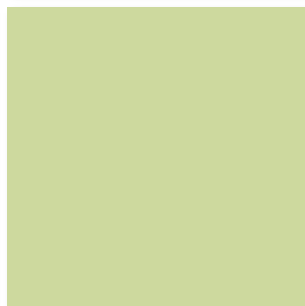


EXPOSURE TO GREENSPACE/GREENNESS AND HEALTH OUTCOMES

Joachim Heinrich & Iana Markevych

Taipei, October 25th 2015



OUTLOOK

- Motivation
- Greenspace vs. greenness (definitions)
- How to assess exposure to greenspace/greenness
- Green space/greenness and health
- Potential underlying mechanisms

- Conclusions



MOTIVATION

- Common belief about therapeutic properties of nature from ancient time
- Rapid development of GIS and GPS technologies and availability of processed and raw satellite images enabled objective “exposure to nature” assessment
- Emerging evidence on health benefits from green environments from epidemiological studies in adults and children
- It might be easier to launch tree-planting policies in cities than to reduce emissions of toxicants by industrial and traffic sources



WHY GREEN SPACE / GREENESS RESEARCH IN PUBLIC HEALTH?

- Increasing number of cross-sectional and longitudinal associations has been published within past 5 years for
mental health and cognitive function, birth outcomes and mortality
- Increasing urbanization worldwide followed with less exposure to green in cities
- New technologies for exposure assessment (free satellite-derived images of high resolution, detailed land use databases, and more)
- Identical assessment strategy for exposure possible
- Mechanisms not fully understood
Stress relief, facilitated social interactions, physical activity, reduced environmental exposures (air pollution, noise, temperature, etc.)

Green space

- land that is partly or completely covered with grass, trees, shrubs, or other vegetation



Urban



Natural



Agricultural



Greenness

- Green spaces are not equally vegetated



VS.



Greenness is general level of vegetation both in structured green spaces and in unstructured like backyards, street line trees etc.



EXPOSURE TO GREEN SPACES AND GREENNESS: GENERAL EPIDEMIOLOGICAL APPROACHES

- **Subjective (=perceived) measures** are typically questionnaire-based, questions on:
 - *walking distance to green spaces from residences*
 - *qualitative characteristics of green spaces as well as a neighbourhood (e.g. greenness, safety, maintenance, esthetical feature)*
 - *use of green spaces as well as a neighbourhood (type of activity and time/frequency of use)*

- **Objective measures** are based on modern technologies:
 - *GIS → Accessibility:*
 - *general level of residential vegetation / amount of structured green spaces in a neighbourhood*
 - *residential distance to structured green spaces*
 - *GPS → time/frequency of use of green spaces as well as a neighbourhood*



HOW TO ASSESS EXPOSURE TO GREEN SPACES AND GREENESS?

- Based on residential address. Residential history would be helpful.
- Addresses have to be geocoded

Greenness: Satellite images

- Landsat satellite images for a cloud-free day(s), which allows to assess the fine spatial contrasts in greenness during the vegetation-rich season. These images are available from 80s until now. Greenness could be assigned for different buffer sizes (30-1,000m) around the residential address.

