FACULTY OF BIOSCIENCE ENGINEERING

DEPARTMENT OF ENVIRONMENT

Stadsbomen, noodzakelijk voor klimaatrobuuste steden

Prof. Hans Verbeeck

GHENT UNIVERSITY

Met bijdragen van Prof. Frieke Van Coillie, Prof. Matthias Demuzere (B-kode.be), Barbara D'hont, Todi Daelman

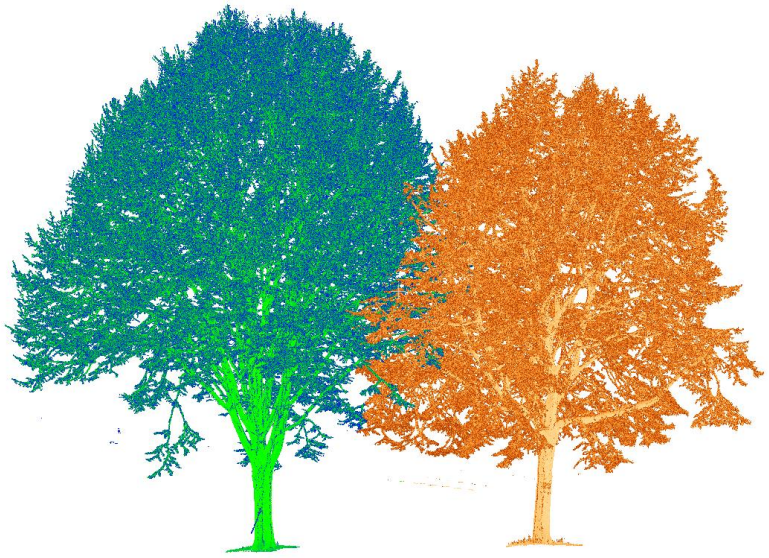
NATIONALE BOMENDAG
Don. 19 oktober 2023
5de editie
Klimaatslim boombeheer
Boven- en ondergronds

WIE BEN IK?

- UGent
- C-cylcus van bossen
- Tropisch bos en klimaat
- Natural Capital Platform

CAVELAB

- Computational & Applied Vegetation Ecology



- Vegetatiemodellering, Opmeting precieze 3D structuur

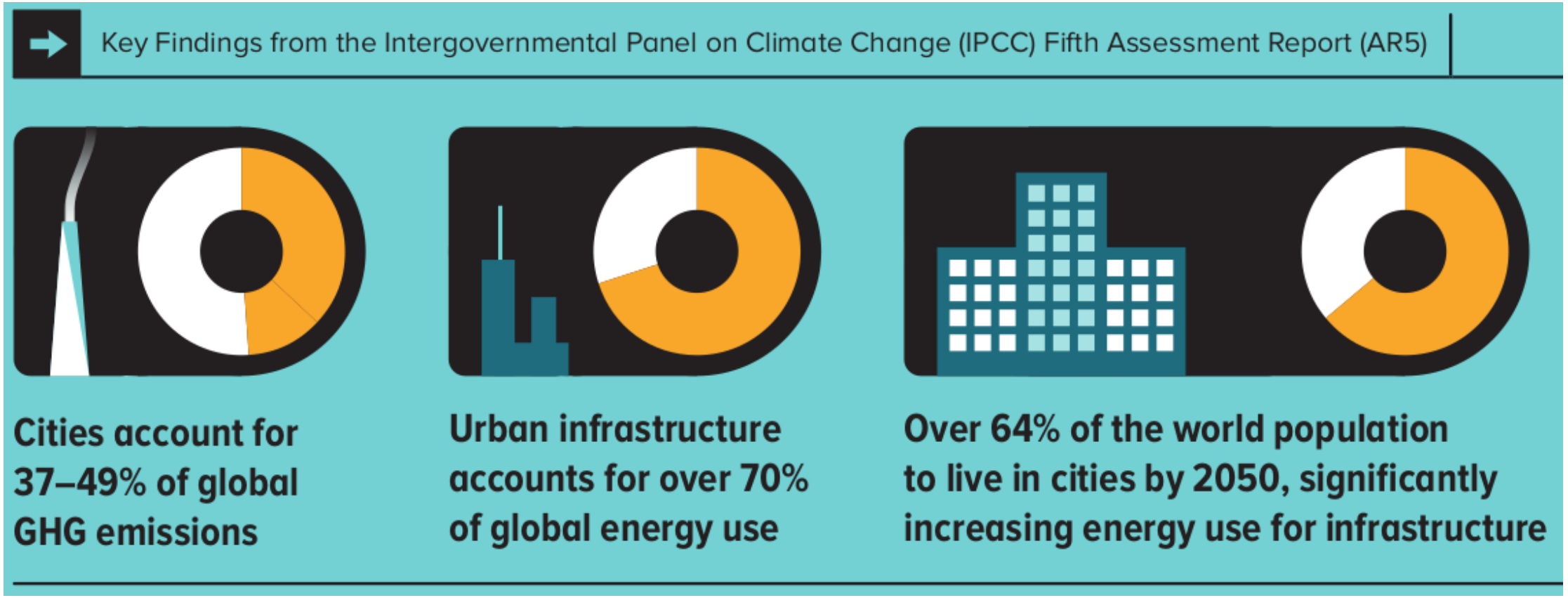
INHOUD

- **Planetaire grenzen en klimaatverandering**
  - Klimaatopwarming: mechanisme, broeikasgassen
  - Observaties: opwarming en impact op steden
  - Voorspellingen: modellen, onzekerheden
  - Impact van klimaatverandering op steden
- **De biosfeer**
  - De globale C cyclus
  - Sources and sinks: fossiele emissies, ontbossing
  - Impact van klimaatverandering op stadsecosystemen
- **Stadsbomen een nature-based solution voor klimaatrobuste steden**
  - Mitigatie
  - Adaptatie
  - Ons onderzoek

DE VLAAMSE CONTEXT

- Verstedelijking
- Versnippering
- Steden en gemeenten in een verstedelijkt Vlaanderen
- …

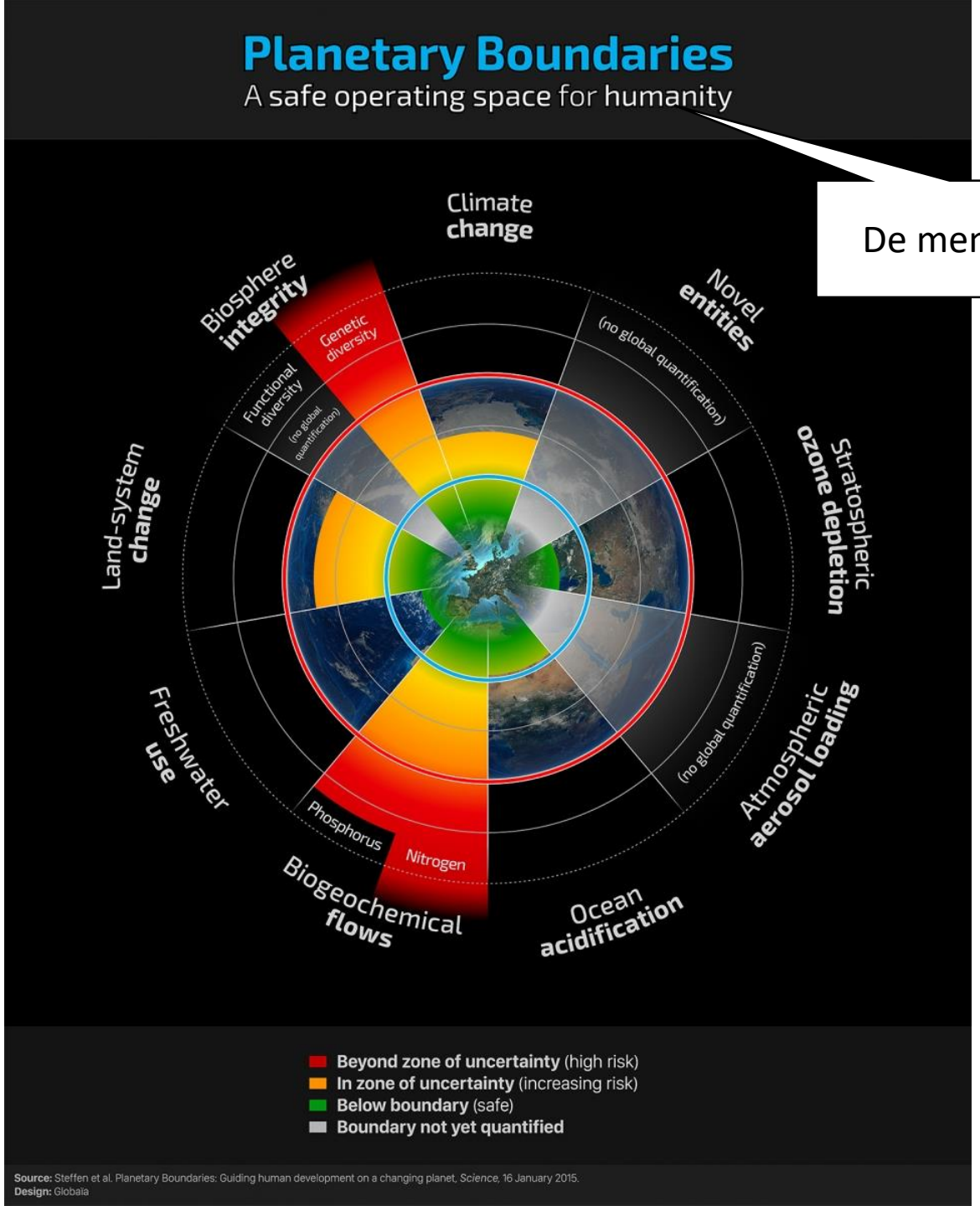
DE GLOBALE CONTEXT



PLANETAIRE GRENZEN

Klimaatverandering altijd zien in de context van de 9 planetaire grenzen.

De mensheid!



Meer weten?

TED-talk J. Rockstrom

https://www.youtube.com/watch?v=RgqtrlixYR4

DE ENERGIEBALANS VAN DE AARDE IS GEMIDDELD IN EVENWICHT

Box 1 | Updated energy balance

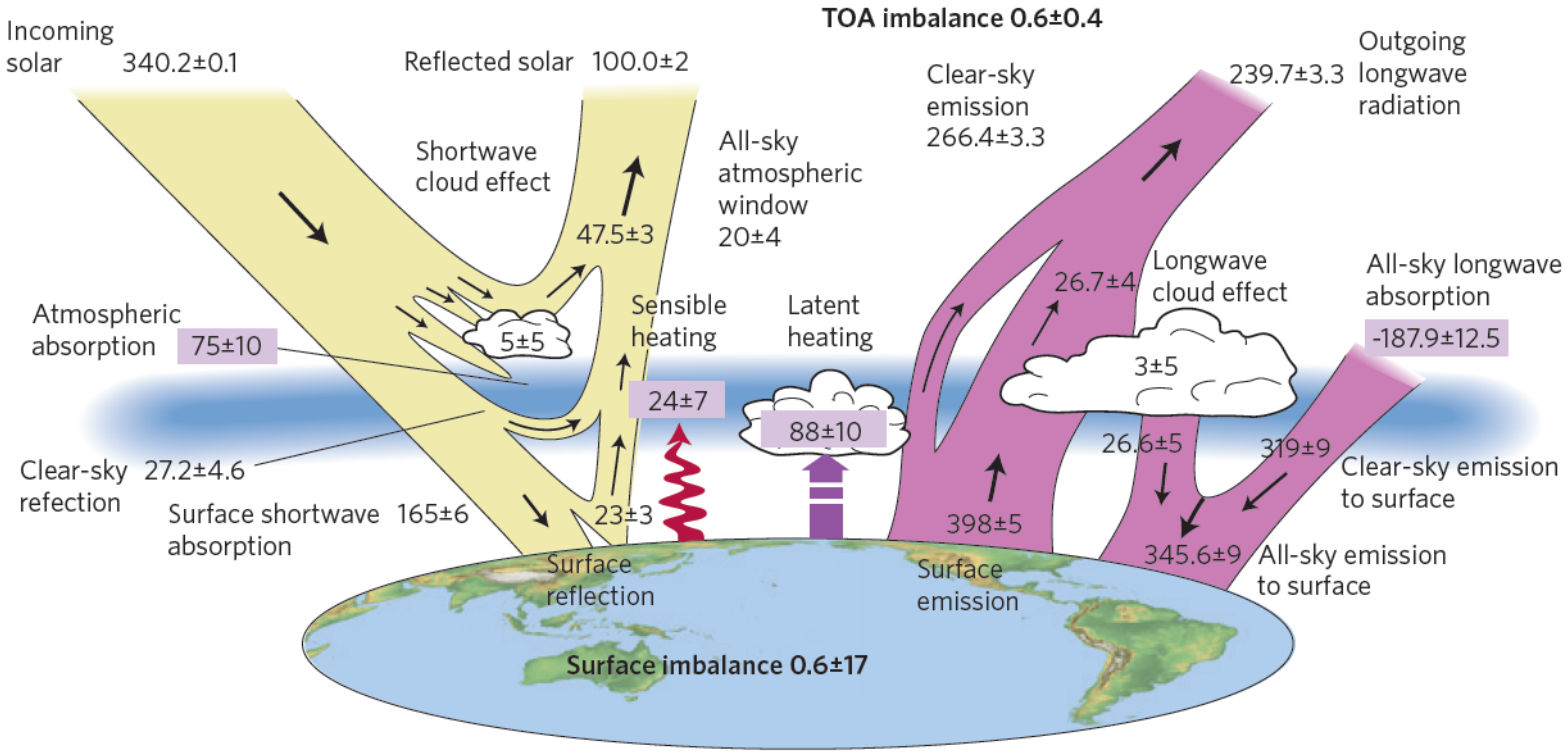
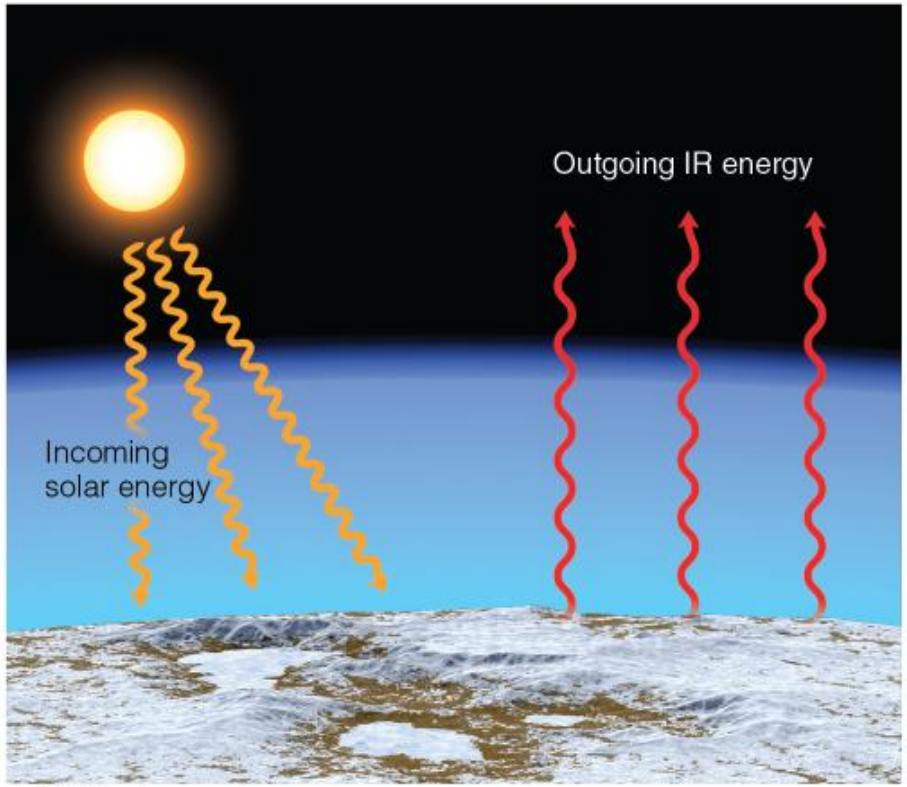
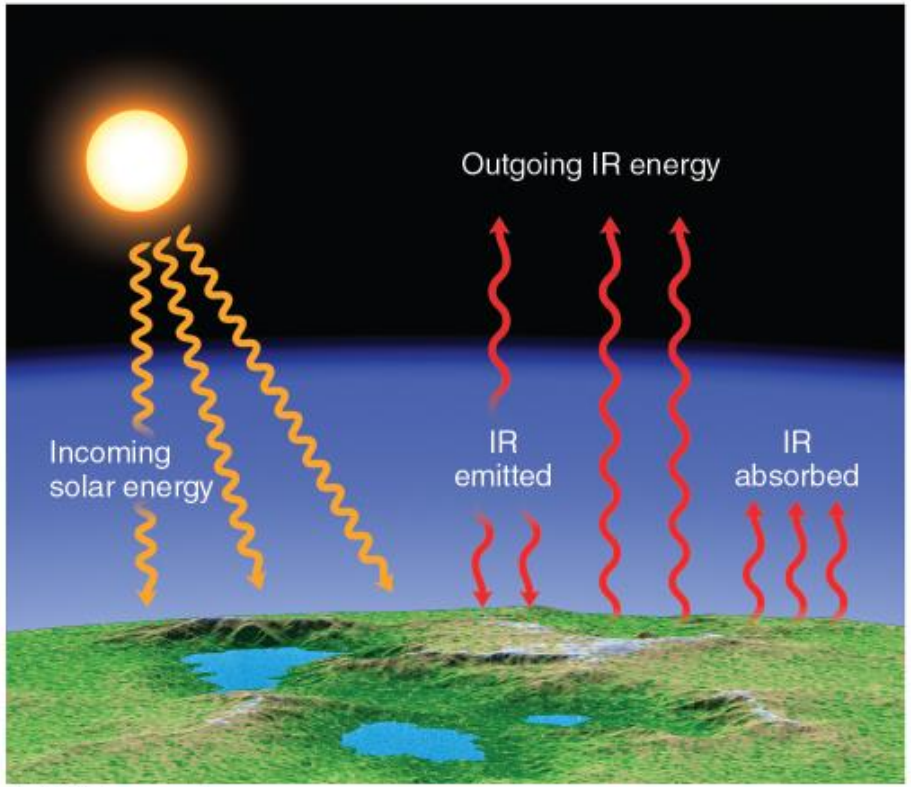


Figure B1 | The global annual mean energy budget of Earth for the approximate period 2000–2010. All fluxes are in Wm^{-2}. Solar fluxes are in yellow and infrared fluxes in pink. The four flux quantities in purple-shaded boxes represent the principal components of the atmospheric energy balance.

DANKZIJ BROEIKASGASSEN STELT DIT EVENWICHT ZICH IN OP +/- 15°C



(a) Without greenhouse gases



(b) With greenhouse gases

● FIGURE 2.13

Aarde zonder broeikasgassen:

-18° C gemiddeld!!!

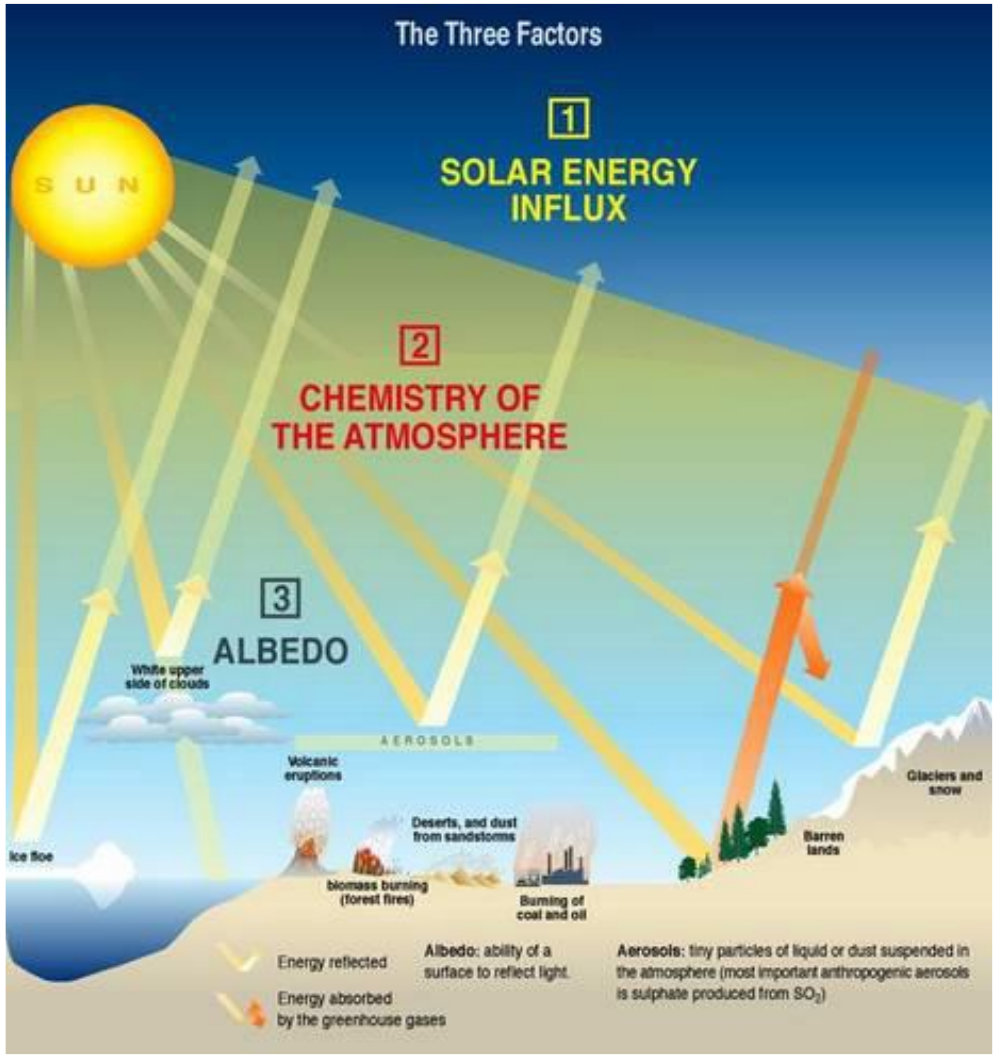
Aarde met broeikasgassen:

15° C gemiddeld!!!

