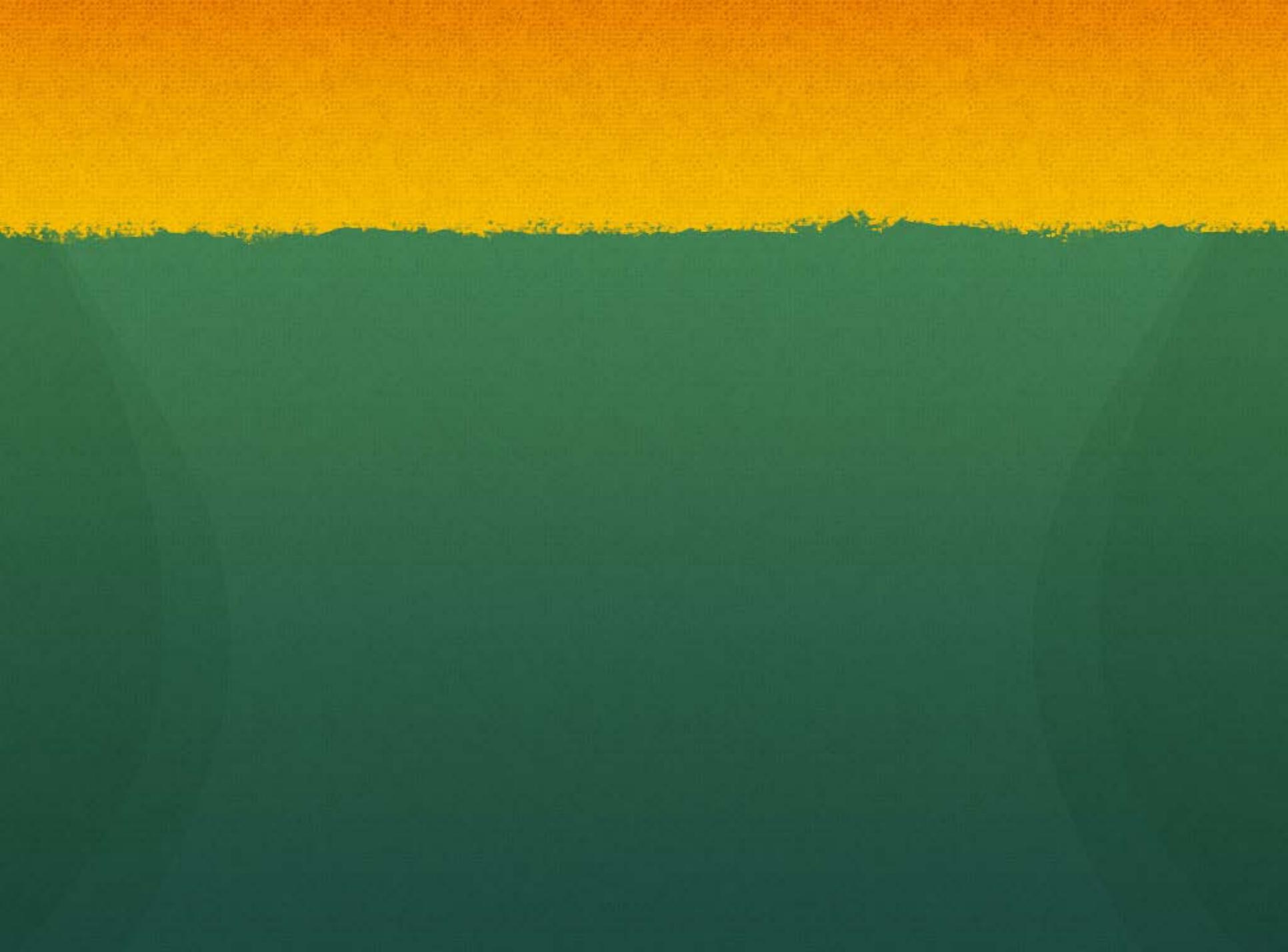
The image features a central horizontal band of bright yellow with a fine, grainy texture. Above and below this band are green areas containing a repeating pattern of stylized, overlapping mountain peaks or hills. The text "Let's do this!" is centered within the yellow band in a dark green, serif font.

Let's do this!

Thank you!

Frances “Ming” Kuo
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Selected Examples of effects from living in nature-poor environments

Health Outcome	Effects
Anxiety disorders	44% increase in incidence
Cancer	10% increase in incidence
Childhood obesity	15% increase in incidence
Coronary heart disease	27% increase in incidence
Depression	33% increase in incidence
Diabetes mellitus	25% increase in incidence
Immune system functioning	28% decrease in functioning
Mortality among older adults	13% increase in incidence
Upper respiratory tract infection (e.g., the common cold)	24% increase in incidence