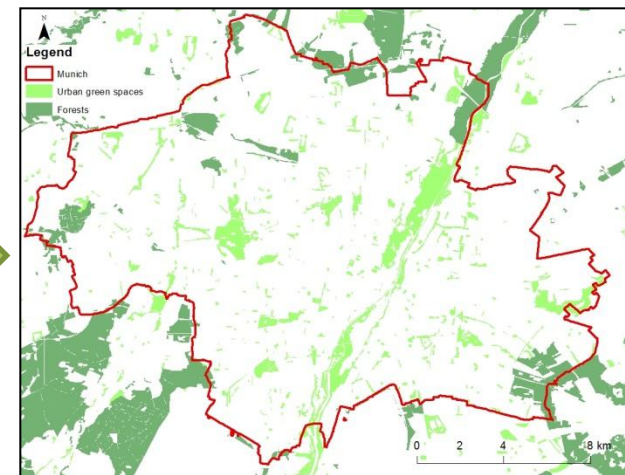
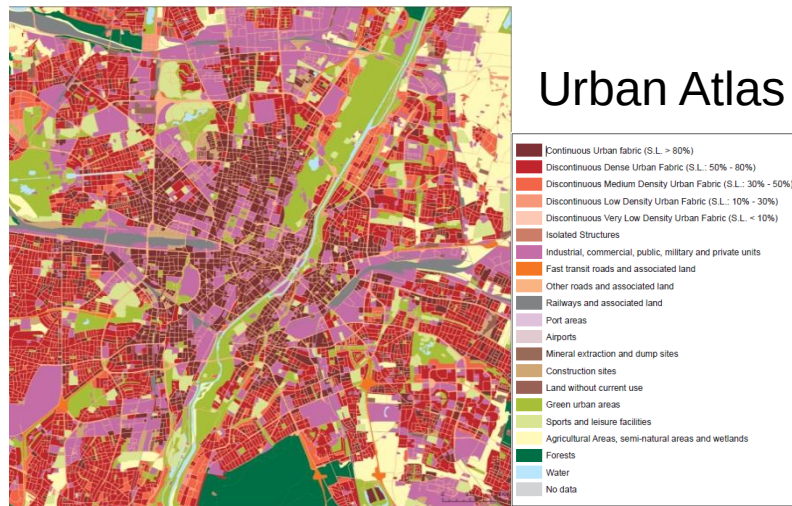
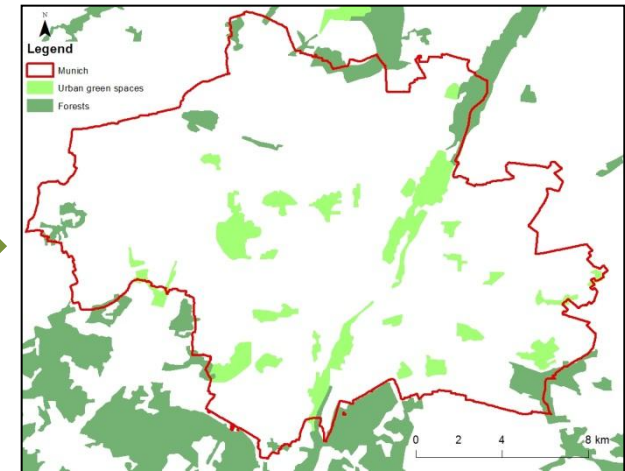
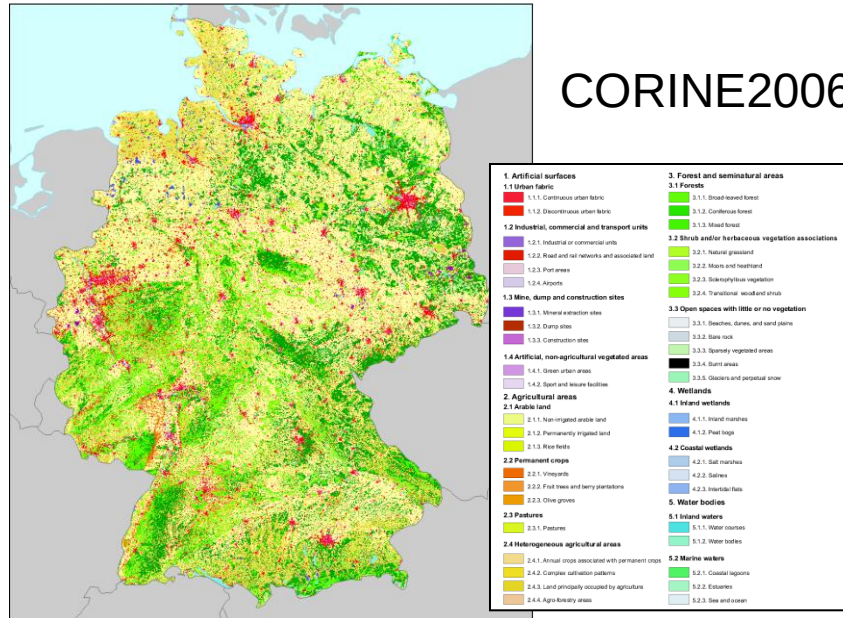
Green spaces: Land use databases (e.g. Urban Atlas for EU)

- Calculation of proportion/presence of different types of green spaces as well as distances to them from the residential address

LAND USE DATASETS

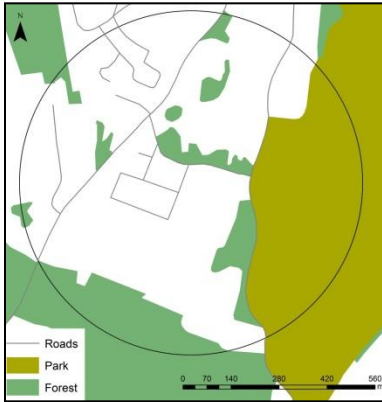


GREEN SPACES DATA



GREEN SPACES – HOW TO MEASURE EXPOSURE?

- **Accessibility** (GIS-derived)
- 1) Percentage (%) / land area (m²) of green space in a neighbourhood



- 2) Distance (Euclidean / network) to green spaces (m)



- **Accessibility and use**
- Combination of GIS and GPS technologies



GREENNESS – HOW TO MEASURE EXPOSURE?