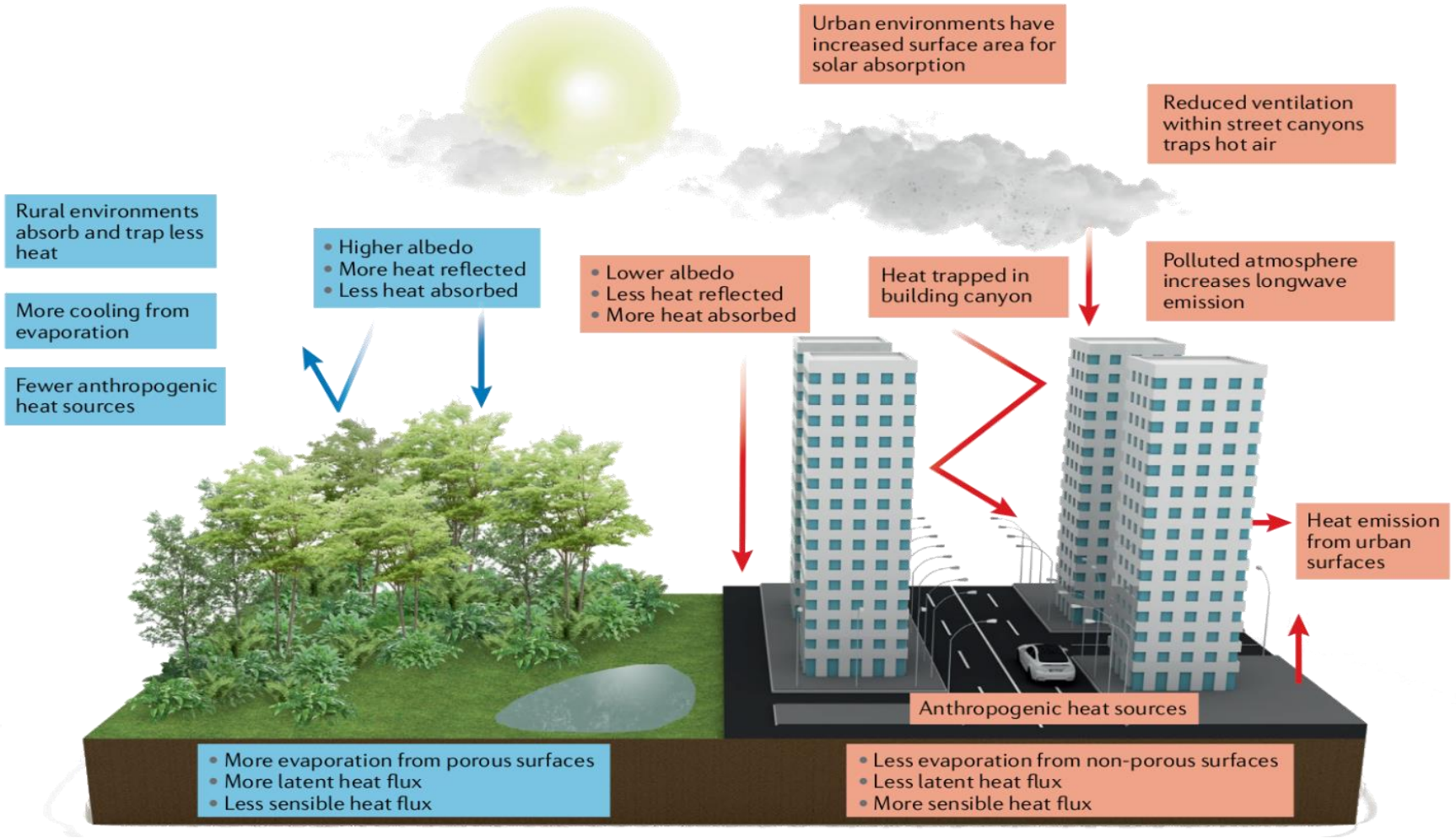
KLIMAATVERANDERING = VERSTORING VAN DE ENERGIEBALANS

- 3 factoren
  1. Verandering in zonnestraling
  2. **Atmosferische samenstelling**
  3. Reflectiviteit aardoppervlak

- Natuurlijke en antropogene klimaatverandering



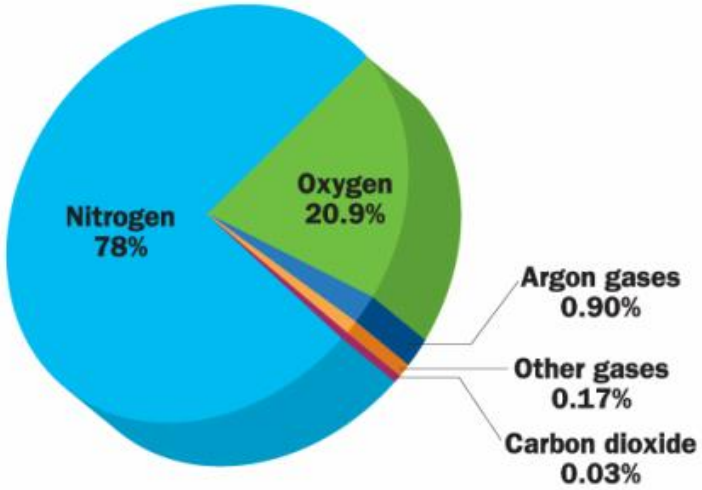
OOK HET STADSKLIMAAT IS HET RESULTAAT VAN EEN ENERGIE BALANS (DIE KAN WORDEN VERSTOORD…)



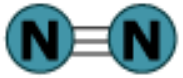
Wong et al. (2021)

PROBLEEM: VERHOOGD BROEIKASEFFECT

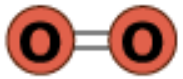
Luchtsamenstelling



Non-infrared-active gasses, 99% of the air



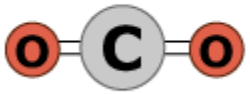
Nitrogen, N_2



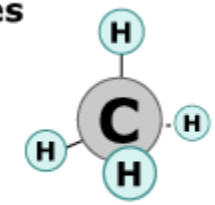
Oxygen, O_2

Infrared-active gases, together <1% of total air

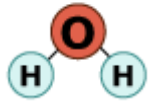
Greenhouse Gases



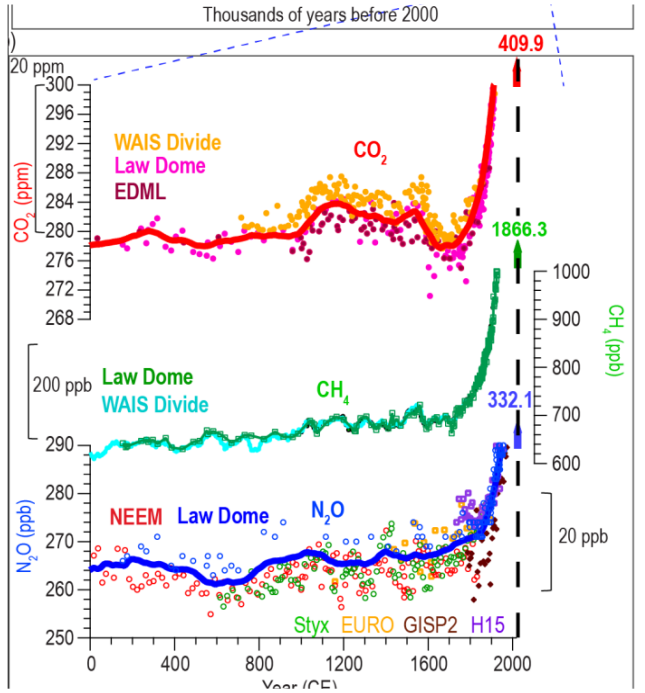
Carbon Dioxide, CO_2



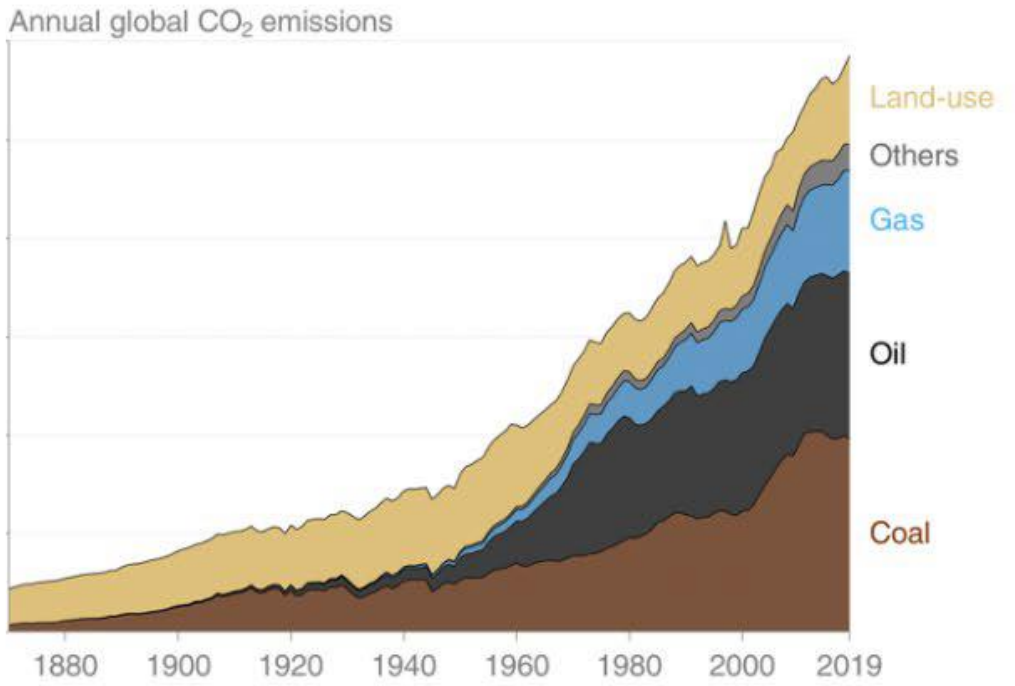
Methane, CH_4



1850:	0,028%	0,00008%	0,000027%	~0,9%
2018:	0,040%	0,00018%	0,000032%	



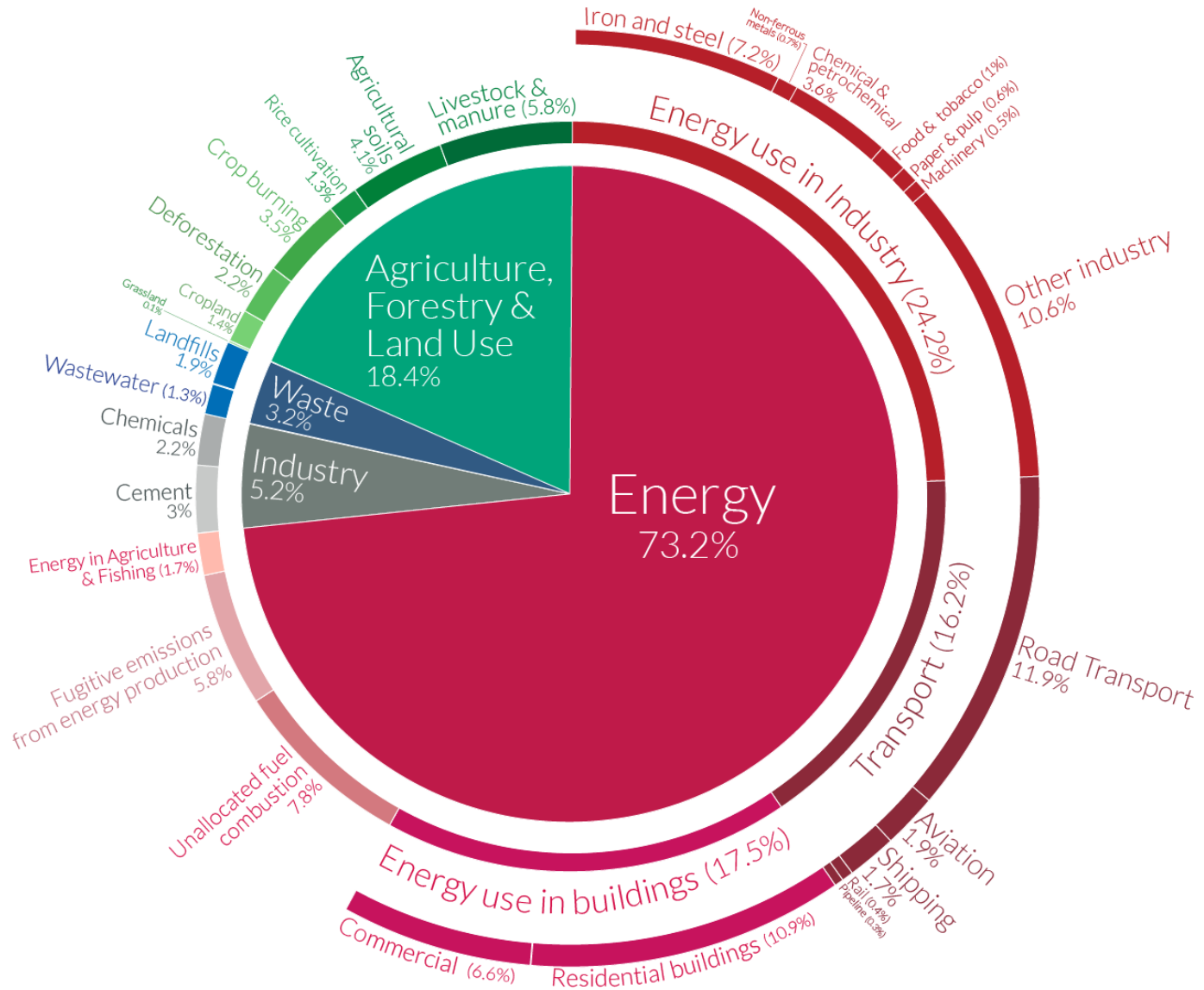
Lage concentratie, MAAR groot effect op stralingsbalans!!



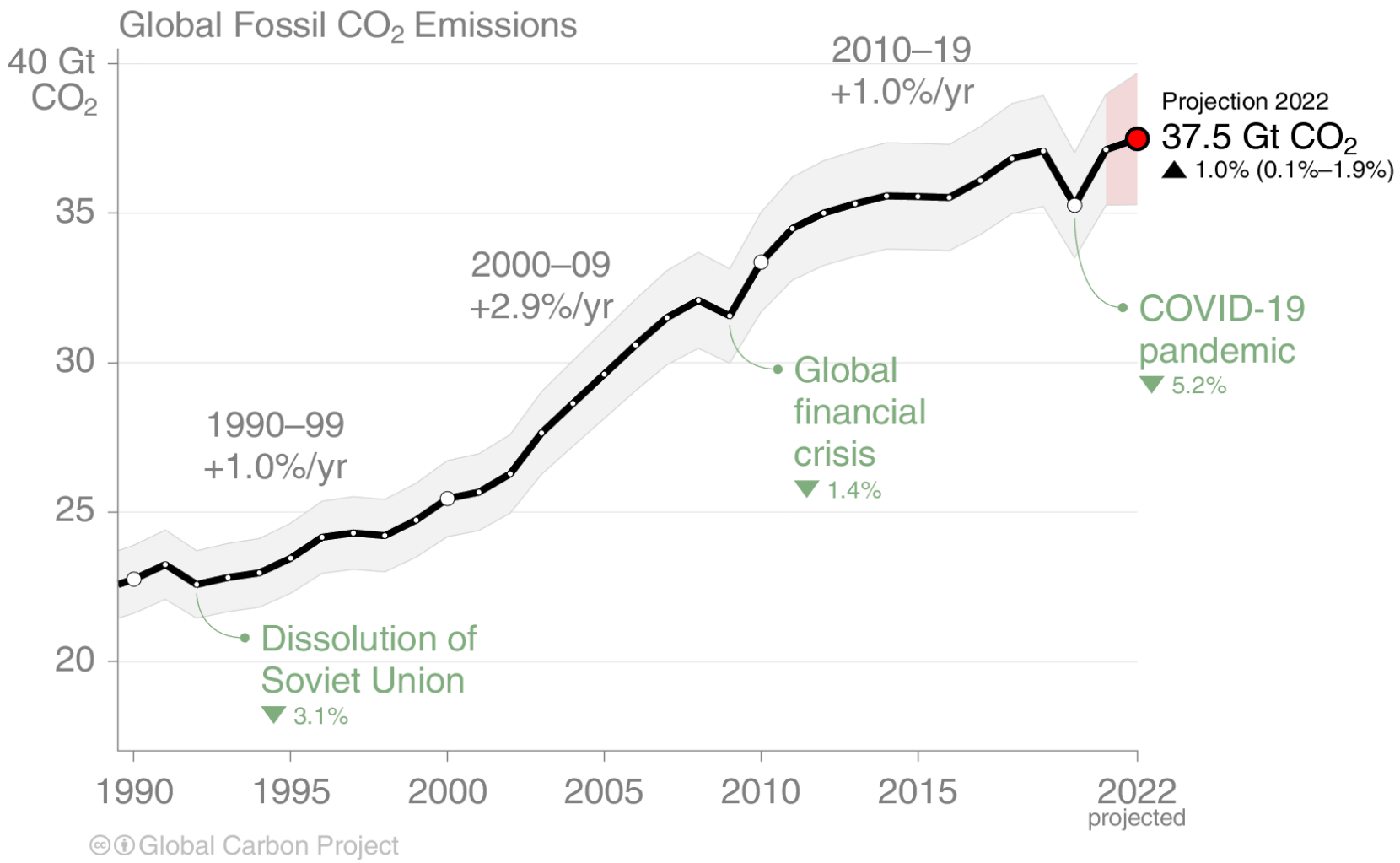
Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data

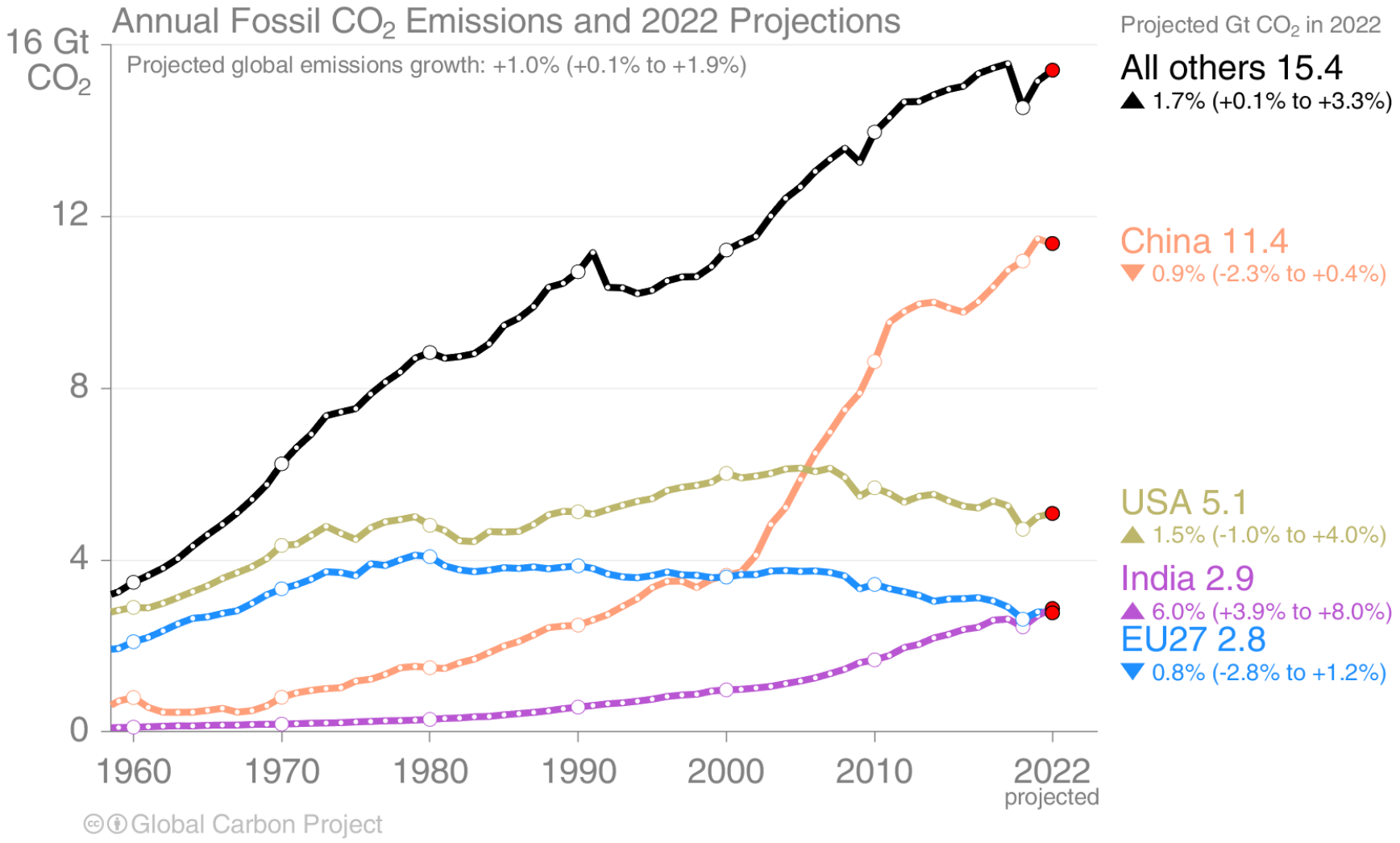


CO_2 emissies wereldwijd sinds 1990



When including cement carbonation, the 2021 and 2022 estimates amount to 36.3 ± 2 $GtCO_2$ and 36.6 ± 2 $GtCO_2$ respectively
The 2022 projection is based on preliminary data and modelling.
Source: Friedlingstein et al 2022; Global Carbon Project 2022

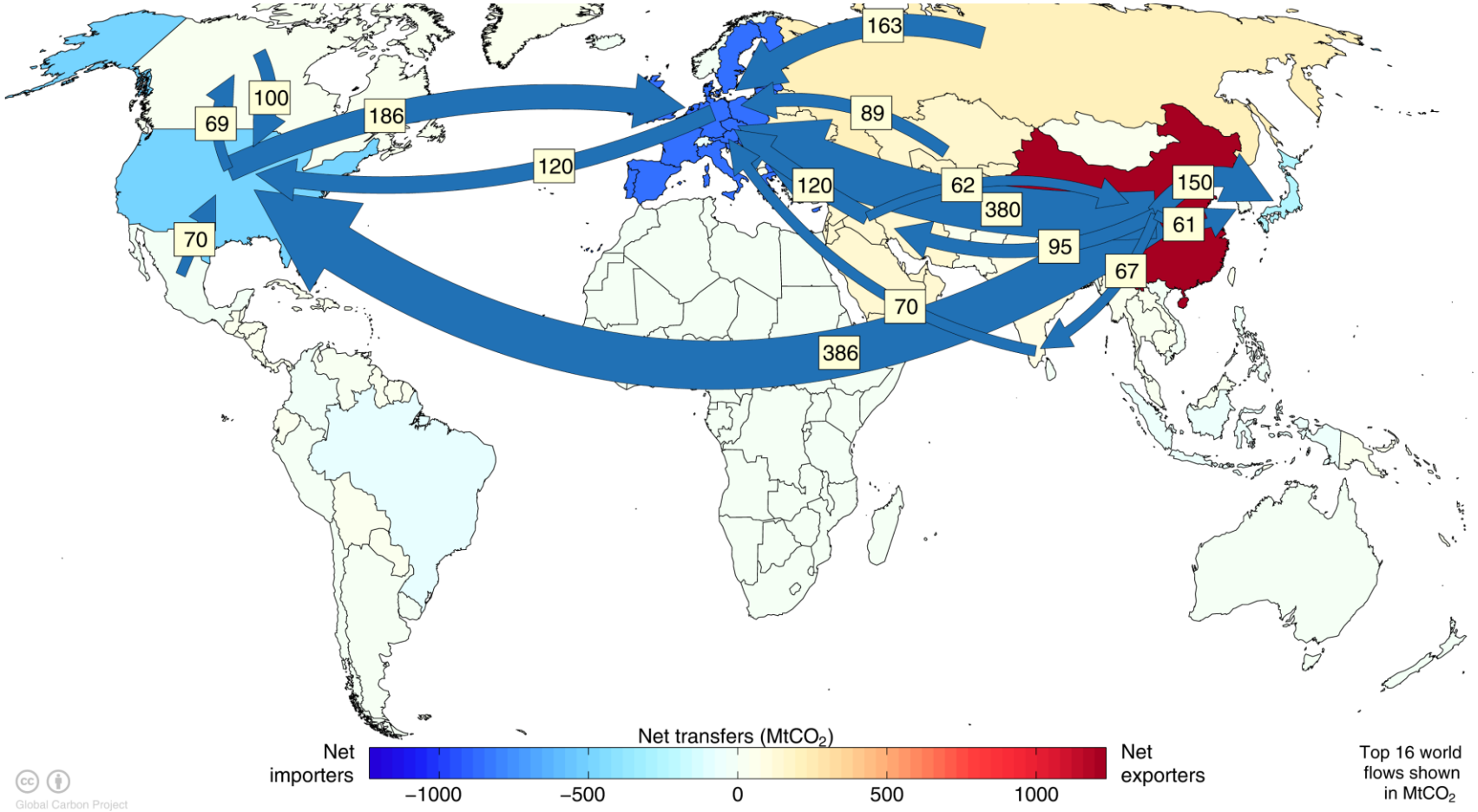
Emissies 1960-2022: totaal + grootste uitstoters



The 2022 projections are based on preliminary data and modelling.
Source: Friedlingstein et al 2022; Global Carbon Project 2022

Stromen van CO_2 productie naar consumptie (2011) – Fossil CO_2

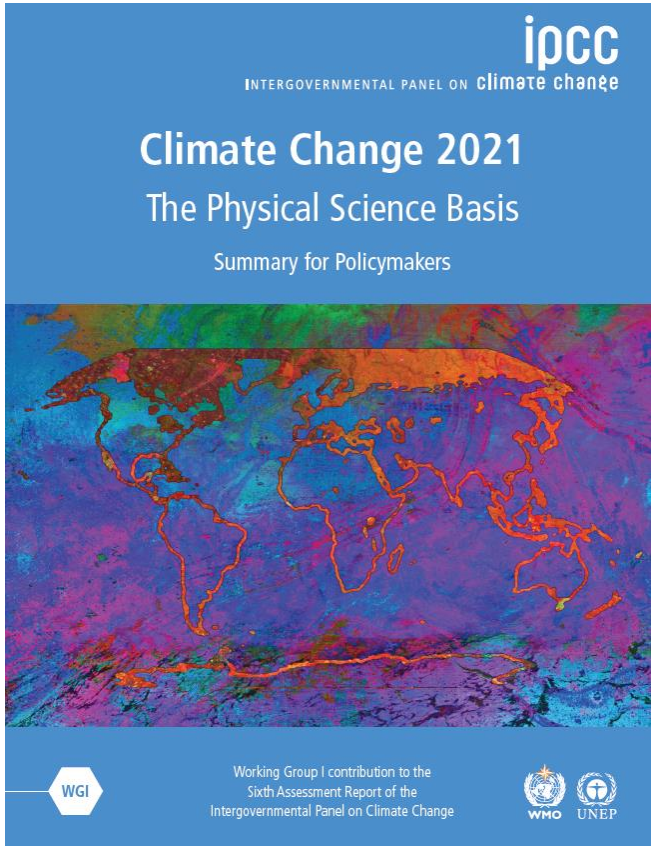
Flows from location of generation of emissions to location of consumption of goods and services



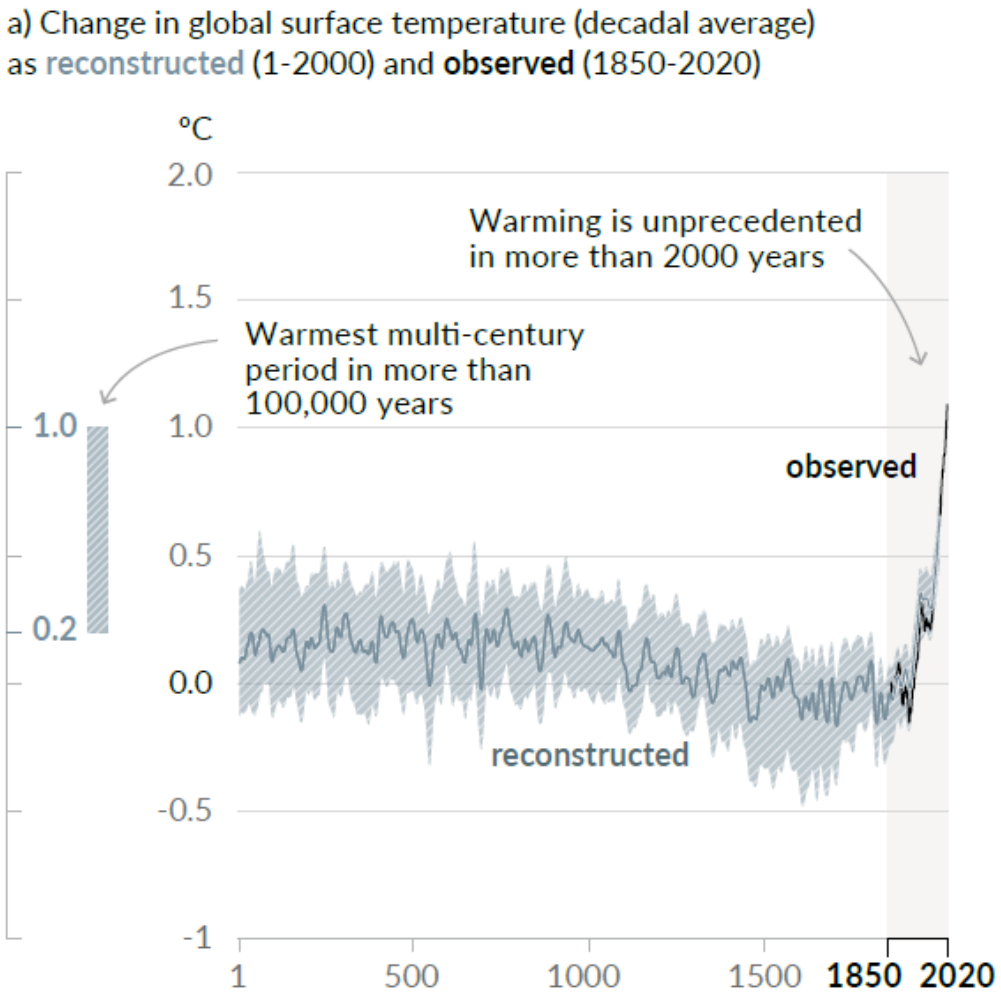
Values for 2011. EU is treated as one region. Units: $MtCO_2$

Source: Peters et al 2012

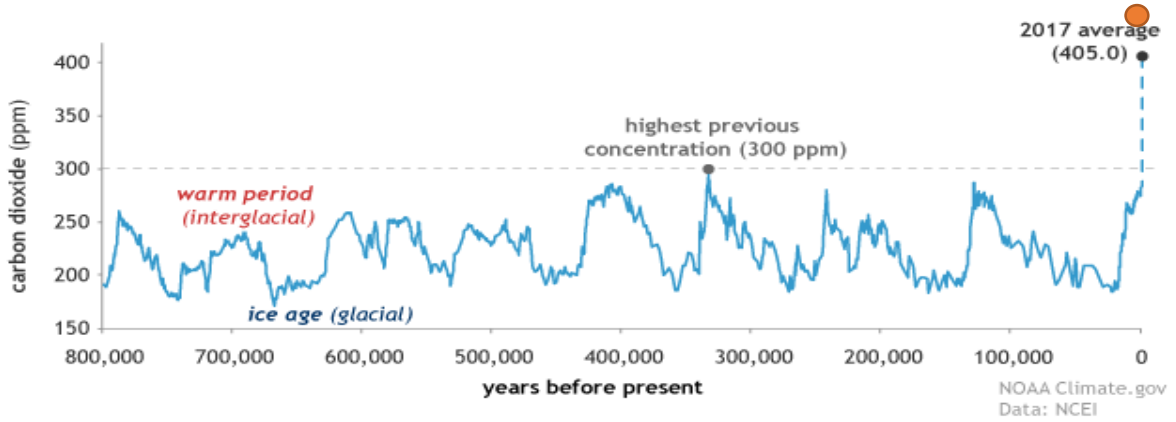
OPWARMING
METINGEN & VOORSPELLINGEN

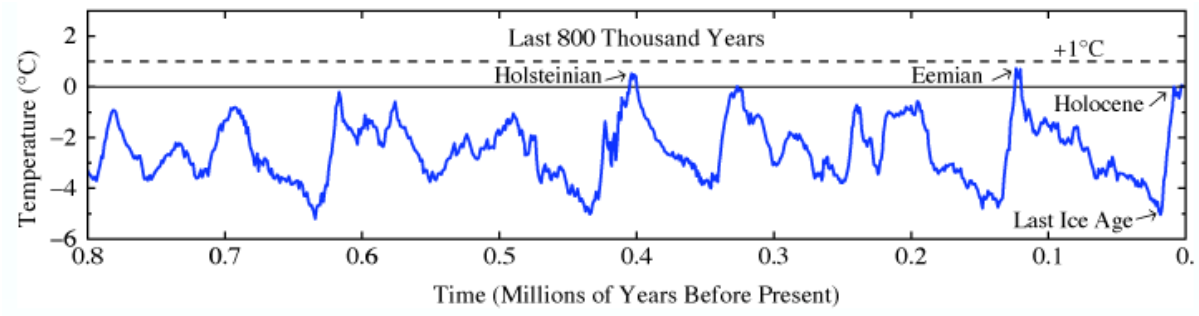


OBSERVATIES: GLOBALE TEMPERATUUR

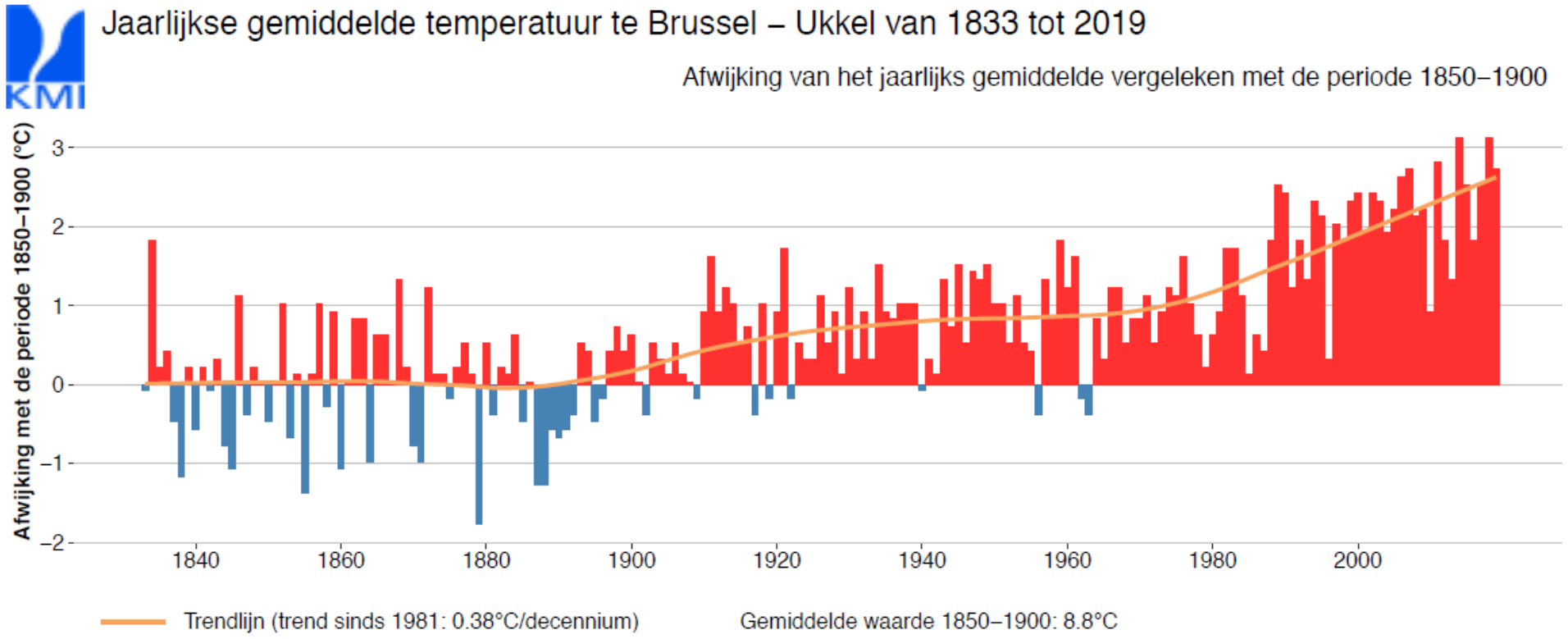


2023: 424 ppm



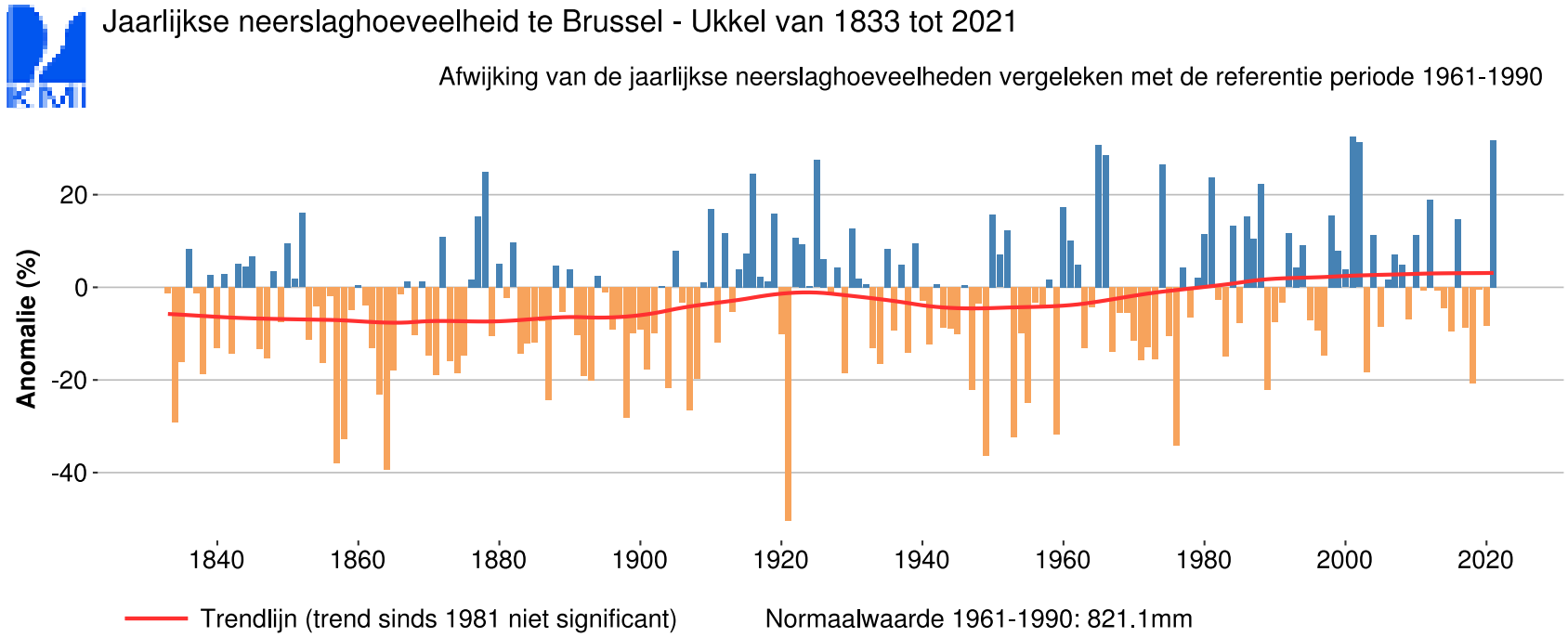


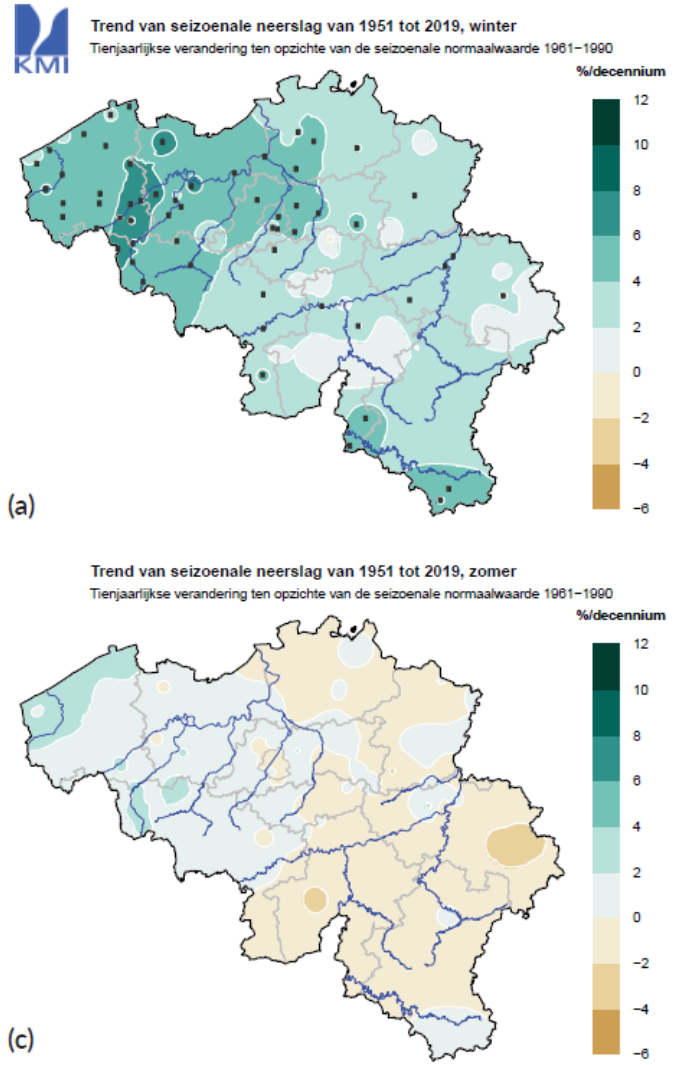
OBSERVATIES: TEMPERATUUR IN BELGIË



Belgium: +2°C, global +1°C

OBSERVATIES: NEERSLAG IN BELGIË

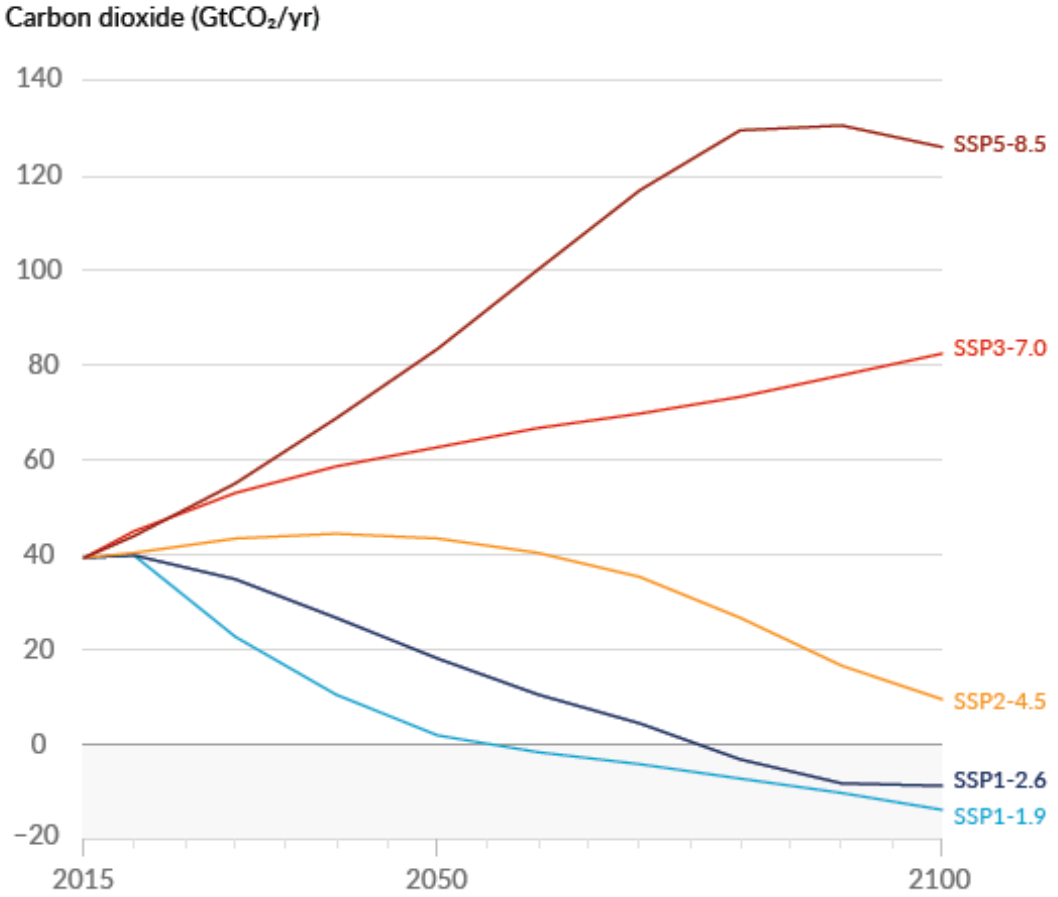




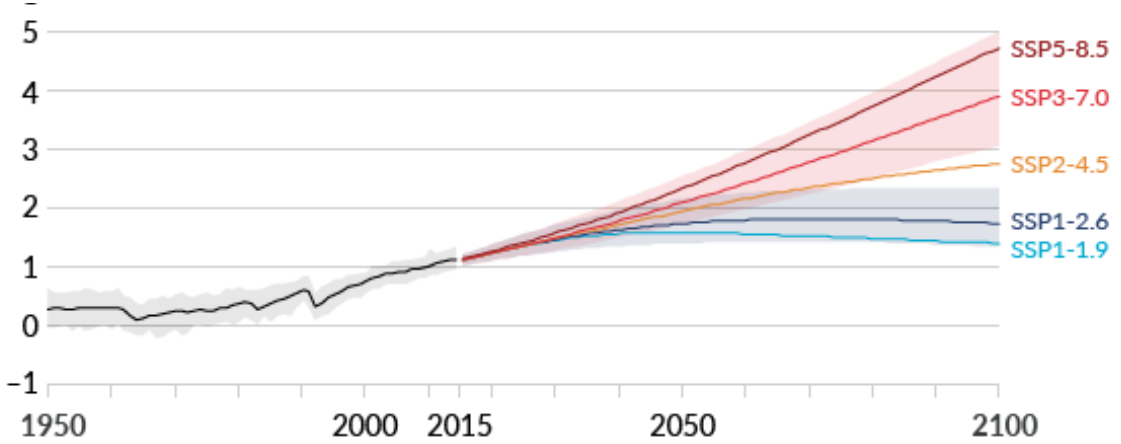
VOORSPELLINGEN

Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

(a) Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios

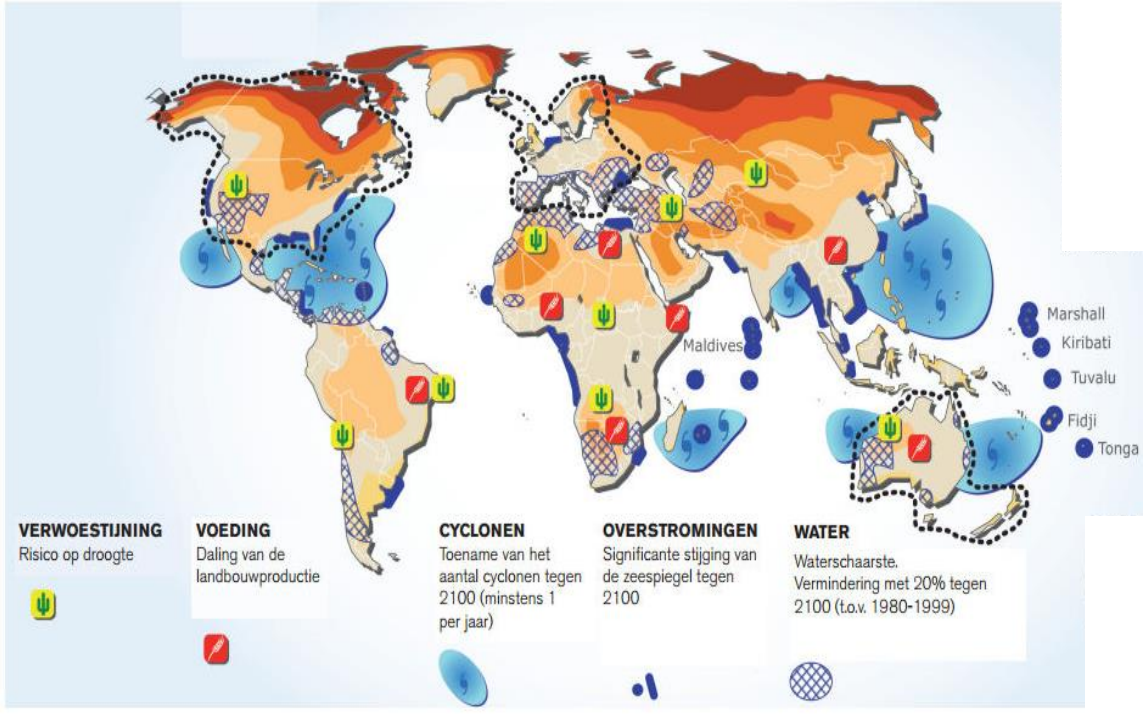


- **Elke ton extra (meer of minder) CO_2 telt!!**
- **Meer extremen**



1°C OPWARMING IS DAT EEN PROBLEEM?

Vooral de toename van extremen heeft een impact!



BUT CITIES ARE AS VULNERABLE AS THEY ARE POWERFUL.

70% of cities are already dealing with the effects of climate change, and nearly all are at risk. Over 90% of all urban areas are coastal, putting most cities on Earth at risk of flooding from rising sea levels and powerful storms.

IMPACTS

Climate change is expected to affect numerous aspects of urban life.

Sea-Level Rise

Two-thirds of cities with populations above 5 million are located in the Low Elevation Coastal Zone. Rising sea levels and storm surge flooding could have widespread effects on populations, property, and ecosystems, presenting threats to commerce, business and livelihoods.

ADAPTATIONS

Responses include: **(A)** improving early warning systems, **(B)** strengthening coastal infrastructure, a significant degree of rezoning (including relocation of critical services), **(C)** and evacuation and crisis response management.

Food Insecurity

All aspects of food security are potentially affected by climate change, including access to food, food utilisation and price stability. Climate change is likely to cause food production in some regions (including the ocean due to warming and acidification) to decline.

ADAPTATIONS

Local responses include support for urban and peri-urban agriculture, **(D)** green roofs, local markets and enhanced social (food) safety nets. **(E)** Develop alternative food sources, including inland aquaculture, to replace ocean-based resources under threat.

Freshwater Availability

Risks to freshwater resources, such as drought, can cause shortages of drinking water, electricity outages, water-related diseases (through use of contaminated water), higher food prices and increased food insecurity from reduced agricultural supplies.

ADAPTATIONS

Options include **(J)** encouraging water recycling and grey water use, improving runoff management and developing new/alternative water sources, **(K)** storage facilities and autonomously powered water management and treatment infrastructure.

Extreme Weather Events

Changes in extreme rainfall could cause the amount of sewage released to the environment from combined sewage overflow spills and flooding to increase by 40% in some cities. Inland flooding is often made worse by uncontrolled city development.

ADAPTATIONS

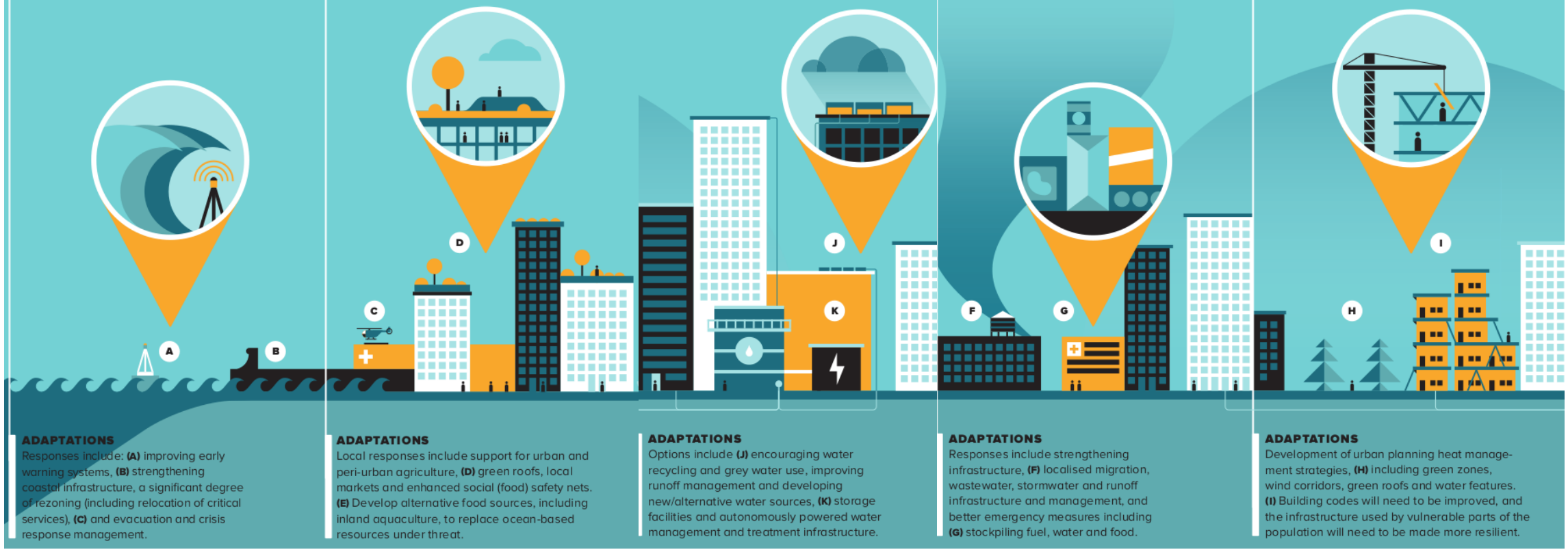
Responses include strengthening infrastructure, **(F)** localised migration, wastewater, stormwater and runoff infrastructure and management, and better emergency measures including **(G)** stockpiling fuel, water and food.