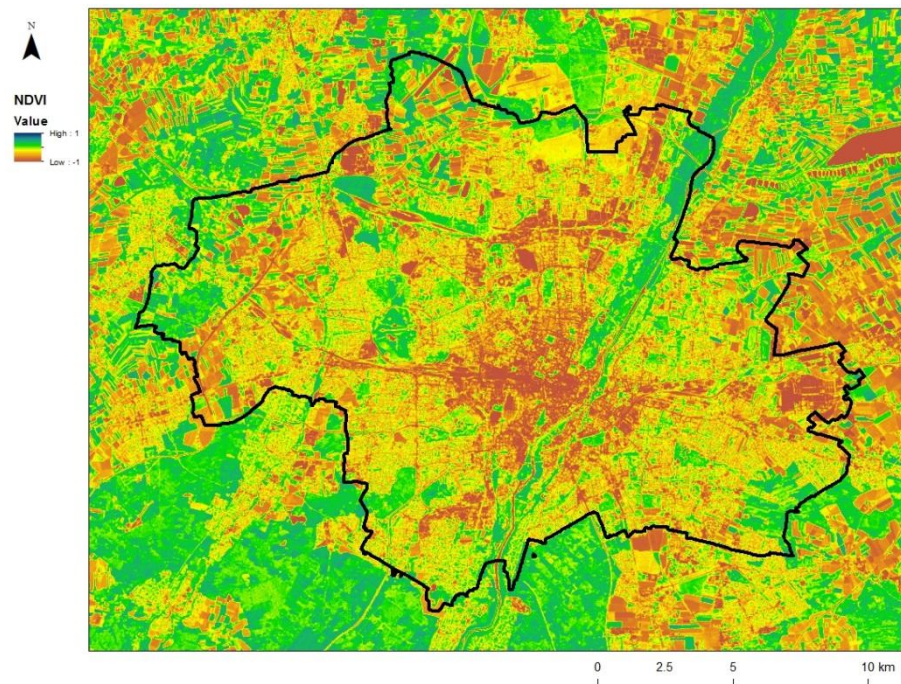
Source: Aerial photography and satellite imagery of different resolutions (1 m, 30 m, 250 m)

Two basic approaches:

1) Tree canopy cover



2) Vegetation indices (like NDVI)



From Lovasi et al. *Environ Health Perspect* 2013

NDVI: RATIONALE

- 1) Chlorophyll strongly absorbs visible light (**RED**; 0.4-0.7 μm) for use in photosynthesis
- 2) The cell structure of the leaves strongly reflects near-infrared light (**NIR**; 0.7-1.1 μm)



Normalized Difference Vegetation Index (NDVI) is based on surface reflectance obtained from remote sensing imagery:

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}$$

NDVI: Interpretation

NDVI is an indicator of green biomass density (i.e. chlorophyll content) and ranges from -1 to 1 where:

-1	water features
-0.1 - 0.1	barren areas of rock, sand, or snow
0.2 - 0.4	shrub and grassland
0.8 - 0.9	tropical rainforests

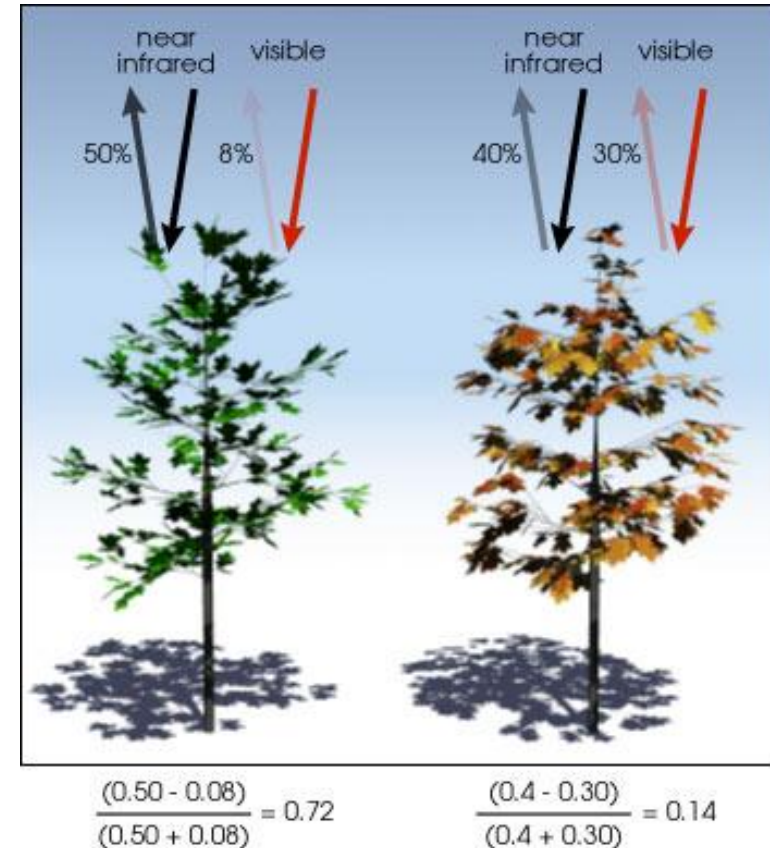


Illustration by Robert Simmon
<http://earthobservatory.nasa.gov/Features/MeasuringVegetation/>

NDVI: SOURCE FOR OUR CALCULATIONS

earthexplorer.usgs.gov

USGS
science for a changing world

EarthExplorer

Home Profile Save Criteria Load Favorite Manage Criteria Logout ymarkevych@gmail.com Feedback Help

Search Criteria Data Sets Additional Criteria Results

4. Search Results

If you selected more than one data set to search, use the dropdown to see the search results for each specific data set.

Show Result Controls

Data Set
L4-5 TM

Export Metadata

Entity ID	Acquisition Date	Path	Row
LT51910272002178MT100	27-JUN-02	Path: 191	Row: 27
LT51910272003181MT101	30-JUN-03	Path: 191	Row: 27
LT51910272003197MT101	16-JUL-03	Path: 191	Row: 27
LT51920272003236MT101	24-AUG-03	Path: 192	Row: 27
LT51910272003261MT101	18-SEP-03	Path: 191	Row: 27

Warten auf maps.googleapis.com...