Increased Temperatures

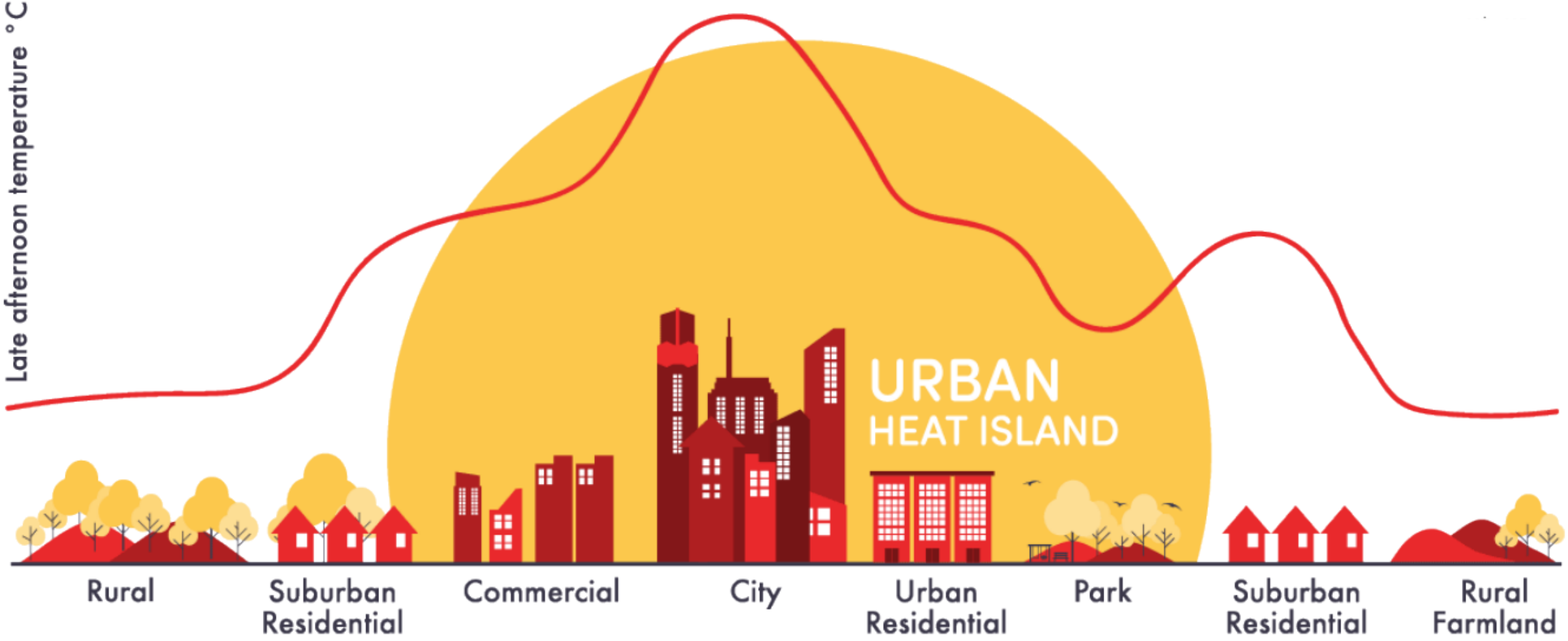
The mean temperature rise in some cities could be over 4°C by 2100, with peak seasonal temperatures even higher. More hot days will exacerbate urban heat island effects, resulting in more heat-related health problems and, possibly, air pollution.

ADAPTATIONS

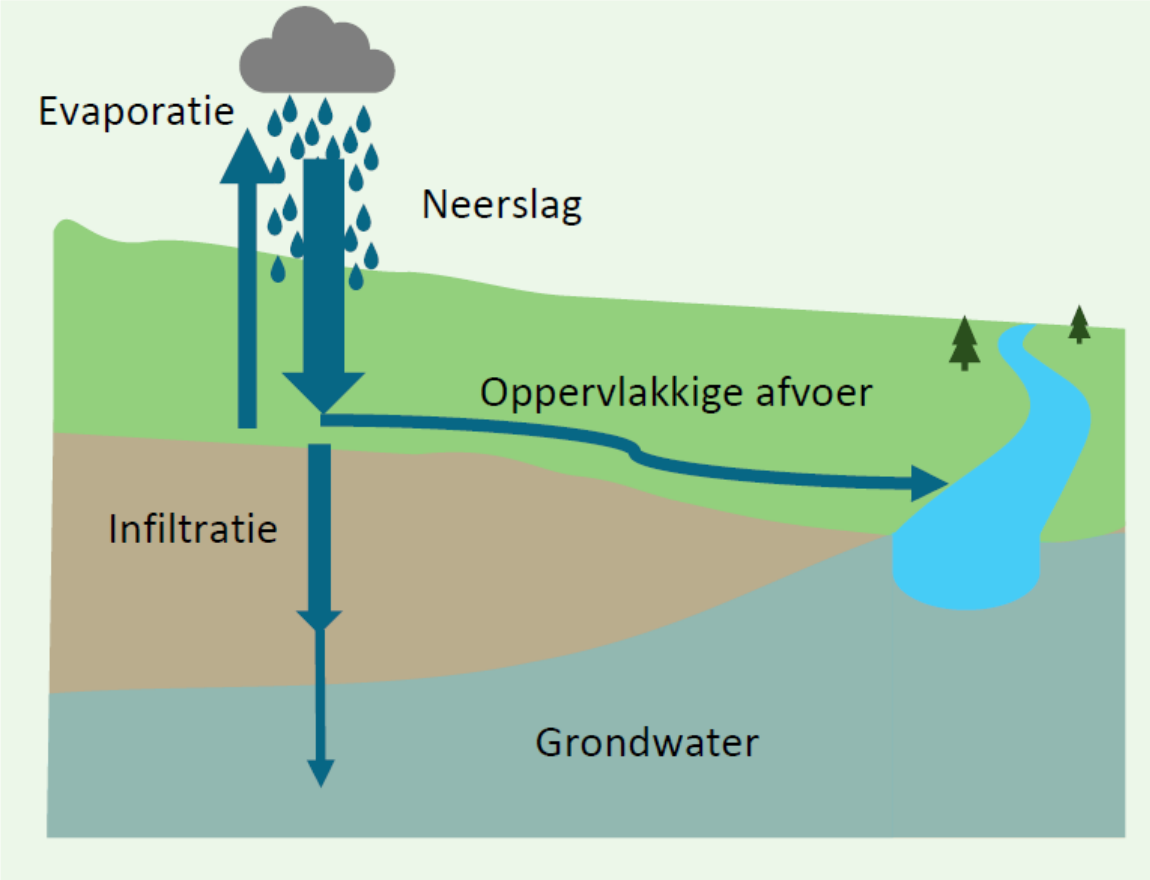
Development of urban planning heat management strategies, **(H)** including green zones, wind corridors, green roofs and water features. **(I)** Building codes will need to be improved, and the infrastructure used by vulnerable parts of the population will need to be made more resilient.

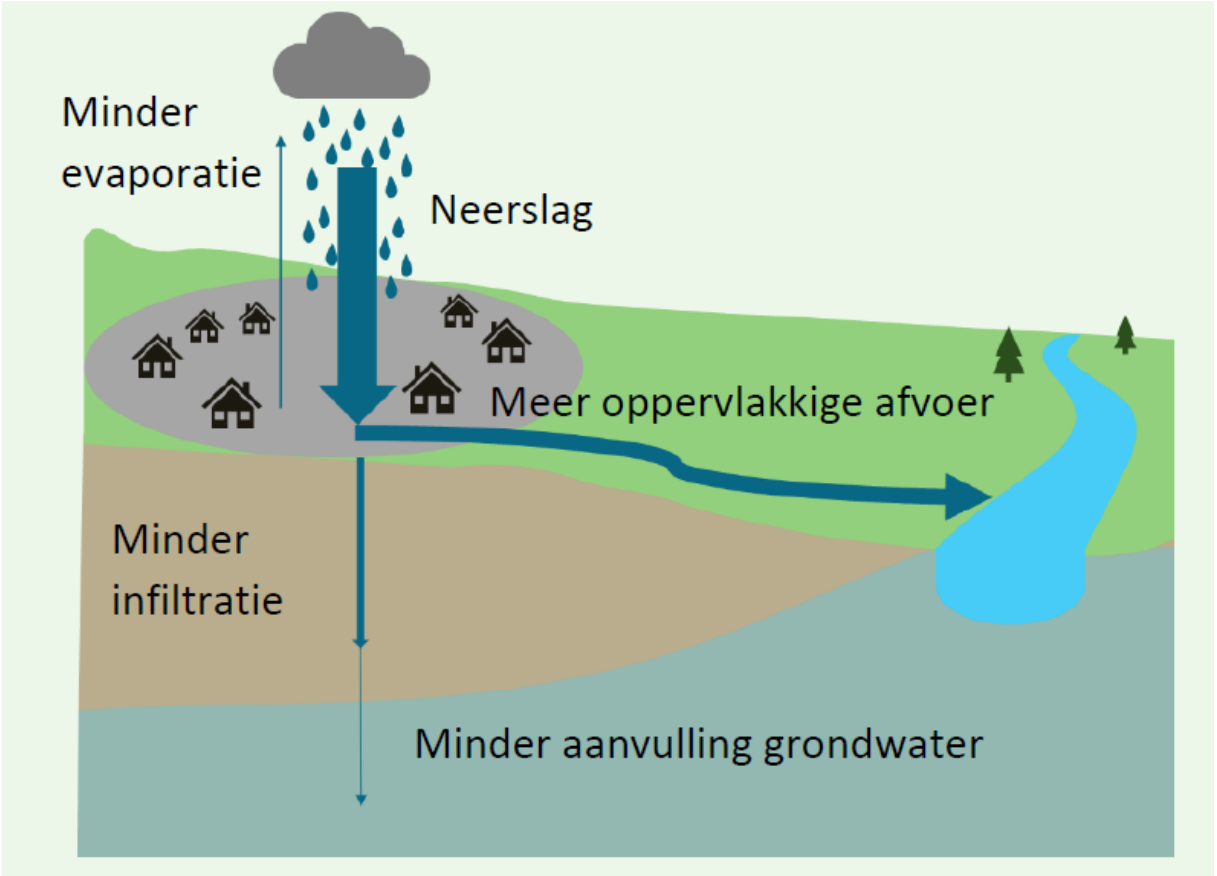


STEDELIJK HITTE-EILAND

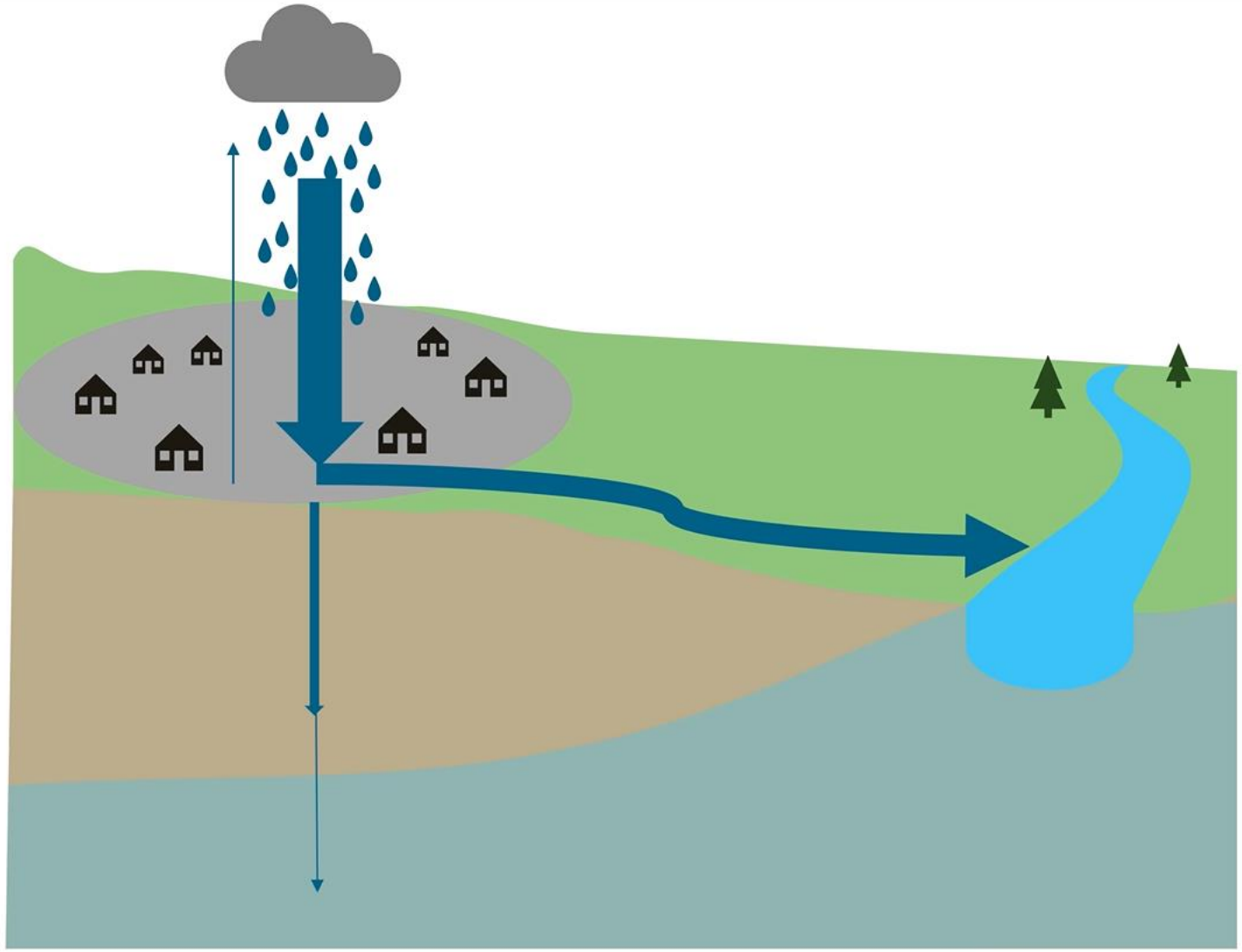


VERDICHTING VERANDERT DE WATERBALANS





VERDICHTING VERHOOGT DE GEVOELIGHEID VOOR EXTREMEN



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  - Sources and sinks: fossiele emissies, ontbossing
  - Impact van klimaatverandering op stadsecosystemen

- **Stadsbomen een nature-based solution voor klimaatrobuste steden**
  - Mitigatie
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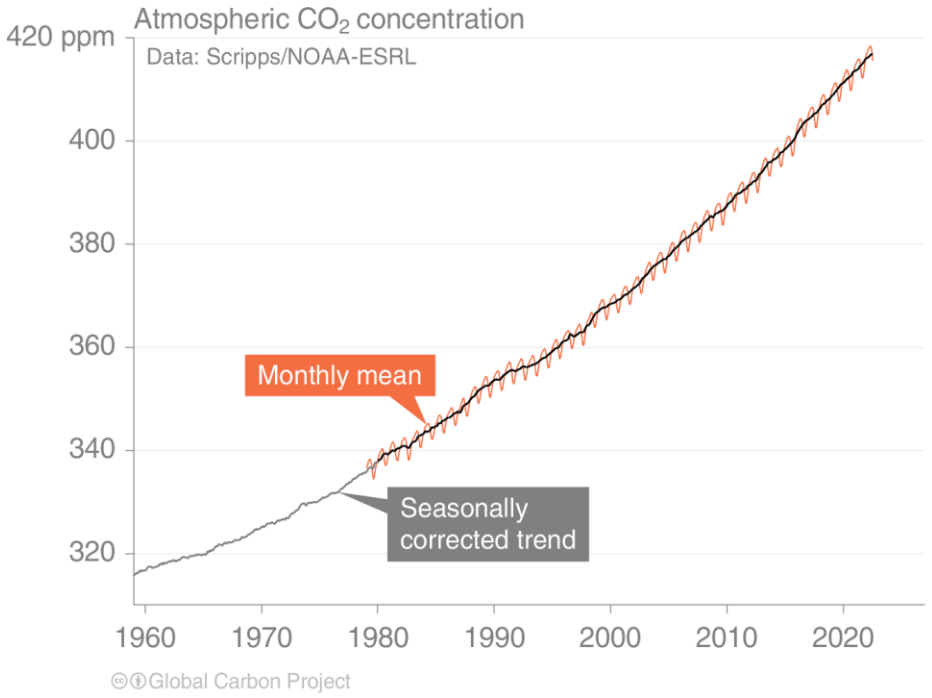
ECOSYSTEMEN OP HET LAND NEMEN MASSAAL CO_2 OP

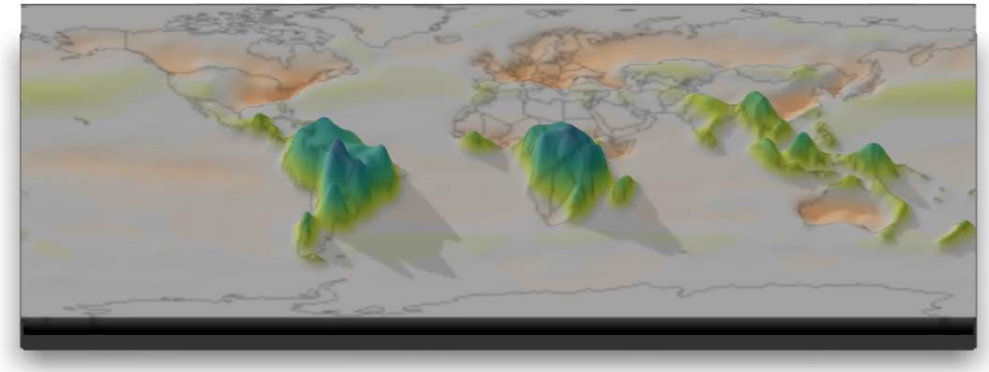
http://www.nasa.gov/press/goddard/2014/november/nasa-computer-model-provides-a-new-portrait-of-carbon-dioxide/#.VrIZ4EYnJpZ

THE KEELING CURVE

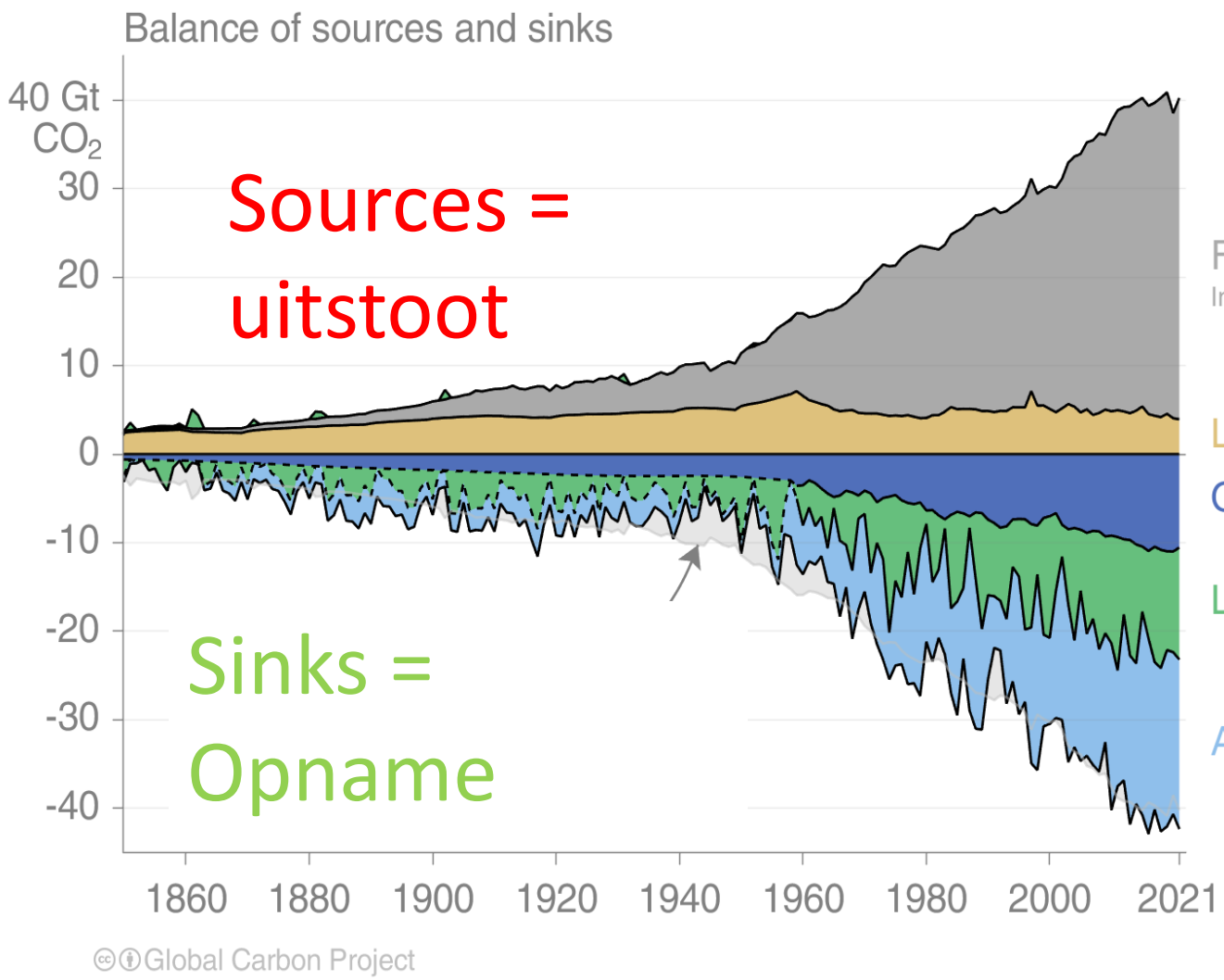
Charles Keeling, sinds 1958, Mauna Loa, 3396 m



January



Globale koolstof (C) budget



Fossil carbon
Includes carbonation sink

Land-use change

Ocean sink

Land sink

Atmosphere

89%

11%

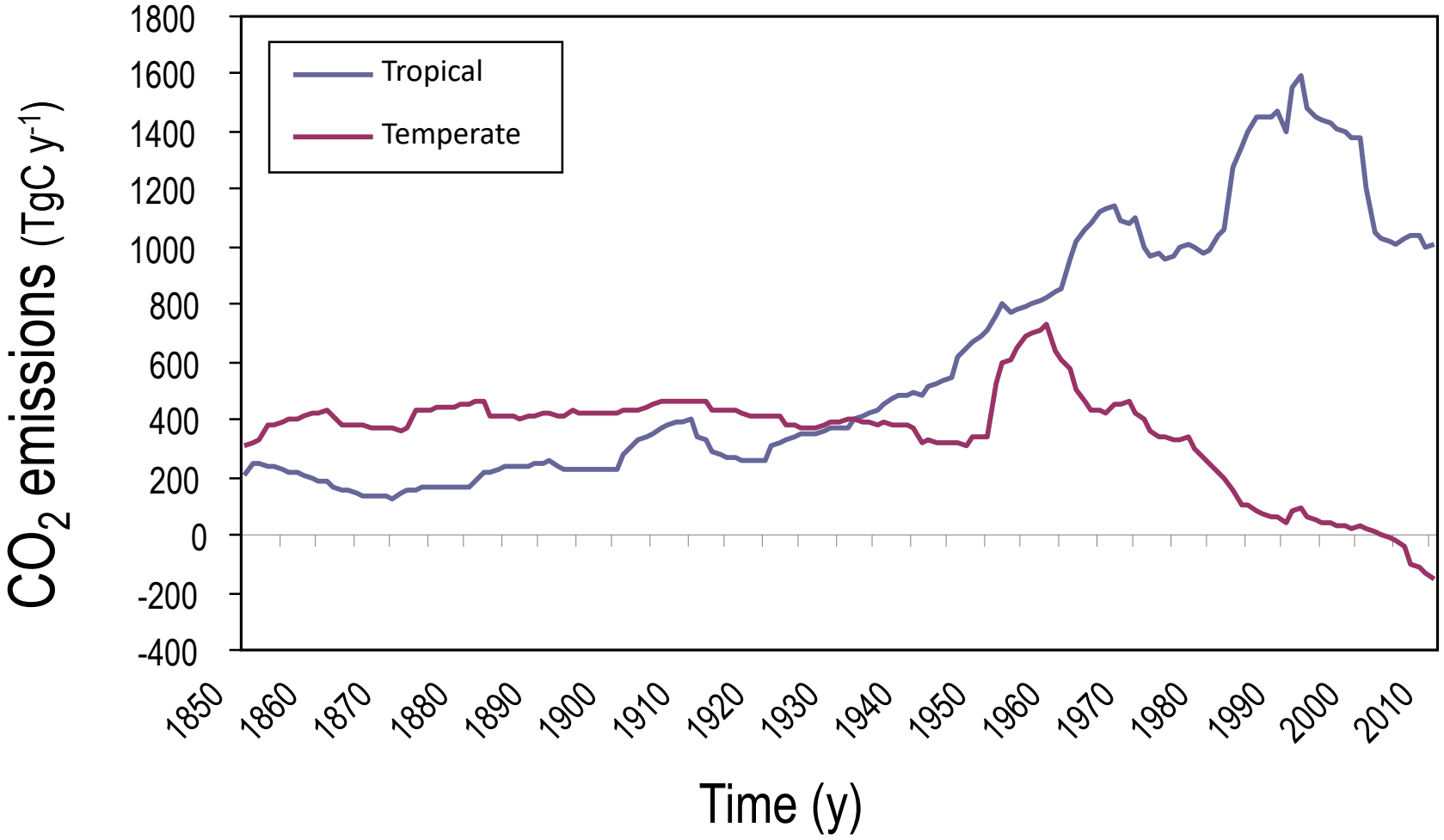
26%

29%

48%

Source: Friedlingstein et al 2022; Global Carbon Project 2022

TROPISCHE ONTBOSSING

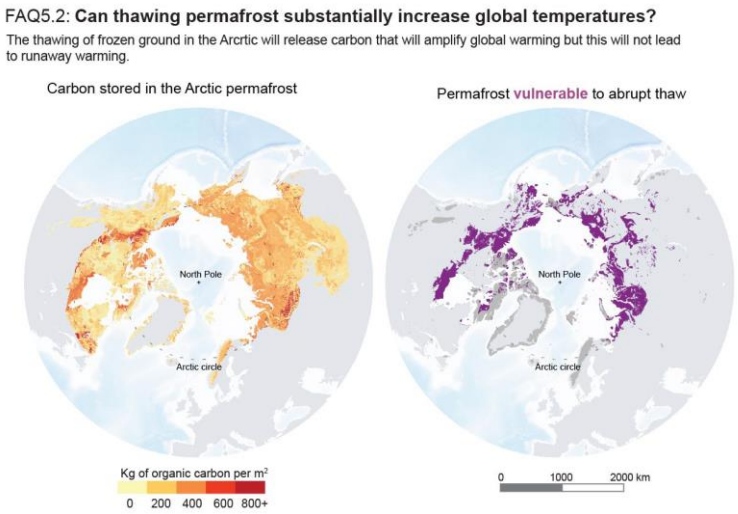


R.A. Houghton 2010, personal communication; GFRA 2010

IMPACT VAN KLIMAATVERANDERING

ZAL HET LAND JAARLIJKS 30% VAN ONZE UITSTOOT BLIJVEN OPNEMEN?