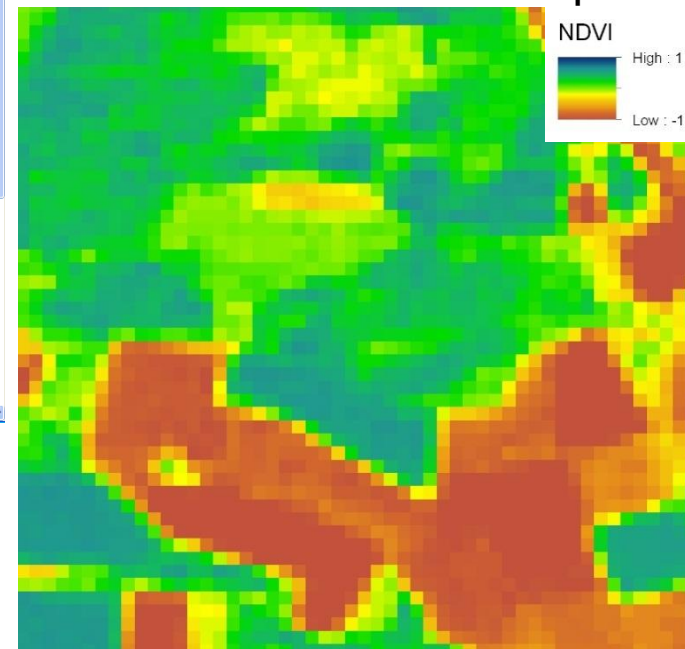
Search Criteria Summary (Show) Clear Criteria