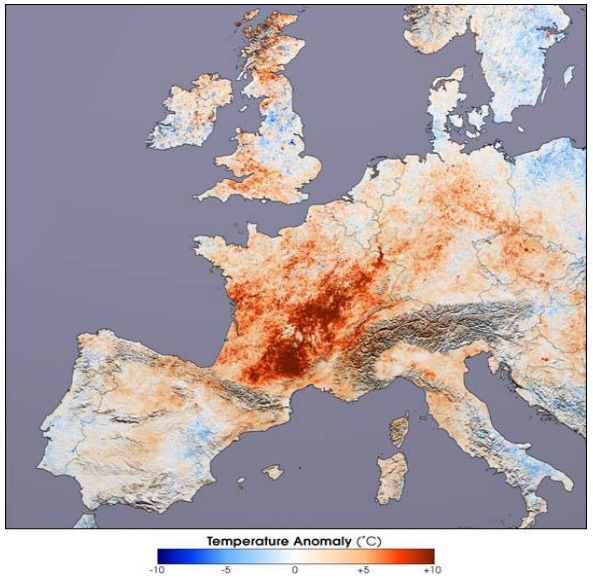
Ontdooien van de permafrost



Meer natuurbranden

“Greening” in het Noorden

Droogtes en hittegolven



IMPACT VAN KLIMAATVERANDERING

HOE GEVOELIG ZIJN STEDELIJKE ECOSYSTEMEN EN STADSBOMEN VOOR DE KLIMAATVERANDERING?

- Hitte eiland
- Water balans
- Meer extremen
- …

ARTICLES
https://doi.org/10.1038/s41558-022-01465-8
nature climate change
Check for updates

Climate change increases global risk to urban forests

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Climate change threatens the health and survival of urban trees and the various benefits they deliver to urban inhabitants. Here, we show that 56% and 65% of species in 164 cities across 78 countries are currently exceeding temperature and precipitation conditions experienced in their geographic range, respectively. We assessed 3,129 tree and shrub species, using three metrics related to climate vulnerability: exposure, safety margin and risk. By 2050 under Representative Concentration Pathway 6.0, 2,387 (76%) and 2,220 (70%) species will be at risk from projected changes in mean annual temperature and annual precipitation, respectively. Risk is predicted to be greatest in cities at low latitudes—such as New Delhi and Singapore—where all urban tree species are vulnerable to climate change. These findings aid the evaluation of the impacts of climate change to secure long-term benefits provided by urban forests.

INHOUD

- **Planetaire grenzen en klimaatverandering**
  - Klimaatopwarming: mechanisme, broaikasgassen
  - Observaties: opwarming en impact op steden
  - Voorspellingen: modellen, onzekerheden
  - Impact van klimaatverandering op steden

- **De biosfeer**
  - De globale C cyclus
  - Sources and sinks: fossiele emissies, ontbossing
  - Impact van klimaatverandering op stadsecosystemen

- **Stadsbomen een nature-based solution voor klimaatrobuste steden**
  - Mitigatie
  - Adaptatie
  - Ons onderzoek

NATURE-BASED SOLUTIONS

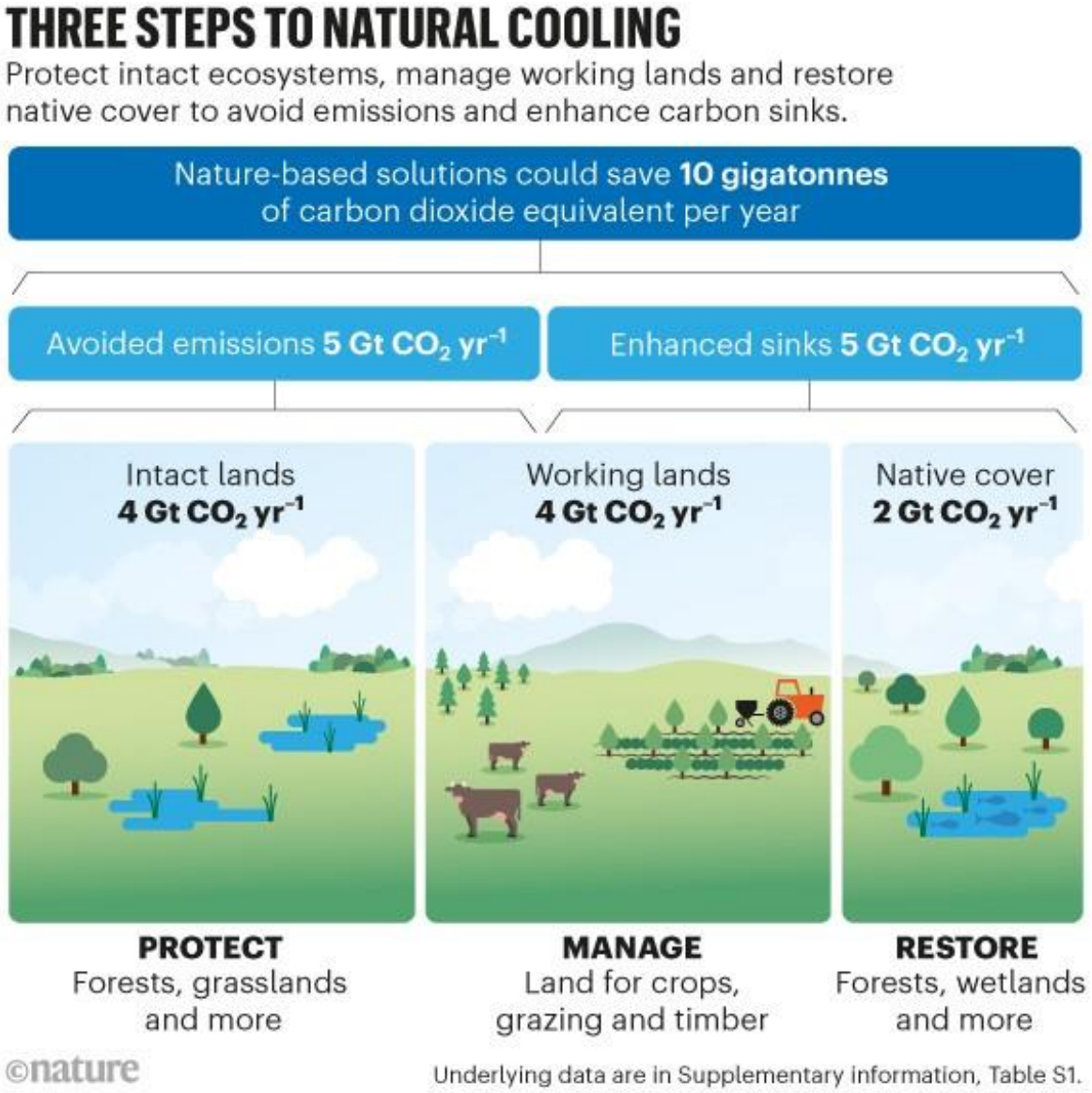
"mitigation aims to avoid the unmanageable and adaptation aims to manage the unavoidable"

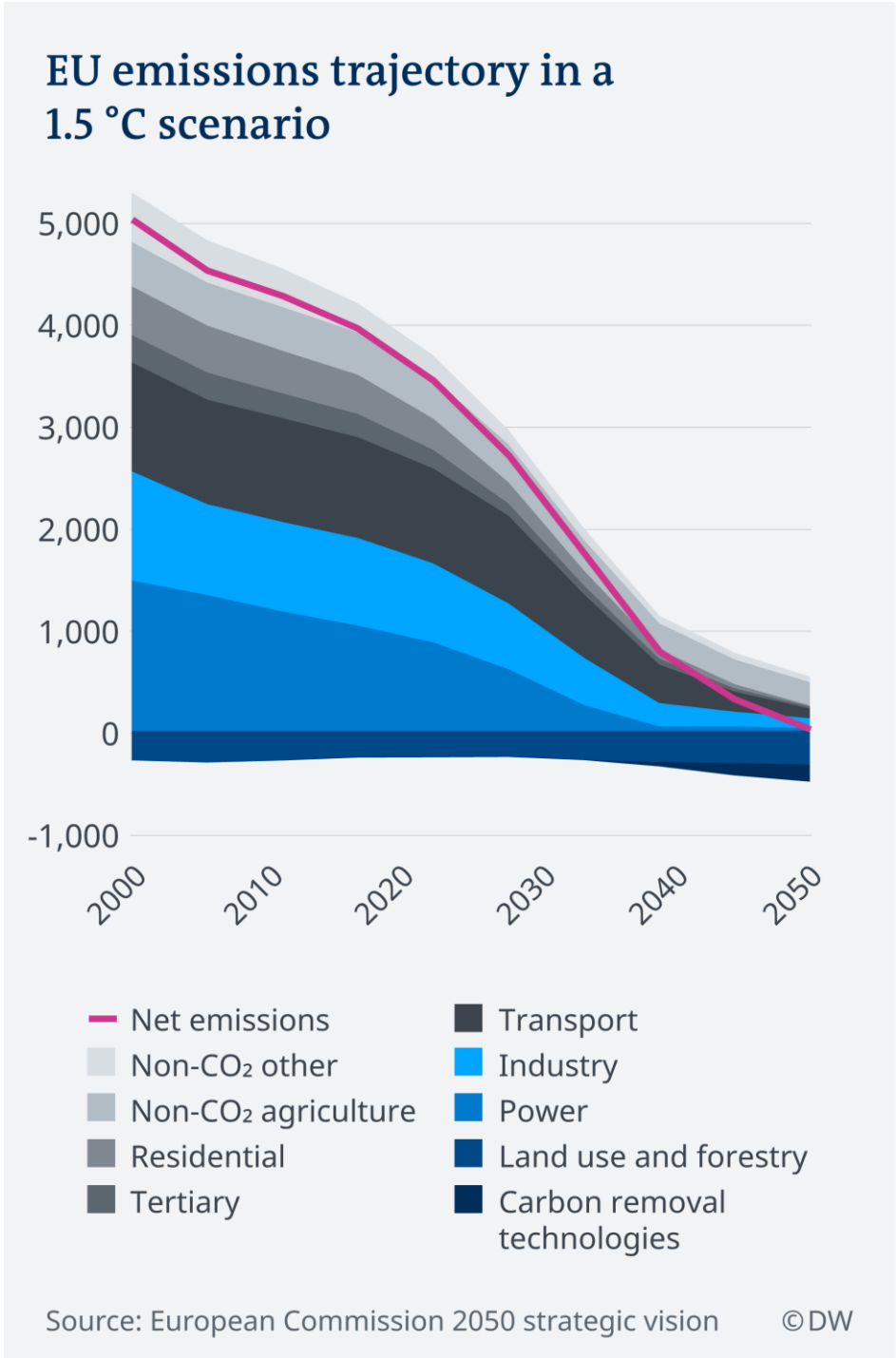
(Laukkonen et al. 2009)

Mitigatie = onze inspanningen om de antropogene klimaatverandering te beperken.

Adaptatie = aanpassing in natuurlijke of menselijke systemen als reactie op actuele of verwachte klimaatverandering …

NATURE-BASED MITIGATIE: COMBINATIE VAN BESCHERMING, BEHEER EN HERSTEL

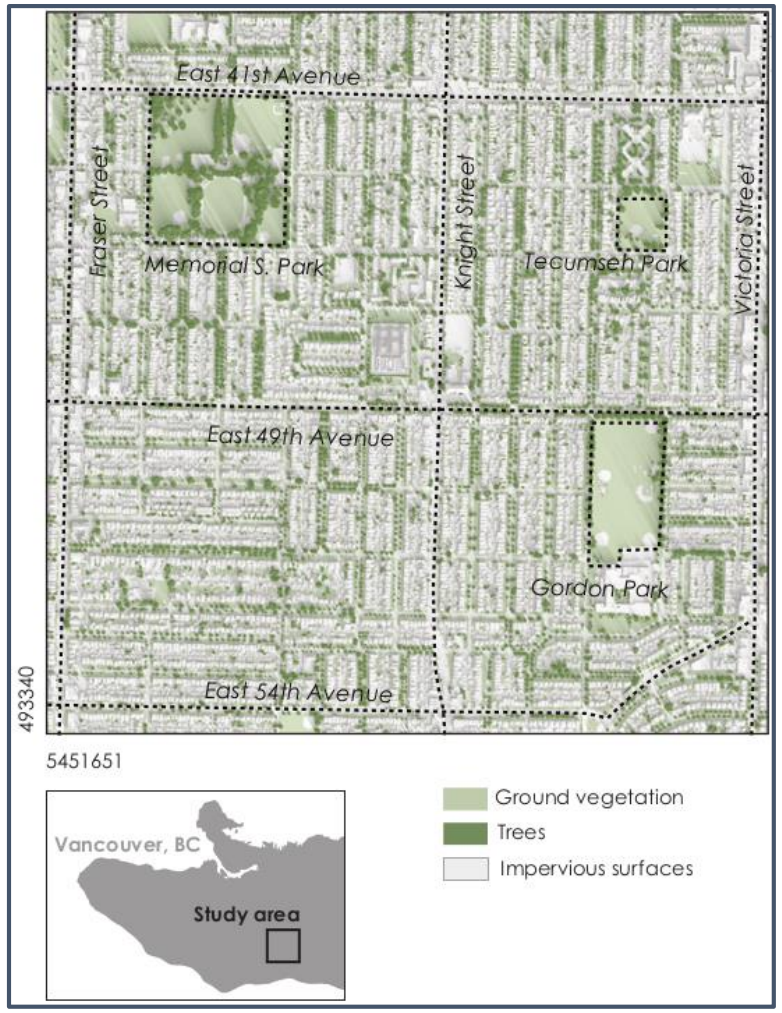


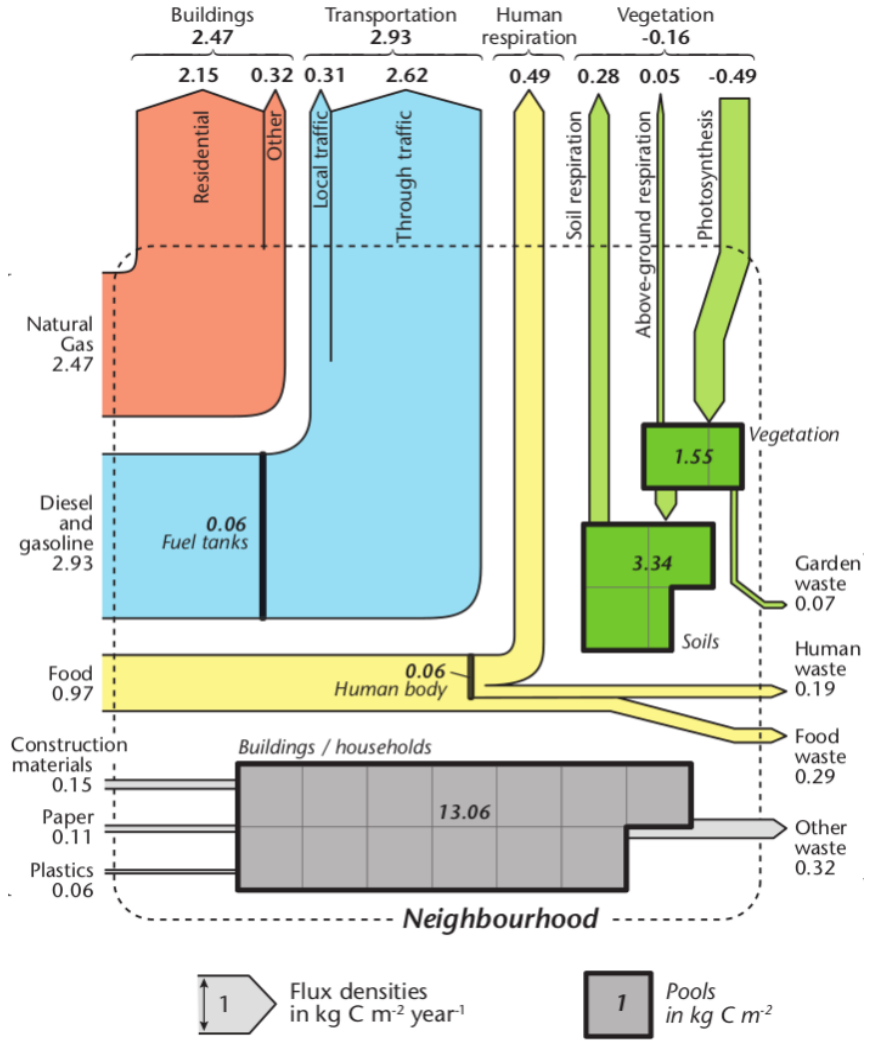


BOMEN PLANTEN: EEN INVESTERING OP LANGE TERMIJN

- De bossen die we vandaag planten zullen onze emmissie van de komende 20 jaar **niet** compenseren
- Het planten van bossen brengt de eindmeet dichterbij (net zero)
- Bossen blijven actief na ‘net zero’, belang voor verdere afkoeling na 2050
- We moeten dus bossen planten volgens dit lange termijn perspectief

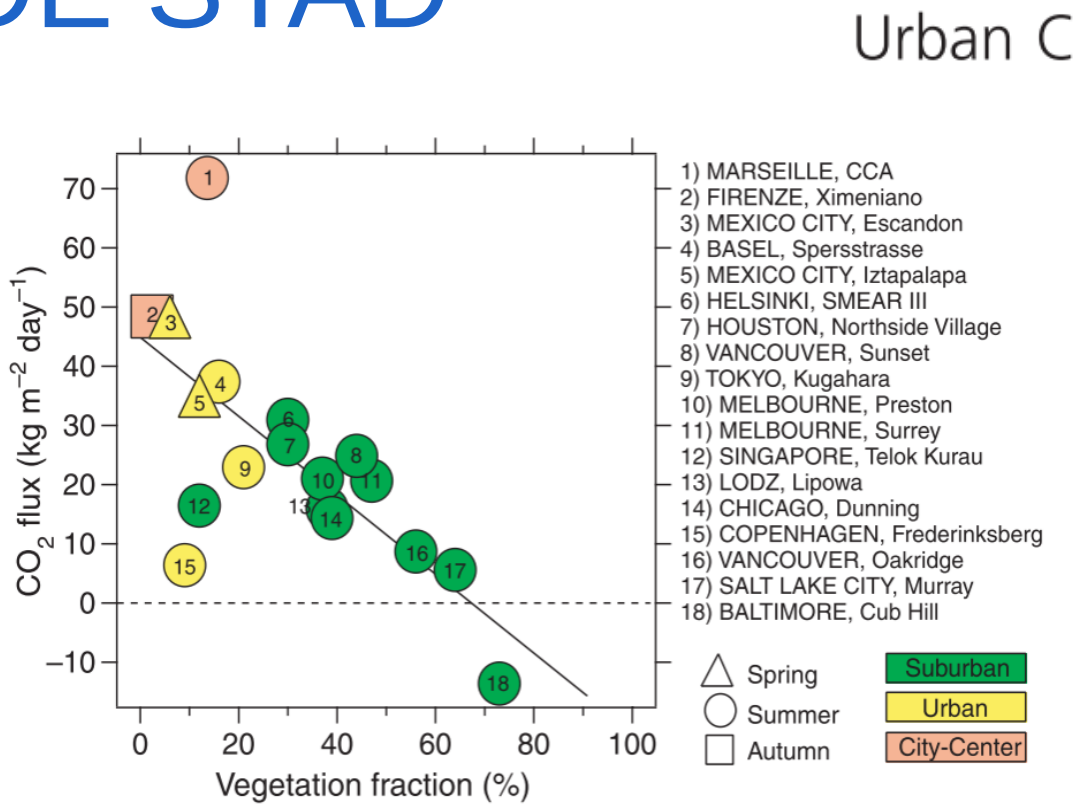
STADSBOMEN MAKEN GEEN C-SINK VAN DE STAD





Kellet et al. (2013)

STADSBOMEN MAKEN GEEN C-SINK VAN DE STAD



Velasco & Roth (2010)

MAAR ELKE TON CO2 TELT!!!

Terrestrial laser scanning can produce high resolution point clouds of forests.

Bomen tellen in Gent

Gentse bomen voor het eerst geteld

(28-06-2021) In Gent groeien 262.863 bomen die hoger zijn dan 4 meter. Deze gegevens zijn belangrijk in de strijd tegen de klimaatverandering.

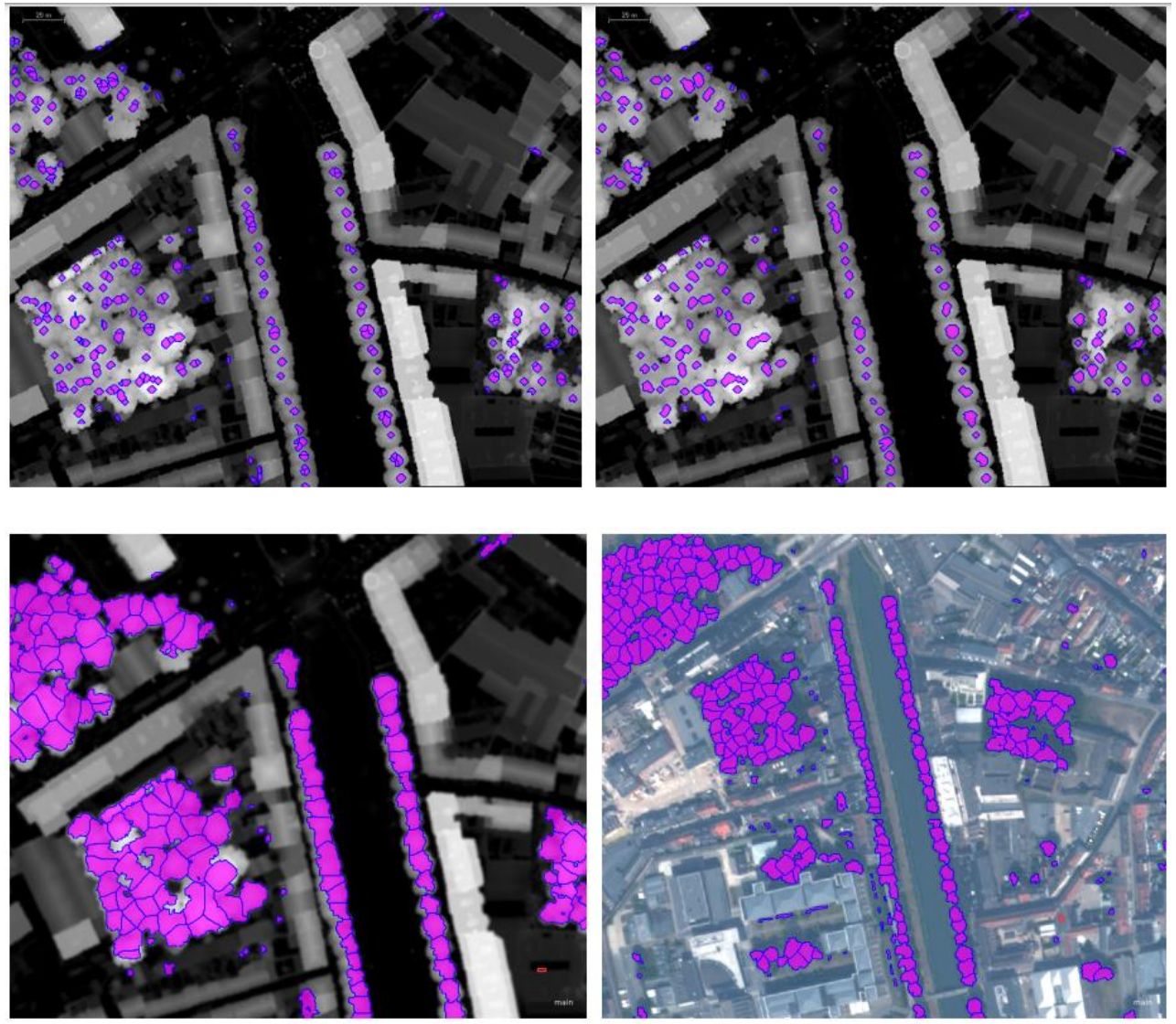
Bio-ingenieurstudent Jasper Meert (UGent) telde de bomen voor zijn thesis, aan de hand van satellietbeelden en data van 3D-laserscanning.

Een jaar geleden zou Jasper voor zijn thesis naar Ecuador trekken, om er onderzoek te doen naar herbebossing. Corona besliste er anders over. Als alternatief ging hij in Gent aan de slag: hij ontwikkelde een methode die op basis van verschillende gegevens bomen automatisch kan tellen én hun volume kan schatten. Via deze methode kon hij voor het eerst alle Gentse bomen tellen: zowel straatbomen, parkbomen als alle bomen op privéterrein.

"Deze resultaten zijn belangrijk voor onze strijd tegen de klimaatverandering", legt de bio-ingenieur in spe uit. "Bomen bieden verkoeling en helpen de opwarming af te remmen, omdat ze CO_2 opnemen."

Bomen tellen in Gent

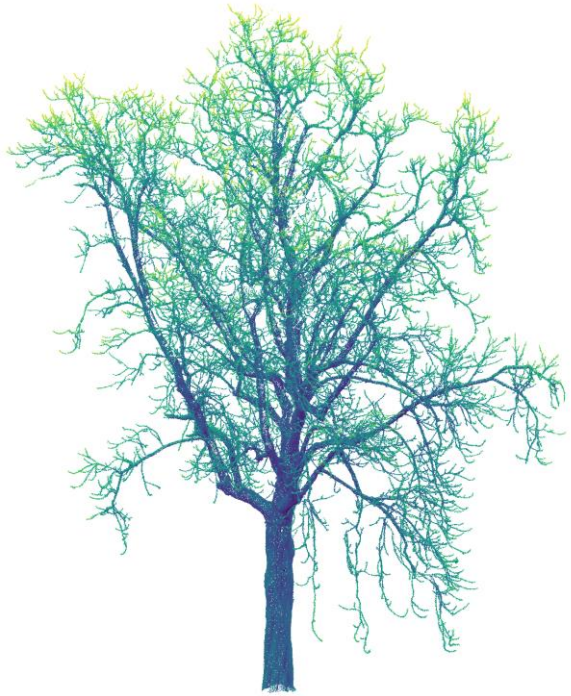
- Airborne laser scanning data + Worldview
- NDVI + Canopy Height Model
- Local Maxima Filtering + Region Growing



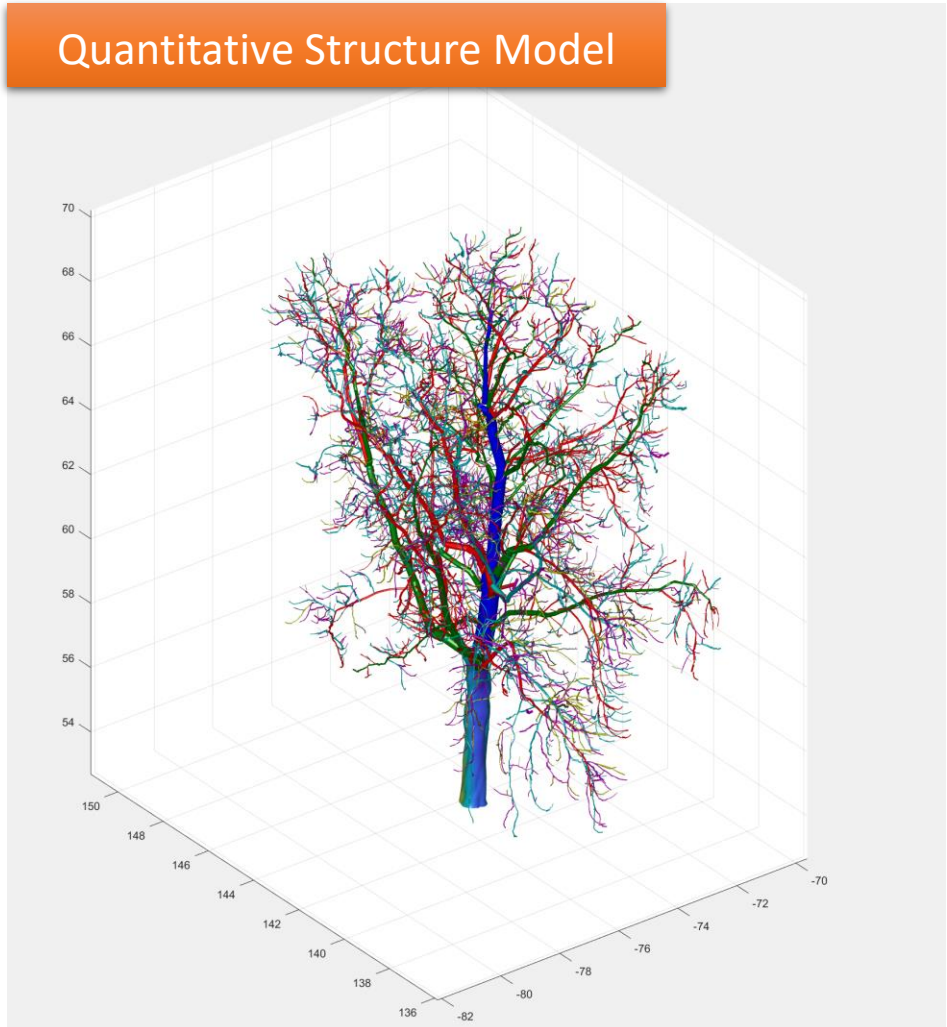
Biomassa in Gent

- Terrestrial laser scanning (zonder blad) -> biomassa

Point cloud



Quantitative Structure Model



CASE: Paul De Smet de Naeyerpark in Gent

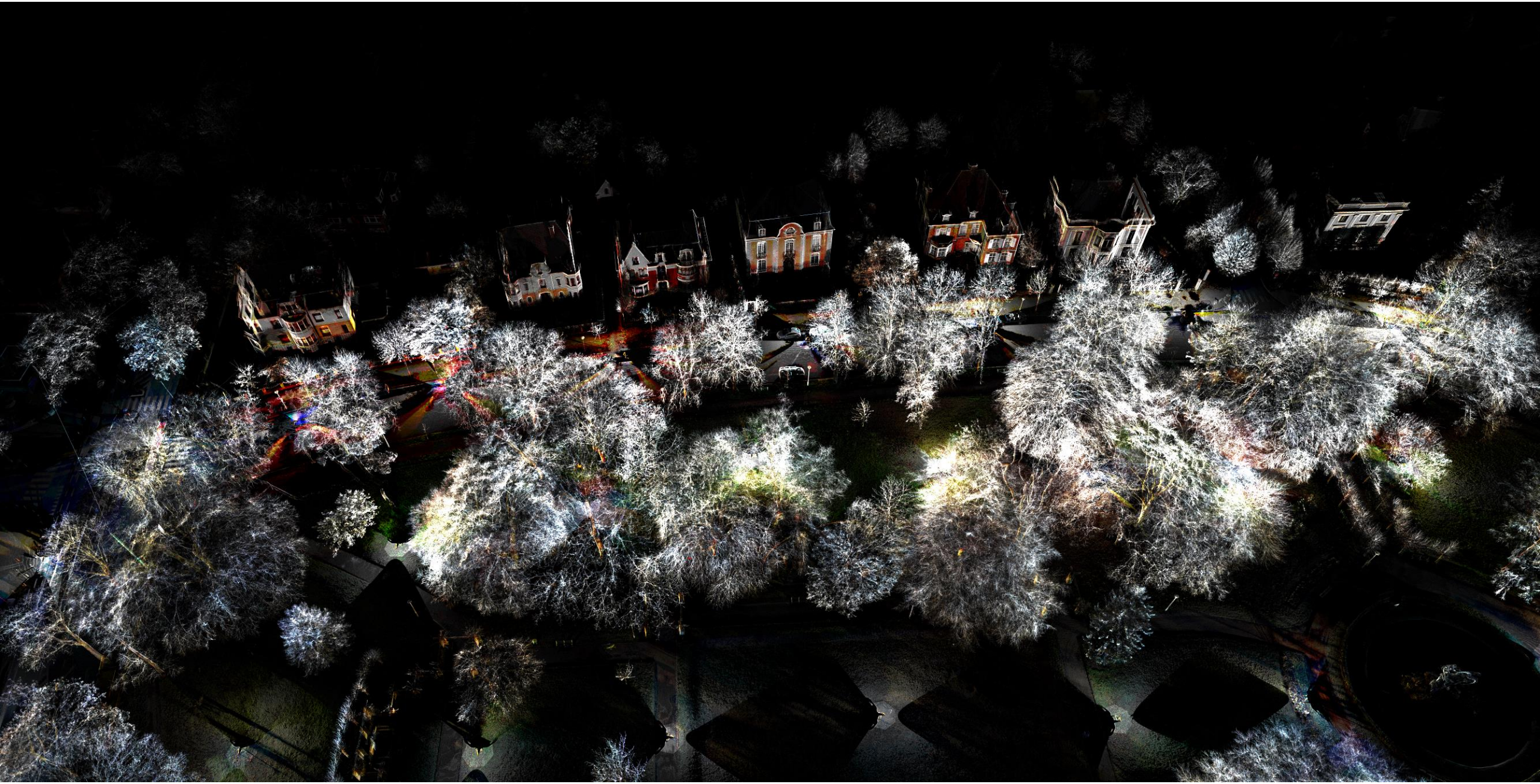
Scan locations (46)

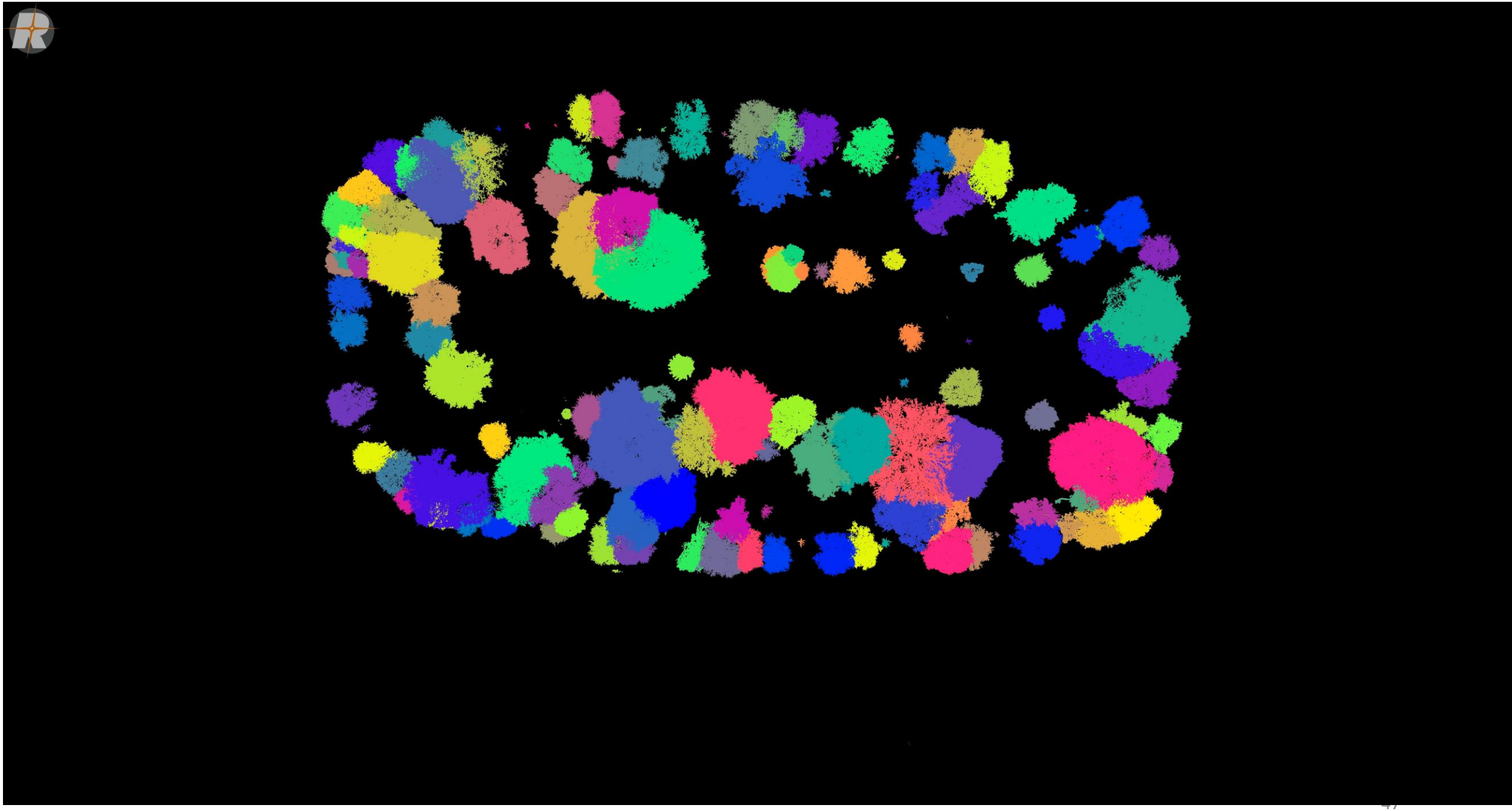
- About 25 m between scans
- In hindsight low number
- 4 hours

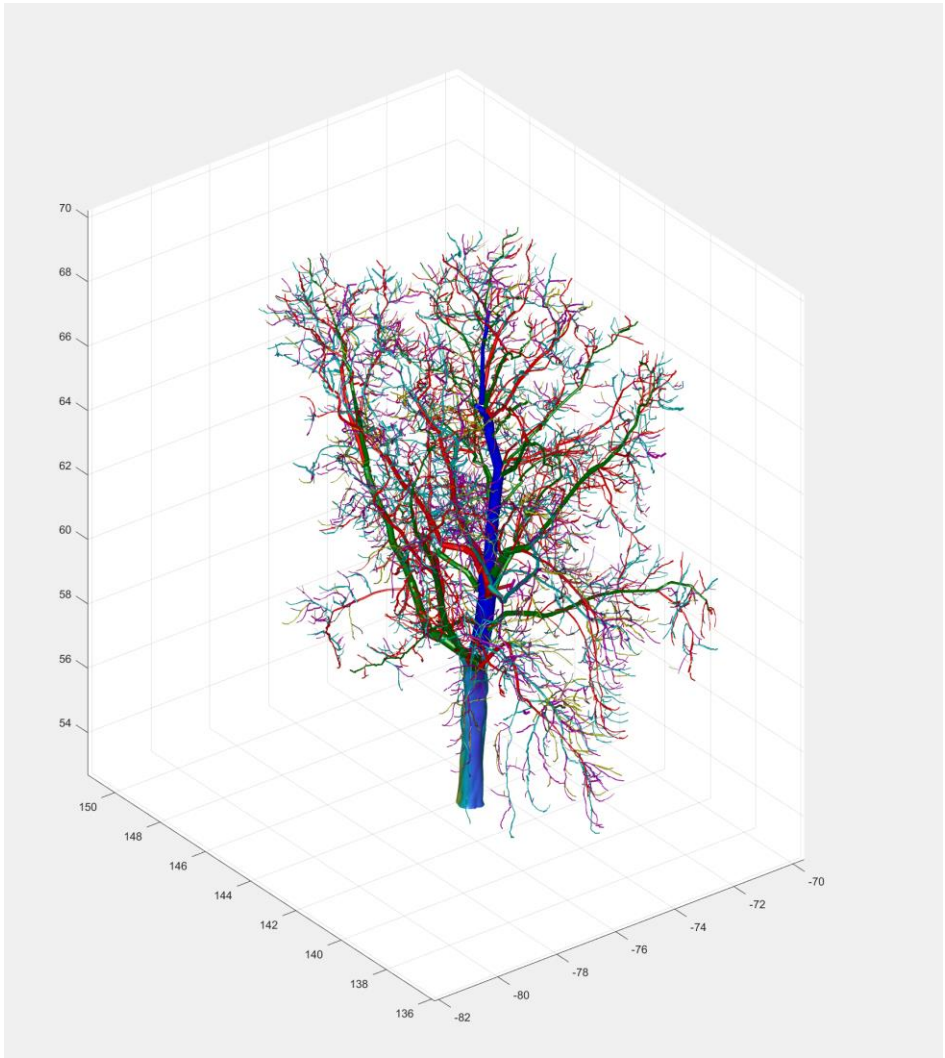
Processing

Registration: automatic

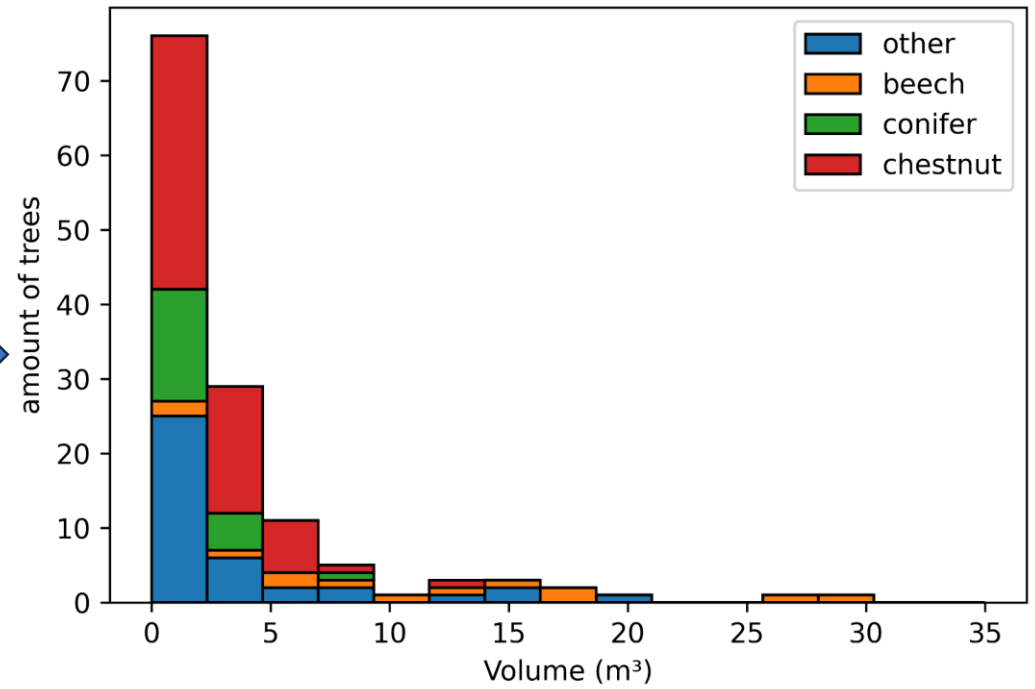
Segmentation trees: 5 days



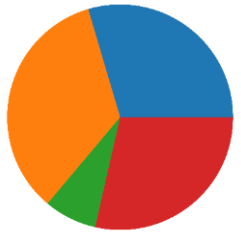




QSM

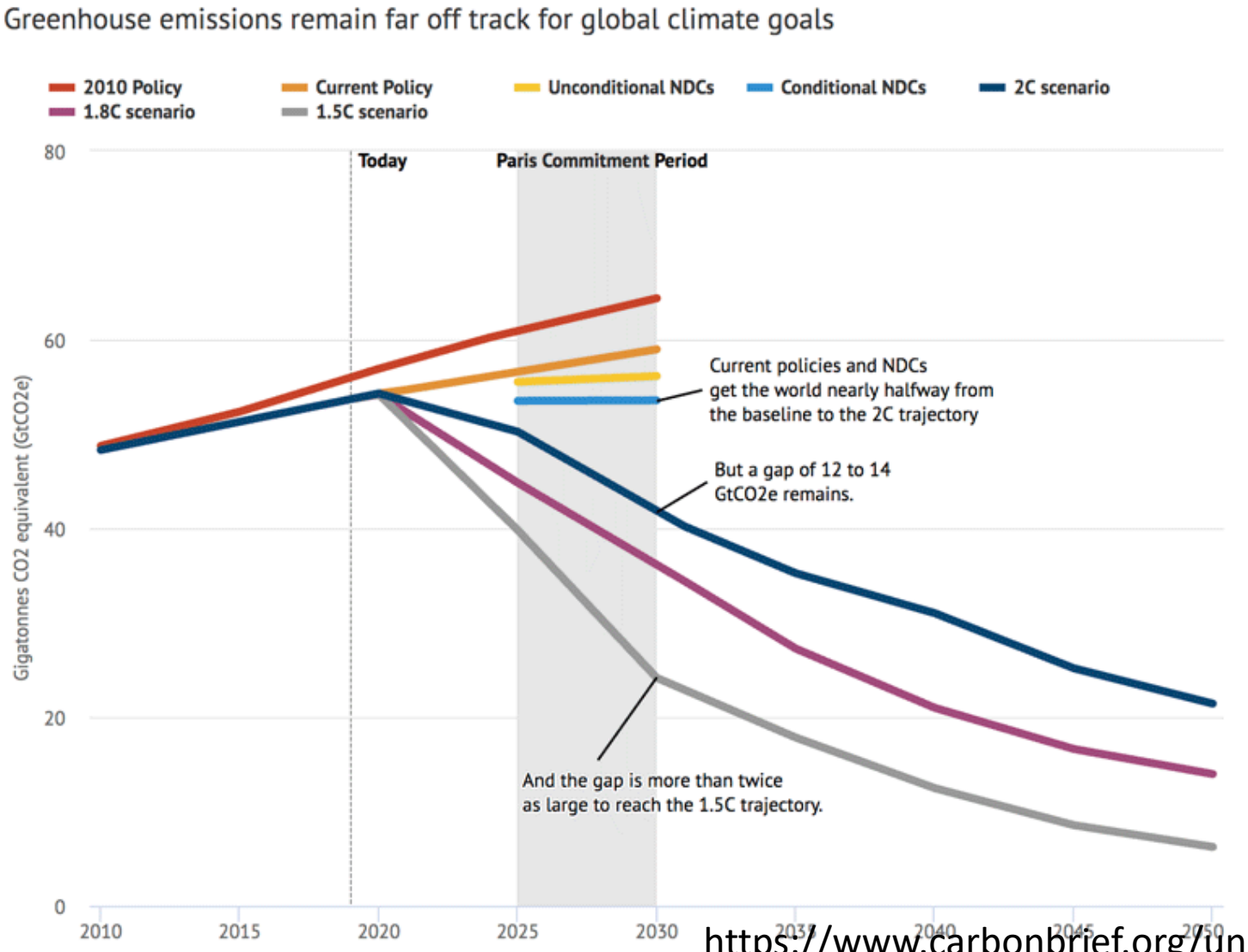


Beech: 152.29 m³
Conifer: 33.55 m³
Other: 131.2 m³
Chestnut: 126.72 m³



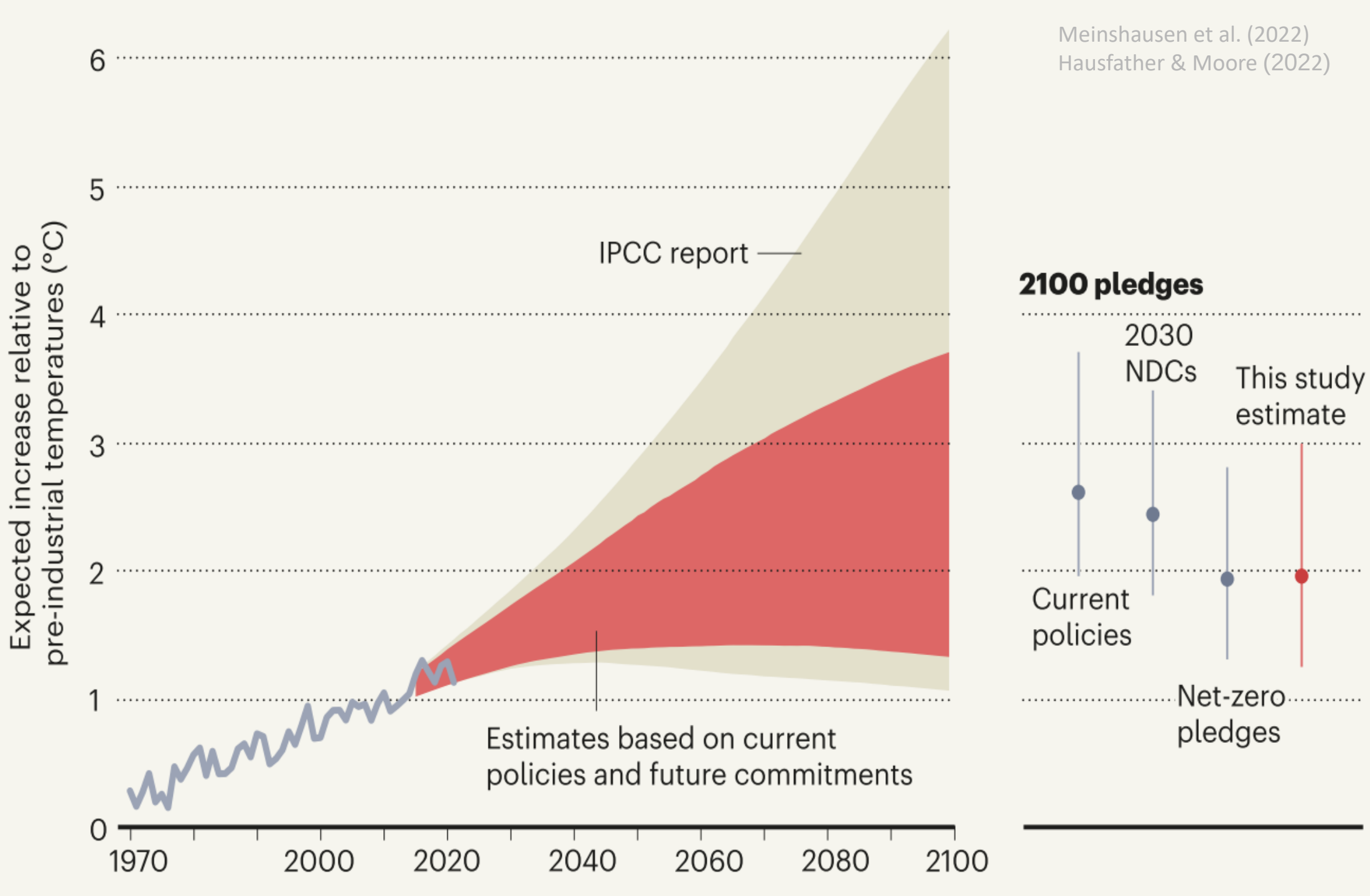
V QSM 443.76 m³ (245.87 ton)