(50° 05' 58" N, 012° 42' 13" E) Options Overlays Karte Satellit

Global Visualisation Viewer of the U.S. Geological Survey

Landsat 5 Thematic Mapper (TM) satellite images at the resolution of 30m by 30m

Band 3 = RED: 0.63-0.69 μm
Band 4 = NIR: 0.76-0.90 μm



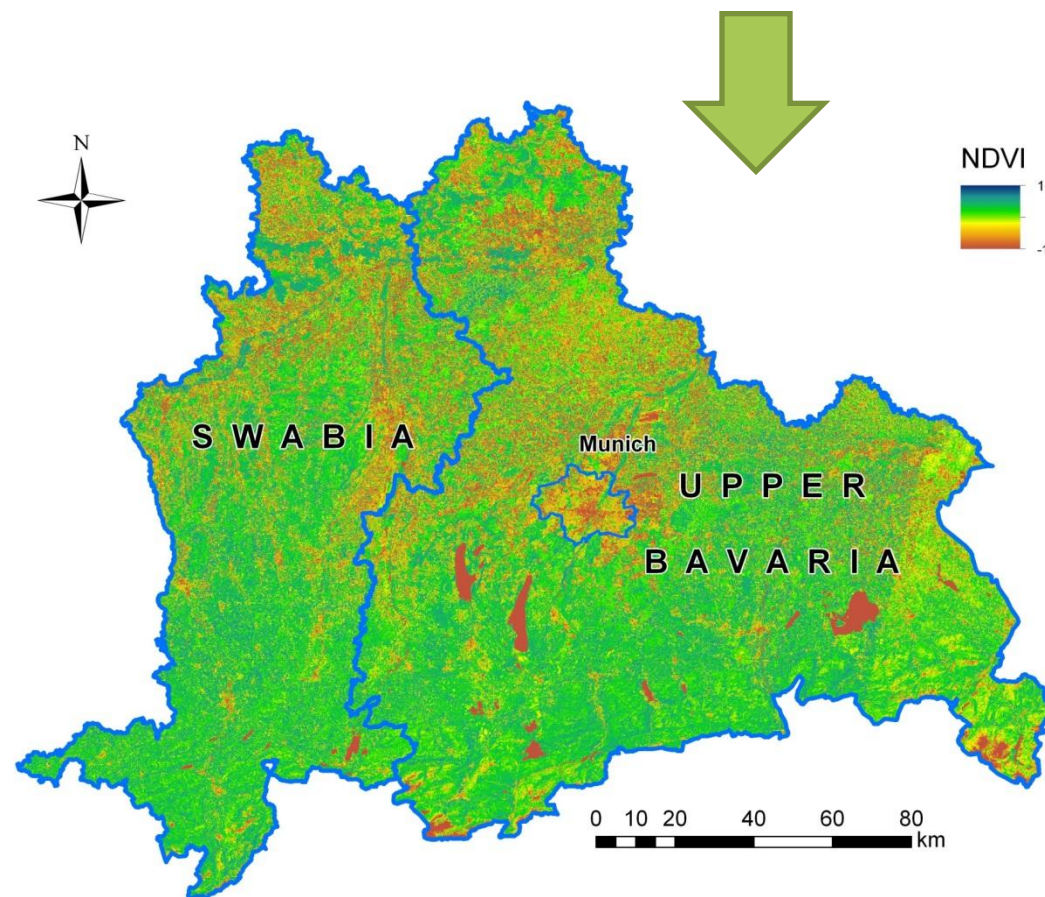
Cloud-free
satellite images

NDVI

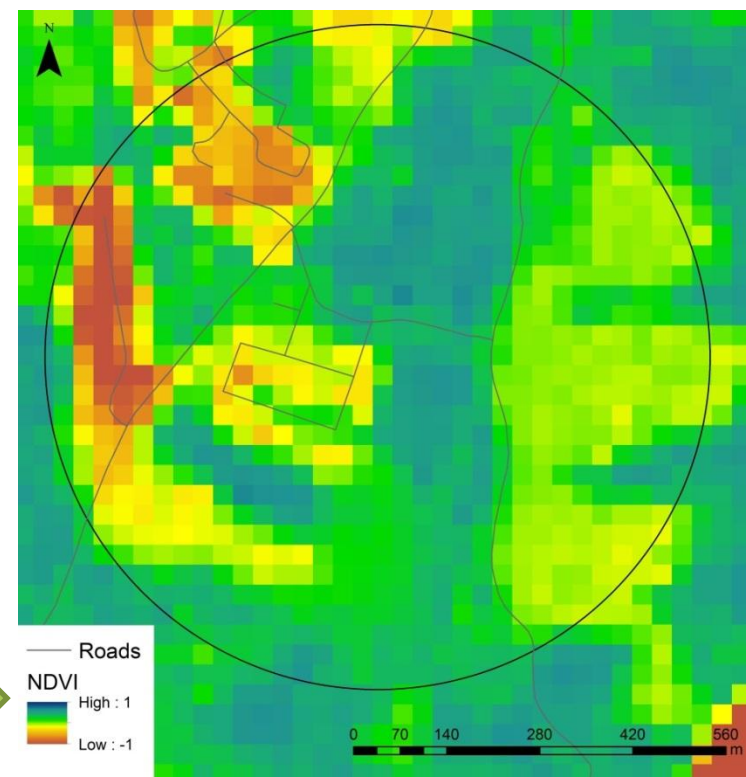
KLINIKUM DER UNIVERSITÄT MÜNCHEN®

LMU INSTITUTE AND OUTPATIENT CLINIC FOR OCCUPATIONAL, SOCIAL AND ENVIRONMENTAL MEDICINE

NDVI MAP FOR THE MUNICH AREA (2003)



Residential surrounding greenness is the mean NDVI in a circular 500-m buffer around the home



Greenspace/Greenness and Health?

RESIDENTIAL GREENNESS AND BIRTH WEIGHT.

SYSTEMATIC REVIEW AND METAANALYSIS.

DZHAMBOV ET AL.: URBAN FORESTRY & URBAN GREENING 13 (2014) 621–629

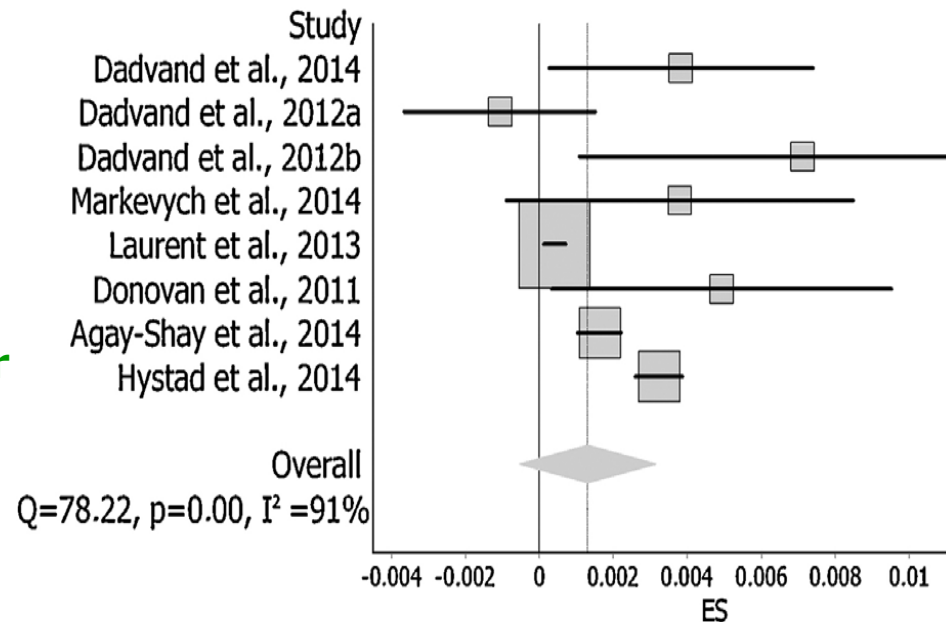
- Total of 8 studies with n=214,940 newborns

4 studies from Europe, 3 from US and 1 from Asia
Greenness defined as NDVI except Donovan study
Birth weight is used except Donovan study
which used SGA
All effect estimates were adjusted for
environmental pollutants and other co-factors

- **Overall statistical significant higher birth weight with greenness in neighbourhood**

The highest beneficial effects in birth weight
were seen in low SES families in 3 studies
Increasing the buffer to 250m yields similar finding

- Limitations: no adjustment for noise,
no data on type and use of vegetation were included,
other birth outcomes such as preterm birth, SGA,
head circumference could not be included in this review



RESIDENTIAL GREEN AND MENTAL HEALTH BENEFITS.

A SYSTEMATIC REVIEW

GASCON ET AL *INT. J. ENVIRON. RES. PUBLIC HEALTH* **2015**, 12, 4354-4379;

- A total of 28 studies,
design: 7 longitudinal, 20 cross-
setting: ~
- Surrounding greenness
adults: longitudinal: 3/3 beneficial effects

Authors' conclusion:
limited evidence for a
causal relationship in
adults
inadequate evidence in
children

Outcom

g
psychiatric disorders

Green: NDM b and cover

2/4 no effect

0/4 detrimental

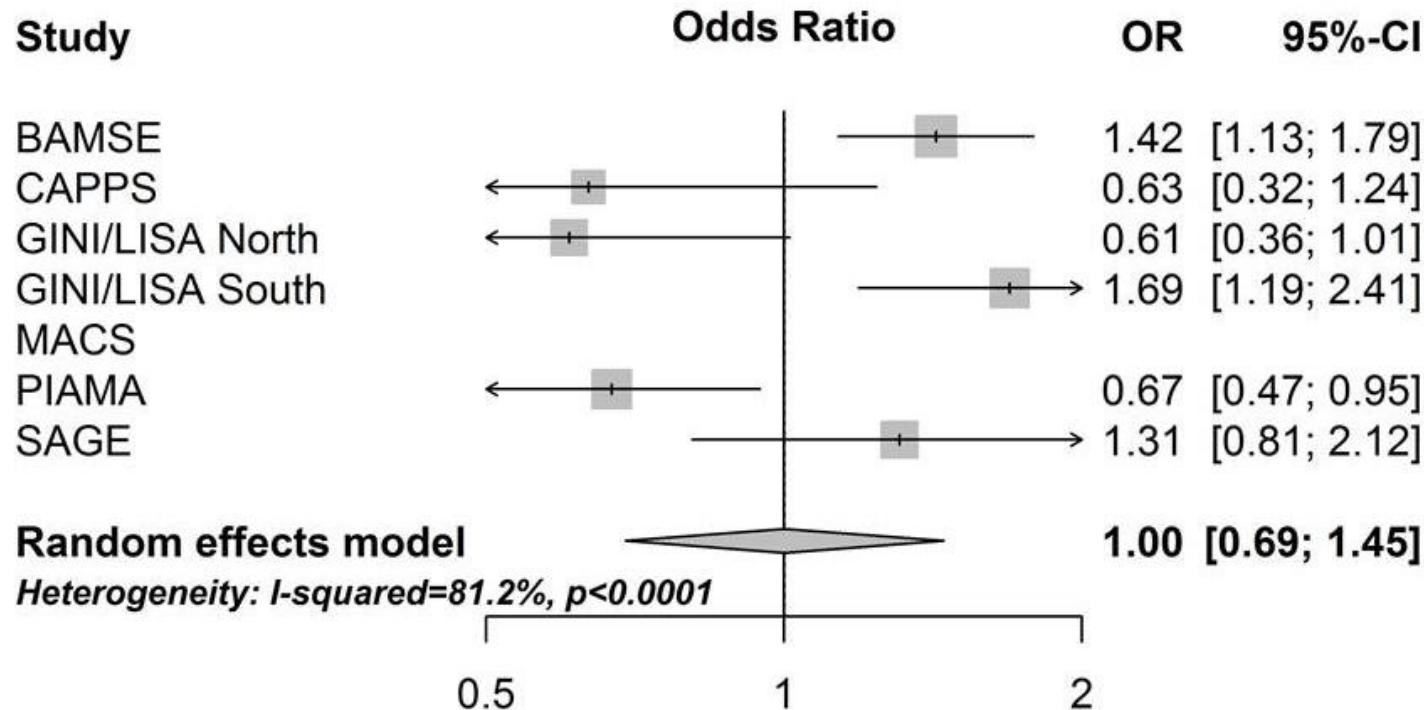
Children: 3/4 beneficial

Health outcome	Effect	Some published studies
Birth weight Other birth outcomes	+++ ++/0	Dzhambov et al., 2014 (meta-analysis); Grazuleviciene et al., 2015 Dadvand et al. 2012 a, b ; Laurent et al. 2013; Agay-Shay et al. 2014;Hystad et al. 2014
Weight status	+	Astell-Burt et al., 2014; Pearson et al. 2014; Lovasi et al., 2013; Nielsen & Hansen, 2013
Mental health	+++	De Vries et al., 2013; Alcock et al., 2014; Astell-Burt et al., 2014; Beyer et al., 2014; Reklaitiene et al., 2014; Richardson et al., 2013; Gascon et al., 2015 (systematic review);
School performance	++	Wu et al. 2014; Dadvand et al 2015
Behavioural development	++	Markevych et al., 2014; Amoly et al., 2014; 2013; Gascon et al., 2015 (systematic review);Dadvand et al 2015
Survival	++	Villeneuve et al., 2012; Richardson et al., 2012; Mitchell & Popham, 2008; Mitchell et al., 2011; Donovan et al., 2013
CVD	+	Tamosiunas et al., 2014; Pereira et al., 2012
Diabetes	++	Astell-Burt et al., 2014; Bodicoat et al. 2014; Maas et al. 2009; Zhou et al 2015
Allergic diseases	+/-	Dadvand et al., 2014; Fuertes et al., 2014; Lovasi et al., 2008; Lovasi et al., 2013; Notas et al 2015 (adverse!)
Self-perceived health	+++	Richardson et al., 2013; Reklaitiene et al., 2014; van Dillen et al., 2011; Mitchell & Popham, 2007; Richardson & Mitchell, 2010; Triguero-Mas et al. 2015; Weinmann et al. 2015
Physical activity	+++/000	Hunter et al., 2015 (systematic review); McGrath et al., 2015 (meta-analysis); McMorris et al., 2015; Dunton et al., 2014; Cohen et al., 2007; Coombes et al., 2010; Mytton et al., 2012