We zitten helaas **NIET** op schema voor net zero



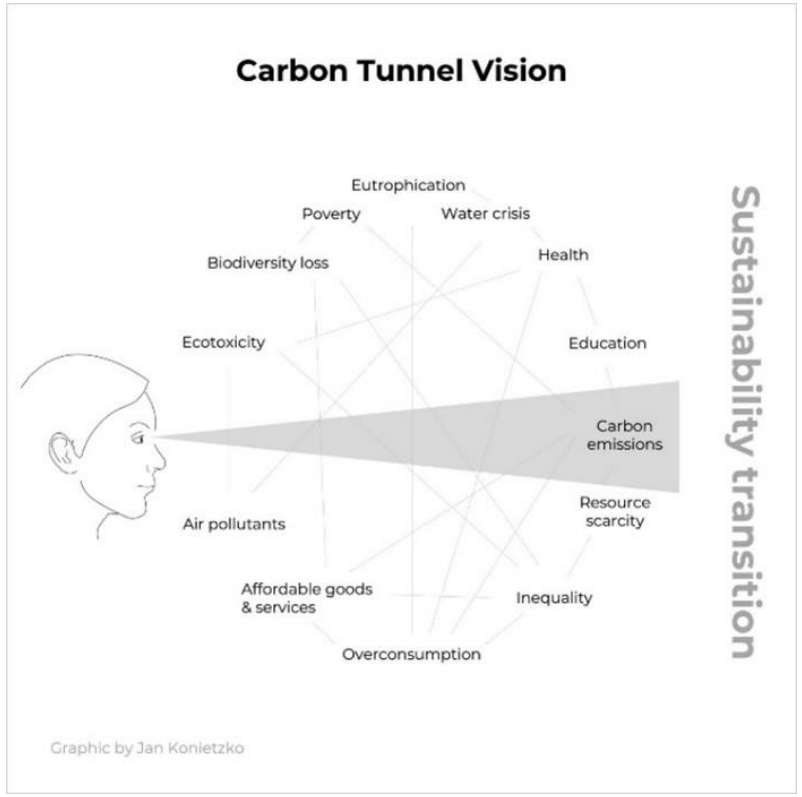
https://www.carbonbrief.org/unep-meeting-global-climate-goals-now-requires-rapid-transformation-of-societies/

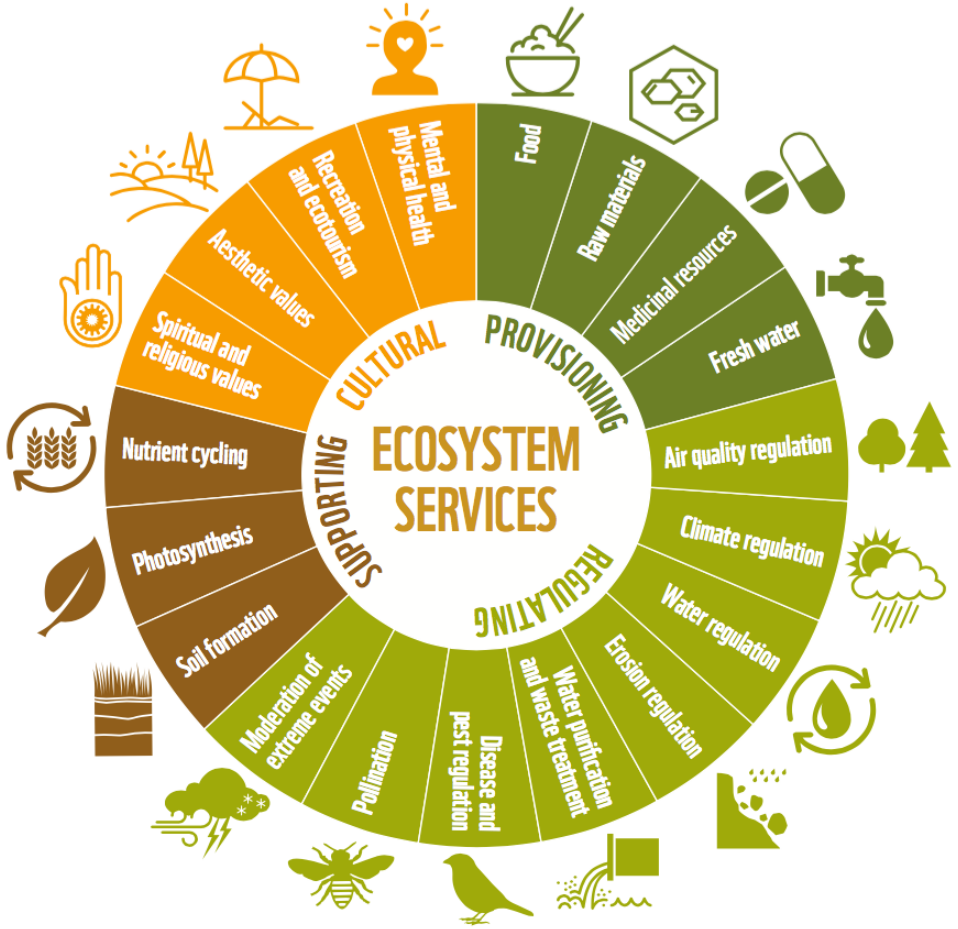
Meinshausen et al. (2022)
Hausfather & Moore (2022)

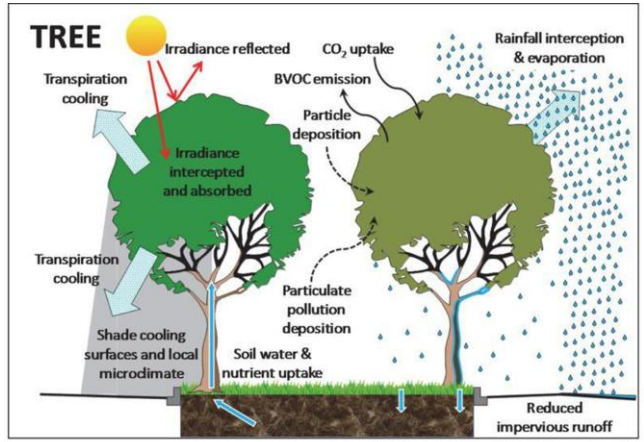


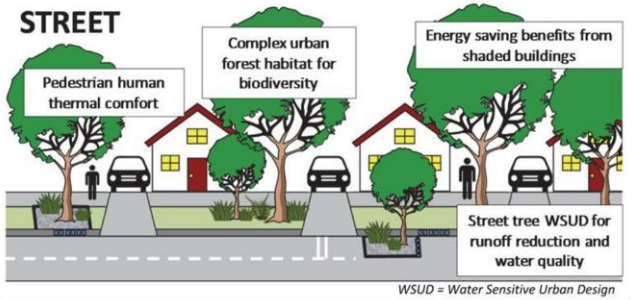
DUS ADAPTATIE IS NODIG, INZETTEN VAN STADS BOMEN VOOR KLIMAATROBUSTE STEDEN

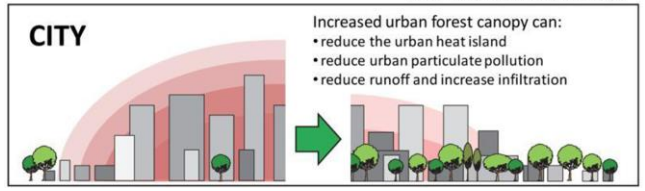
EEN WAAIER AAN ECOSYSTEEM DIENSTEN











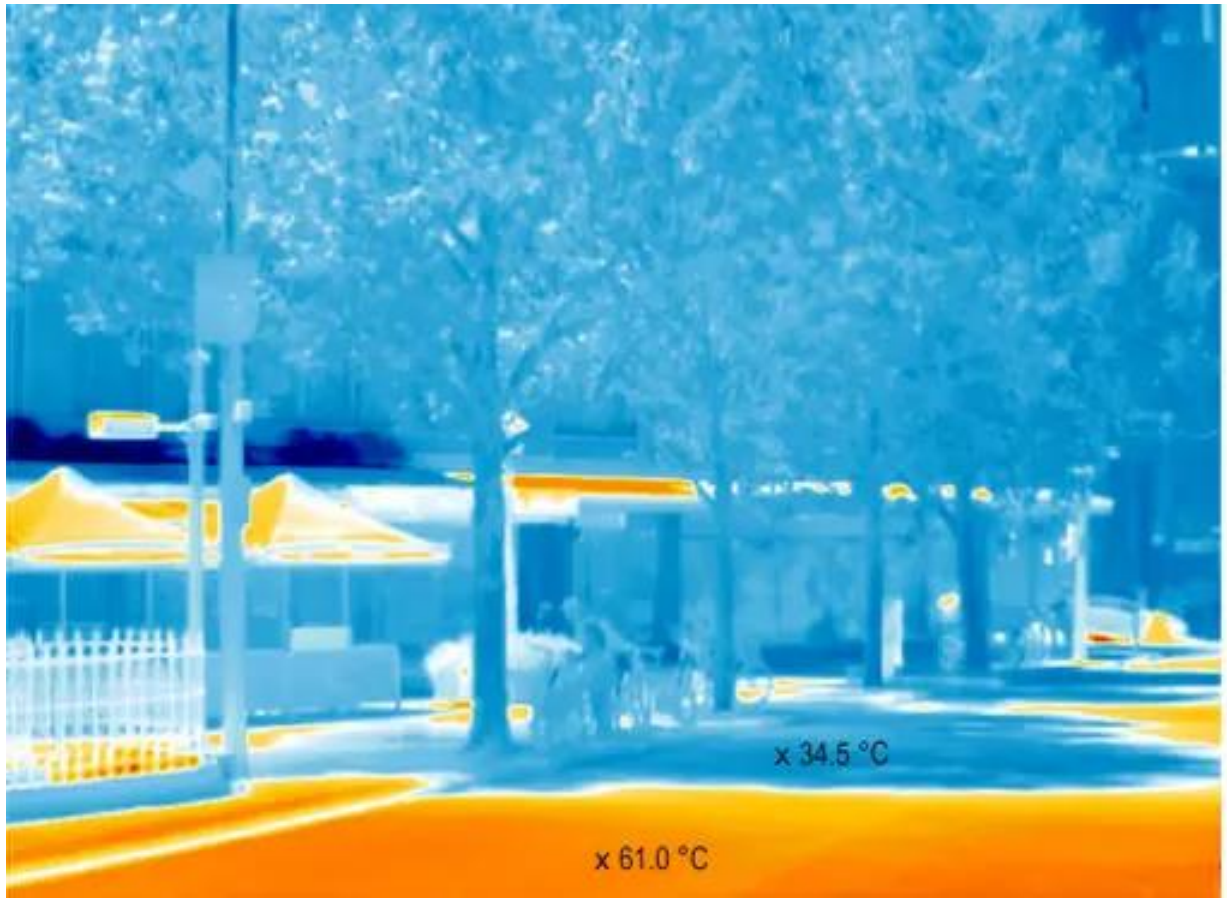
INZETTEN VAN BOMEN VOOR EEN LEEFBAAR KLIMAAT

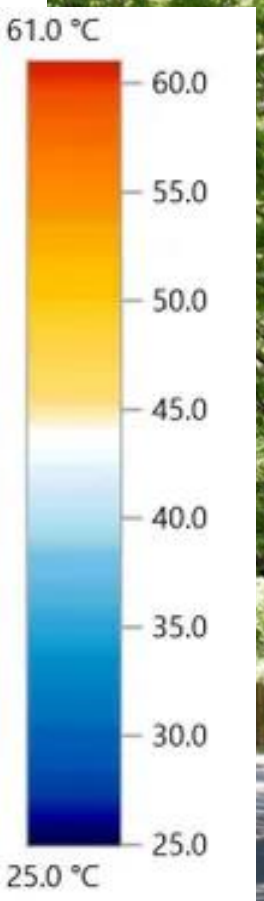
- Stedelijke groene infrastructuur als verkoelend element
- Heat-map Gent Citadelpark

Figuur 167 : De verschillende SUHI kaarten doorheen het jaar (v.l.n.r. eind mei, midden juli en eind september) waarop te zien is dat het Citadelpark koeler is.

Mahieu et al. (2013)

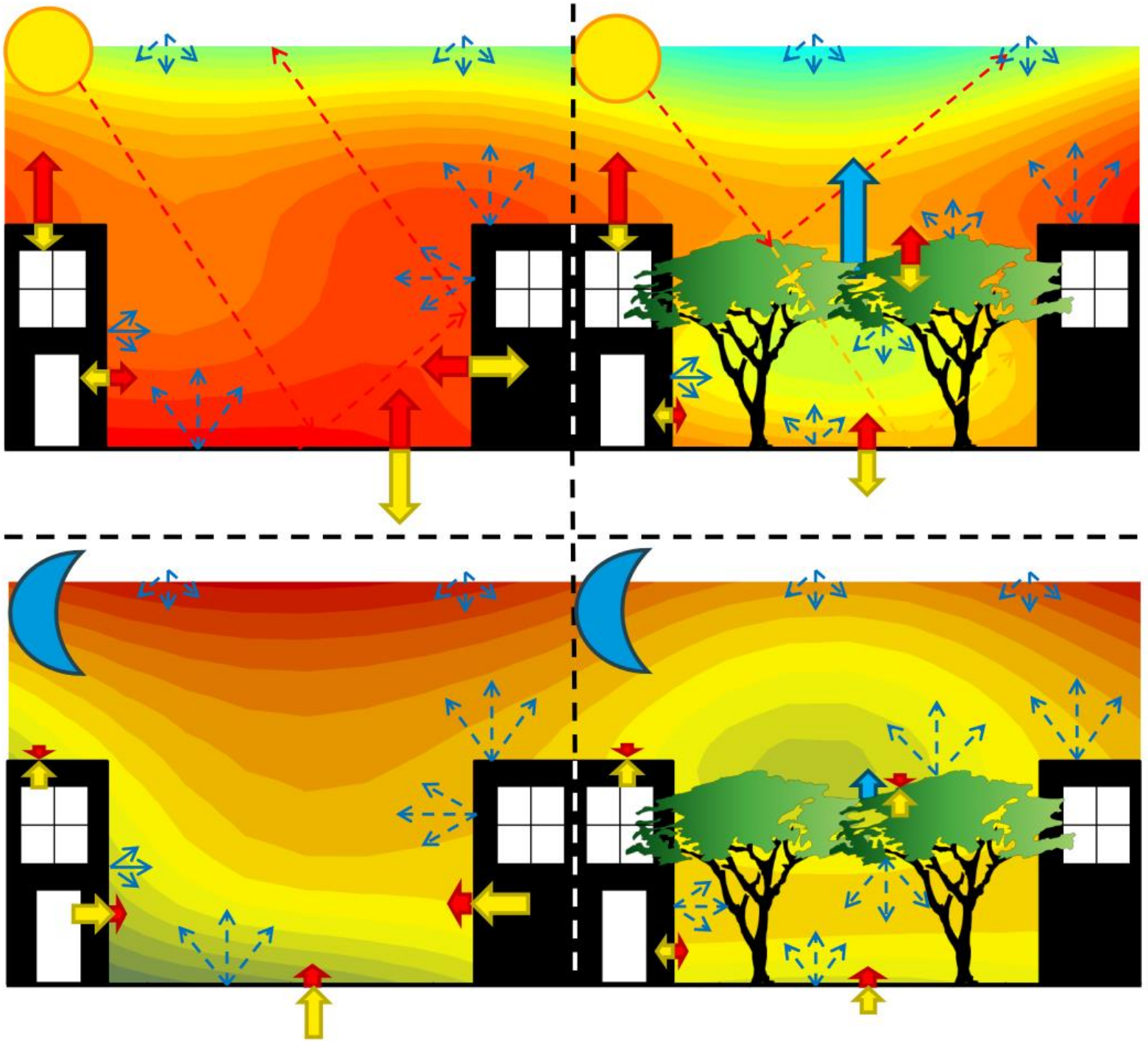
VERKOELING DOOR BESCHADUWING





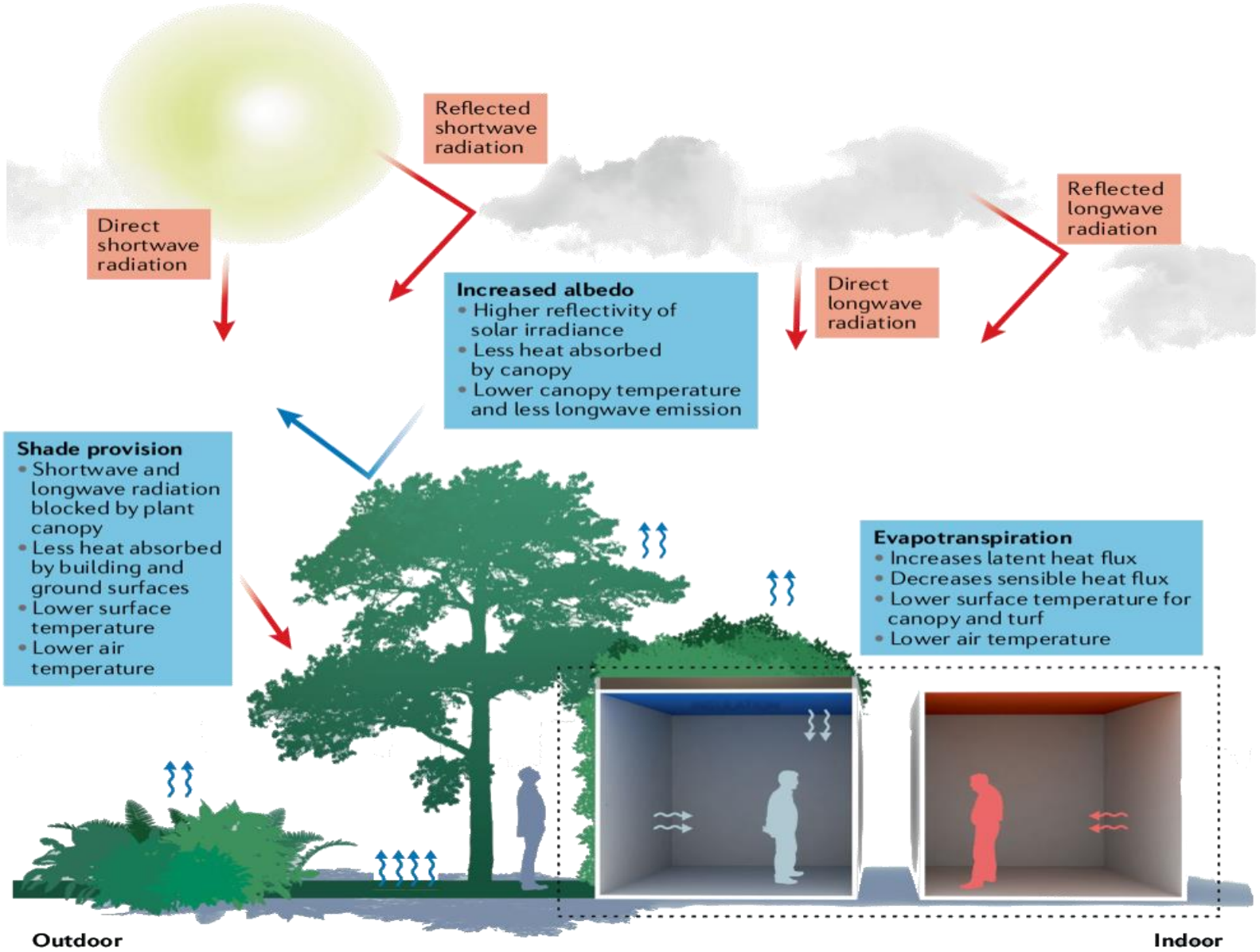
IMPACT OP ENERGIEBALANS

- Albedo (reflectiviteit)
- Verdamping
- Beschaduwing



Andrew Coutts (2015)

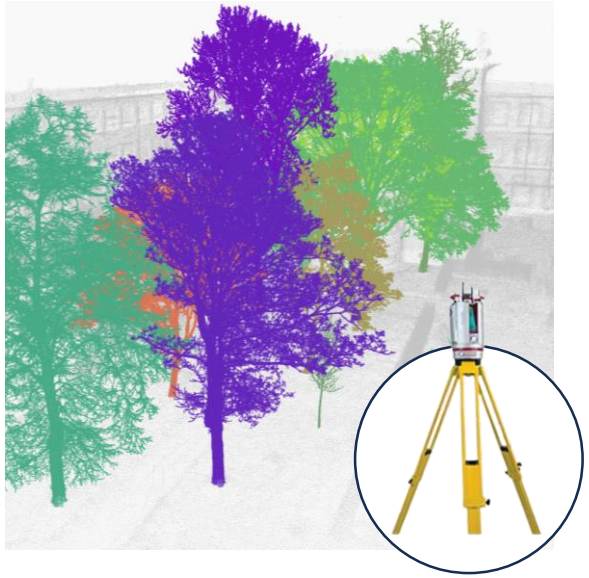
IMPACT OP BUITEN ÉN BINNENKLIMAAT



Wong et al. (2021)

DOCTORAAT TODI DAELMAN

Tree structure



Mircoclimate

3D digital twins

City trees

4+ species
400+ trees

Adjacent buildings

+ Energy exchange characteristics

Structural traits

Height
Density (LAI)
Evapotranspiration rate
Canopy size
Canopy coverage

Functional traits

Spectral properties
Stomatal properties

Thermal comfort data

$T_{air} - T_{MRT} - v_{air} - H_r$

Heat flux model:

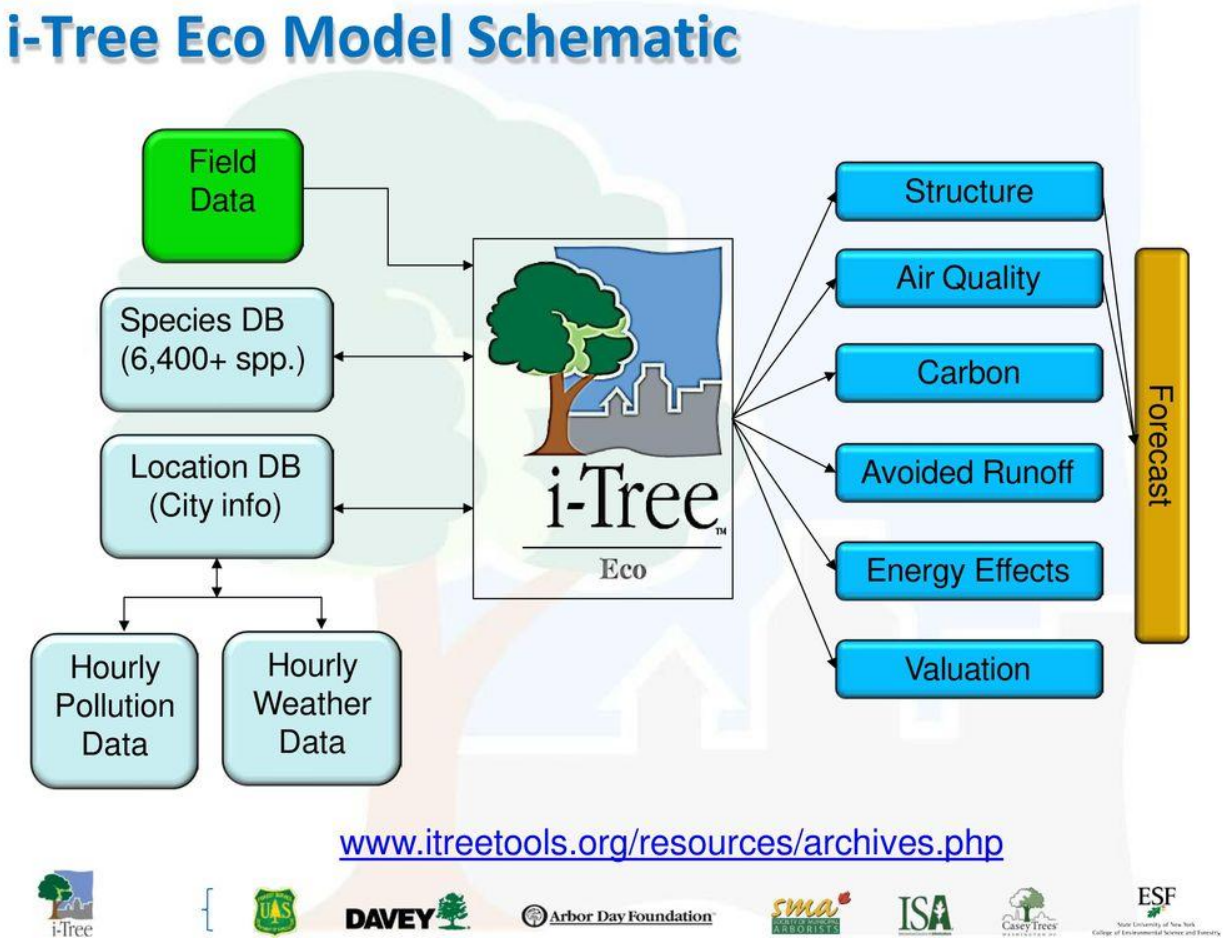
Thermal comfort modelling

DOCTORAAT BARBARA D'HONT

Kwantificatie van ecosysteemdiensten?