NDVI AND ALLERGIES?

- For **allergic health outcomes**, role of green environment may be more complex
 - Beneficial -> greater exposure to number and diversity of microbes (biodiversity hypothesis)
 - Detrimental -> exacerbation of symptoms among those sensitized due to exposure to pollen-releasing plants and fungi
 - Influence of exposure timing is to be clarified
 - A recent multicentre study showed statistically significant associations for children in 7 birth cohorts, but directions were different! (Fuertes et al ISEE 2015)
- So far, there is no study on greenness and **lung function**

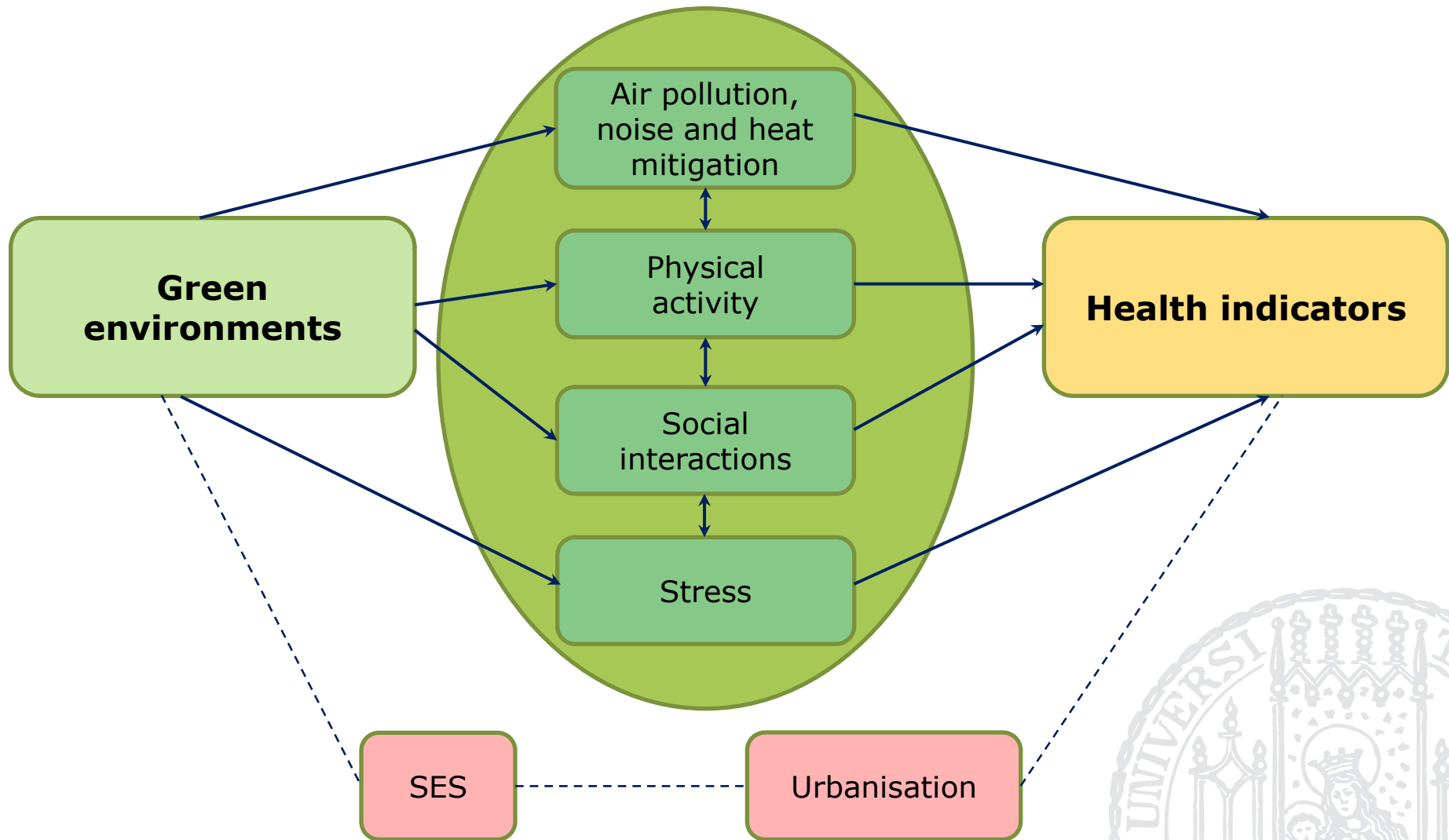
NDVI AND ALLERGIC RHINITIS (6-8 YRS)



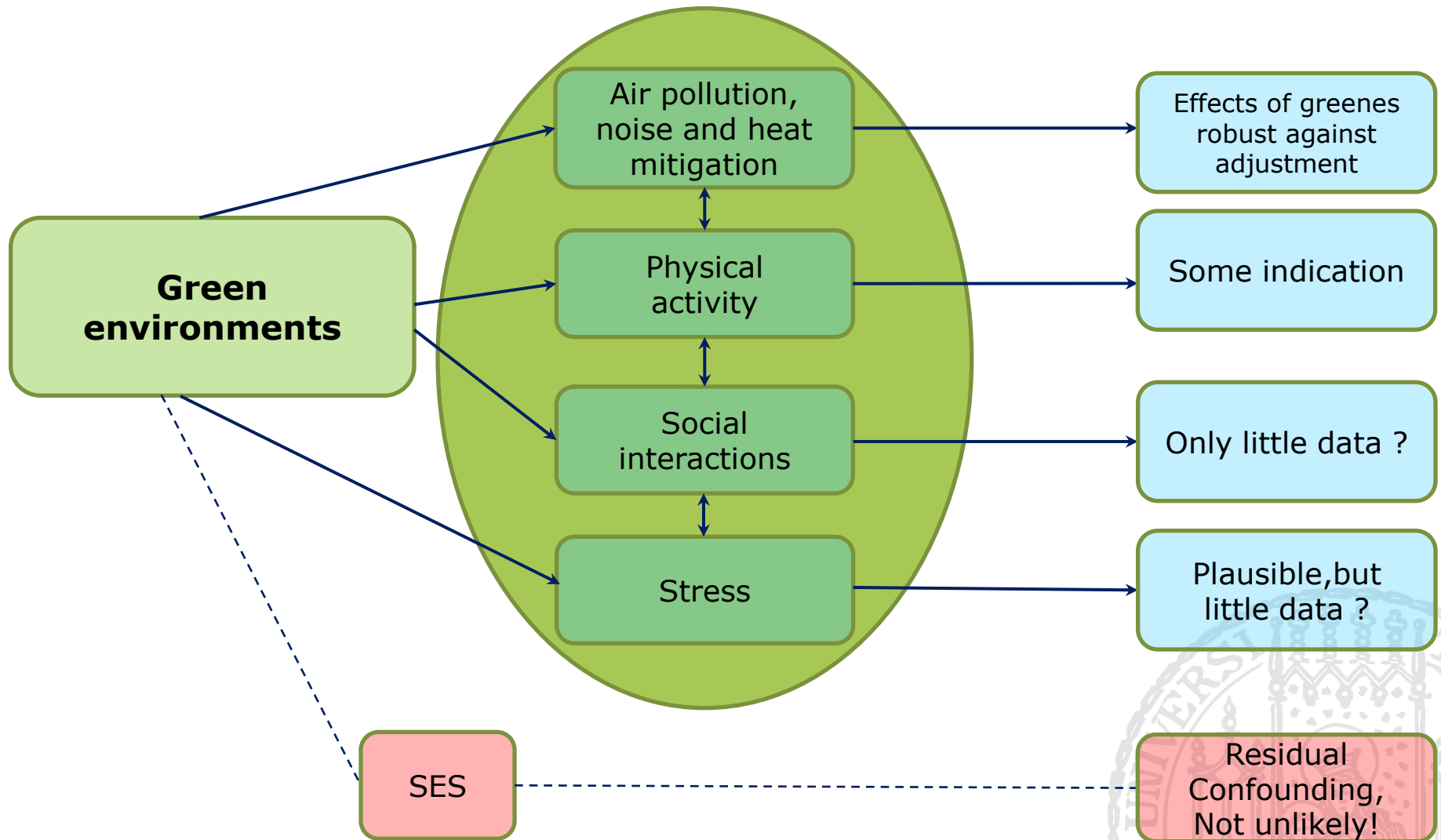
- Presented per 0.2 NDVI increase
- Adjusted for sex, age, parental atopy, older siblings, maternal smoking during pregnancy, secondhand smoke exposure, socioeconomic status, intervention, region, cohort

Fuertes et al 2015 (submitted)

HYPOTHESISED PATHWAYS



HOWEVER, THE EVIDENCE IS NOT STRONG





UNDERLYING MECHANISMS FOR GREENNESS
NOT CLEAR!



SUMMARY AND CONCLUSIONS

- Exposure to greenness and its potential health impact is an emerging research topic
- Several descriptive observational studies showed beneficial health effects when subjects are exposed to more green
- The underlying mechanisms are not clear and residual confounding is not unlikely
- More data is needed on vegetation type and usage of greenspace
- More experimental studies could clarify the role of greenness exposure
- Regardless the uncertainties and the knowledge gaps city planners should be more aware on potential positive aspects on green in cities now!

THANKS TO MY COLLEAGUE

Dr. Iana Markevych, LMU, Munich



**Thanks to you for your
attention!**