- Voorbeeld: I-Tree ECO
- belang van GROTE bomen!

Meeste ecosysteemdiensten gelinkt aan aantal bladeren en bladoppervlakte

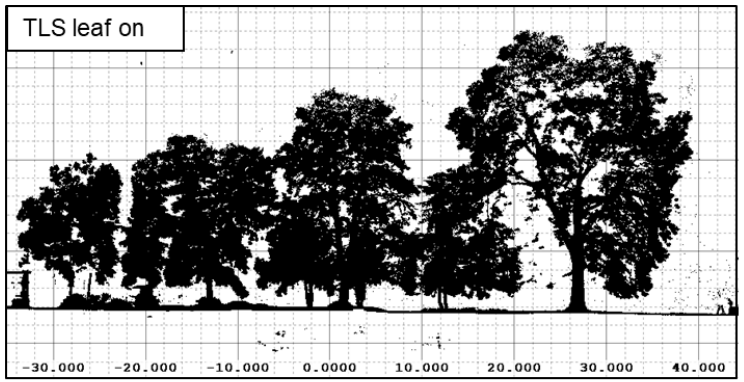


Evaluating different laser scanning approaches for urban tree inventories

Terrestrial Laser Scanning

Mobile Laser Scanning

Airborne Laser Scanning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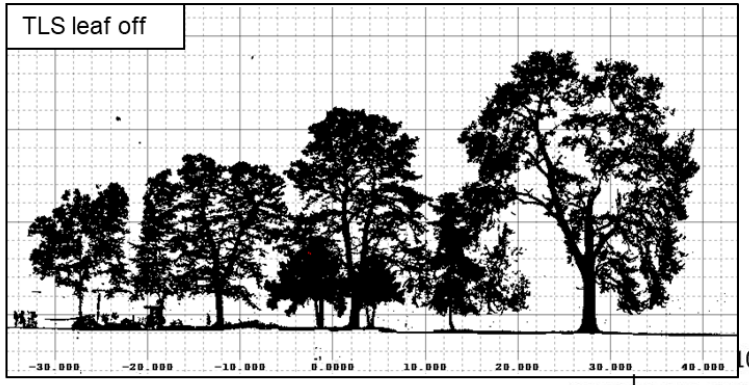
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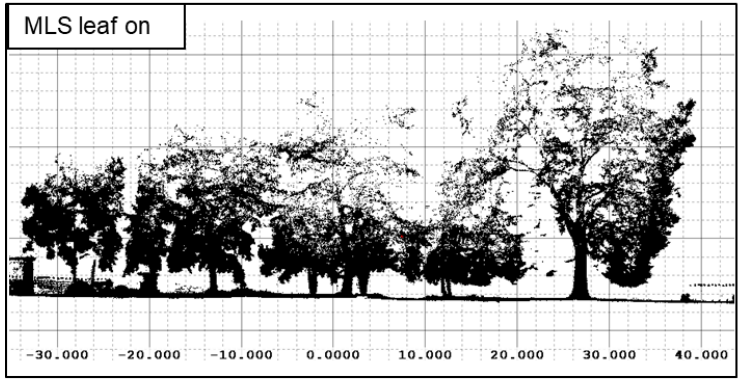
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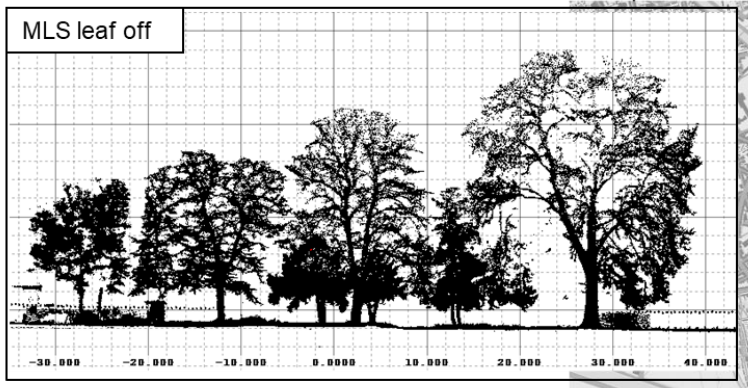
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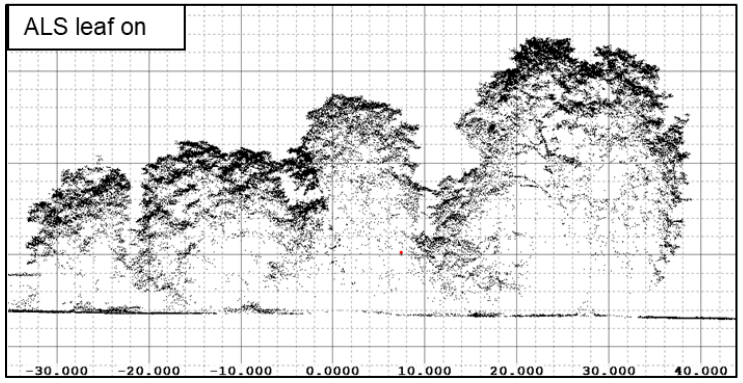
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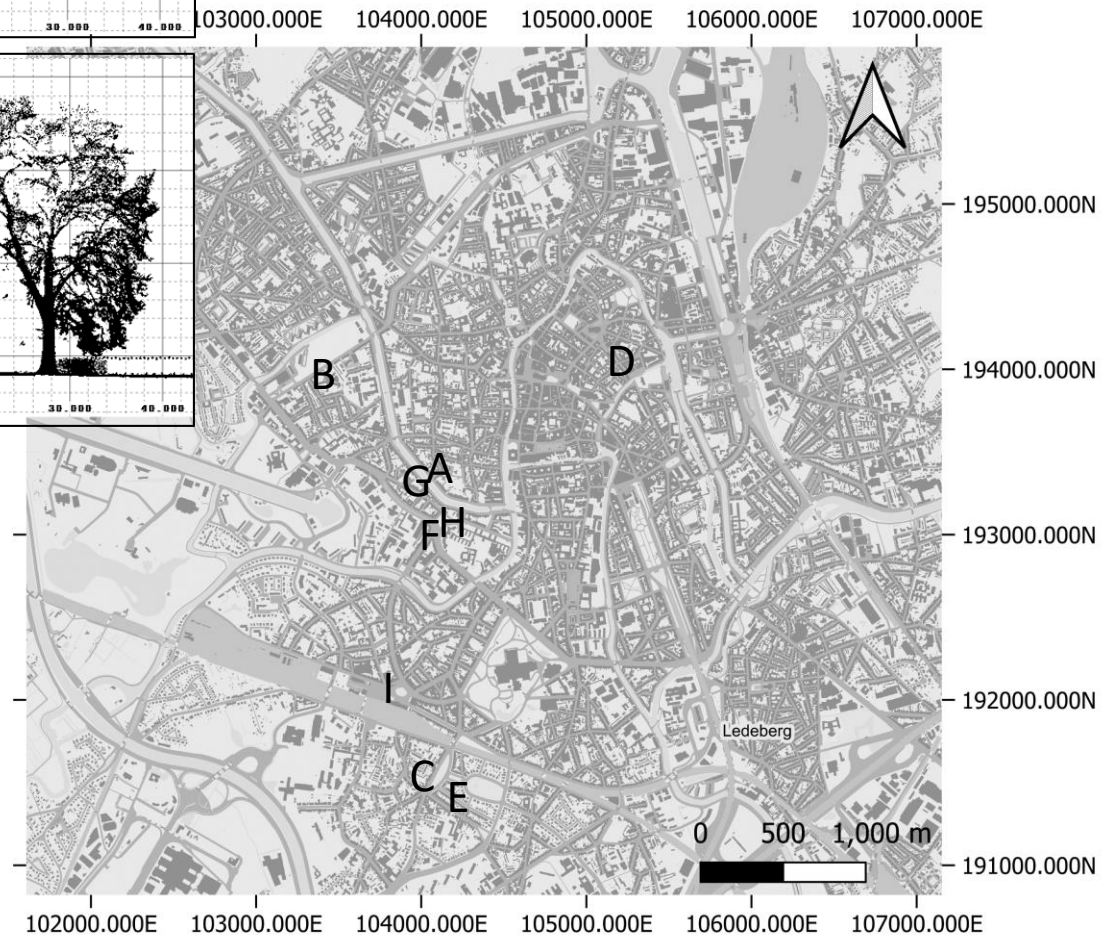
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102000.000E
103000.000E
104000.000E
105000.000E
106000.000E
107000.000E
B
D
A
G
H
F
I
C
E
Ledeberg
0 500 1,000 m

CONCLUSIE

Stadsbomen voor klimaatrobuste steden
- Mitigatie en adaptatie
- Tal van co-benefits (andere ecosysteemdiensten)

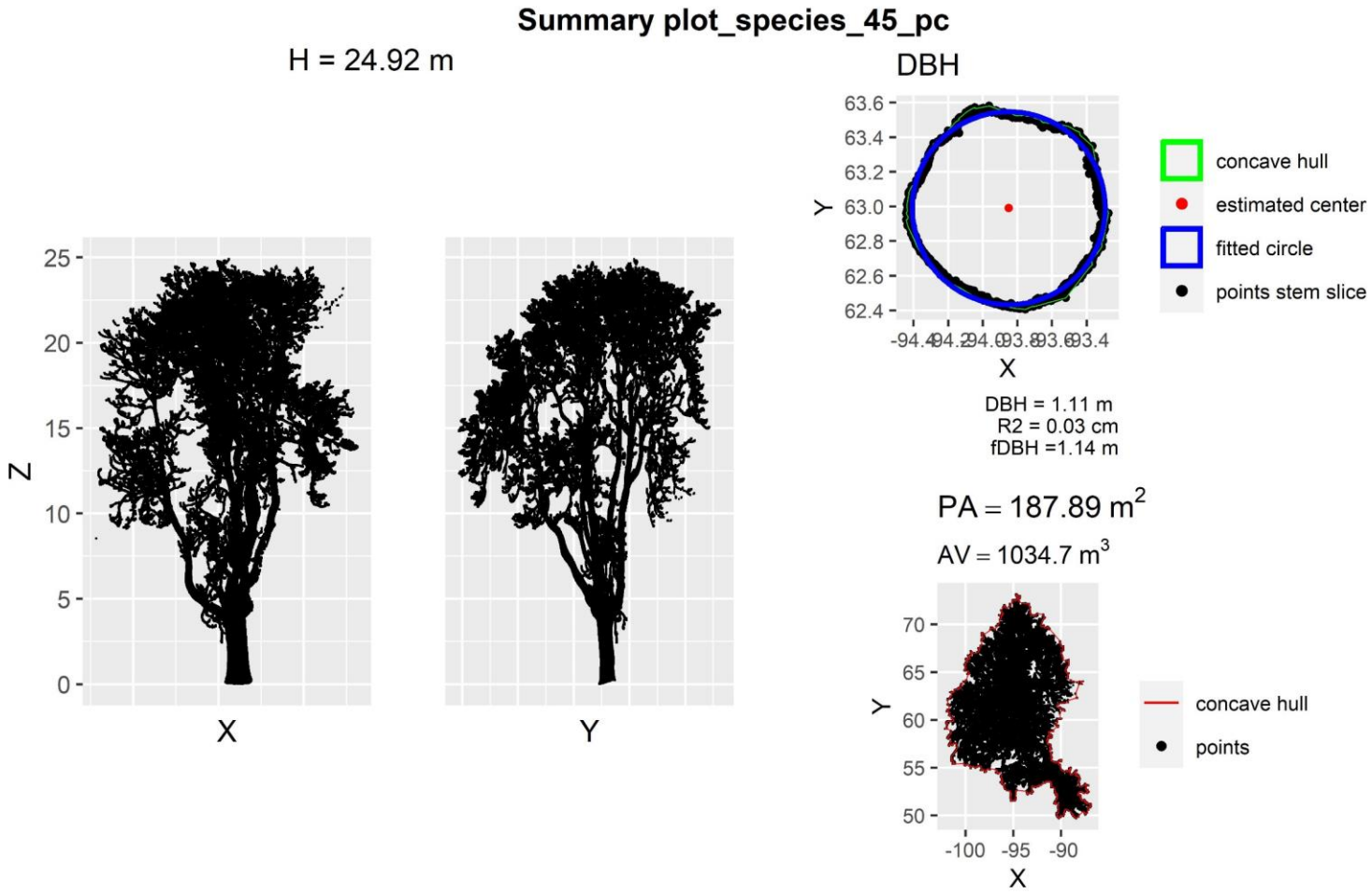
Onderzoek nodig over
- Impact boomstructuur
- Soortenkeuze
- Inplanting
- …

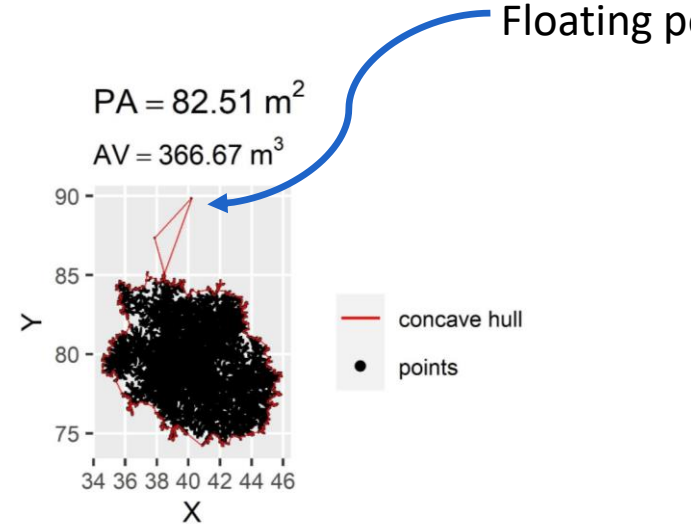
Urgentie
- Nu bomen aanplanten voor later
- Nu steden herinrichten

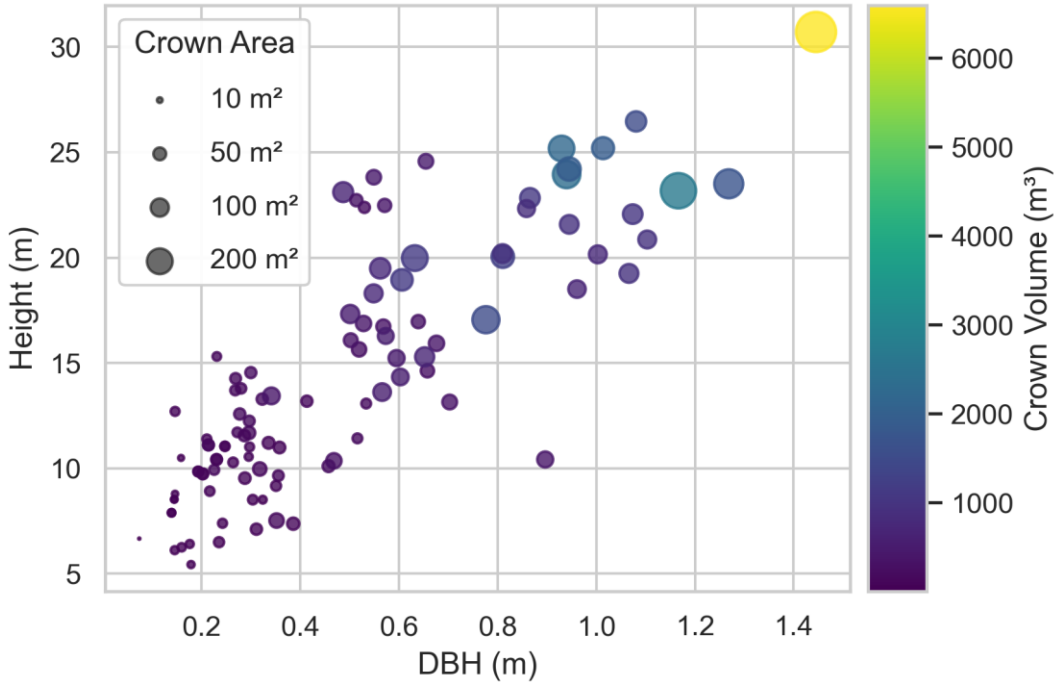
→ Transdisciplinair onderzoek samen met de praktijk

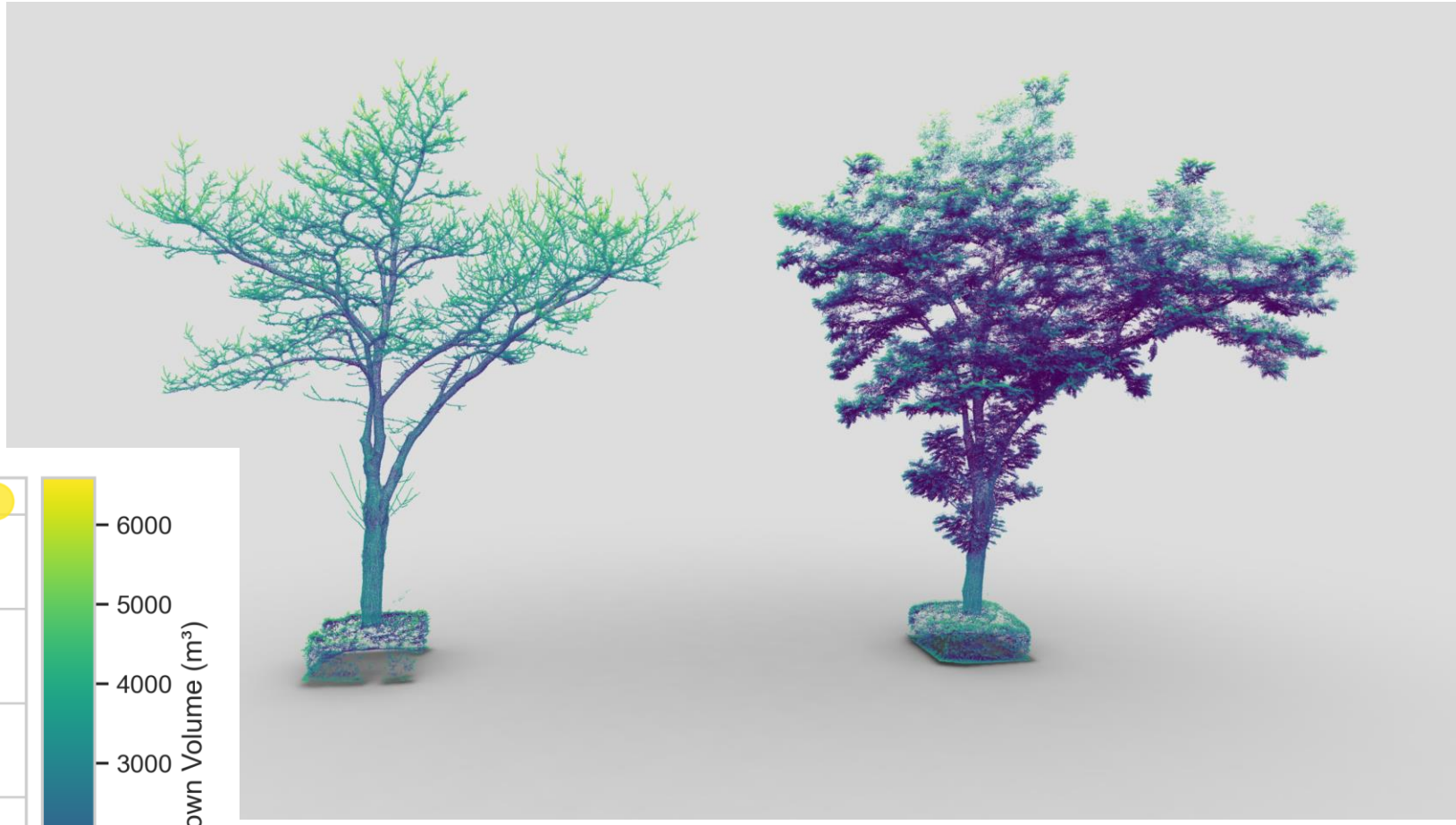
Extra slides

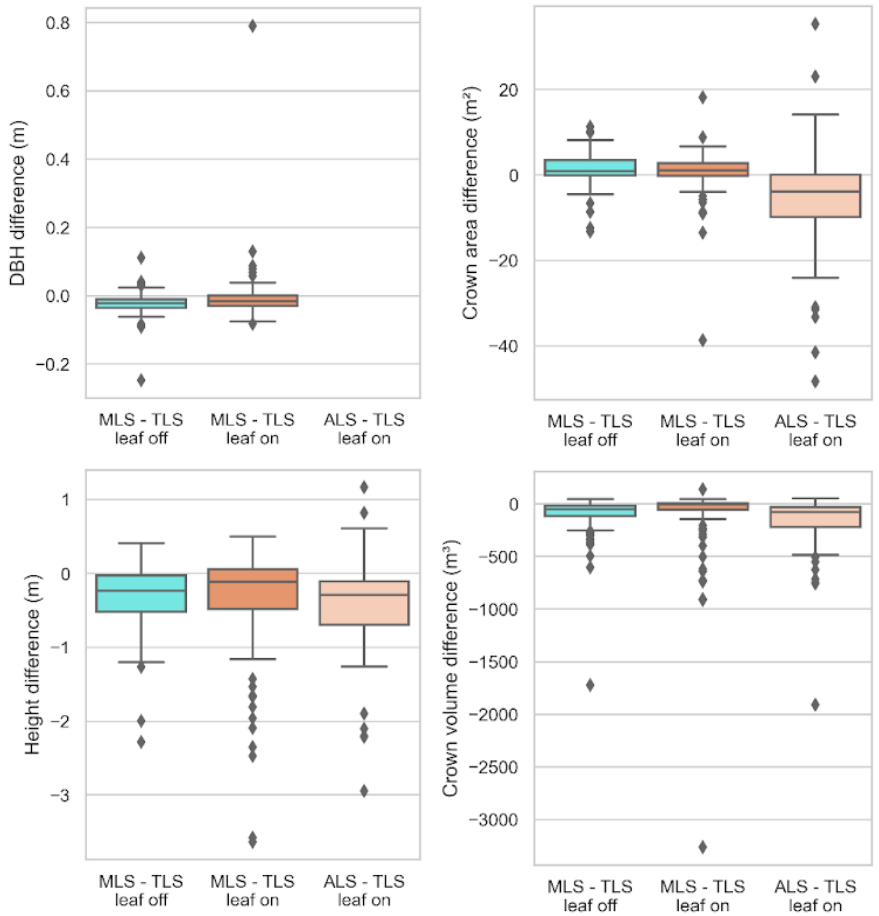
Structural features



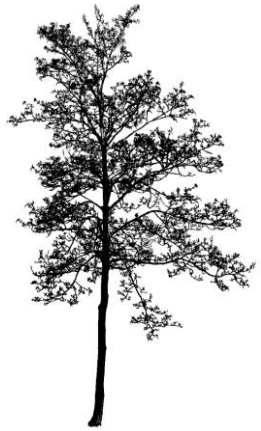


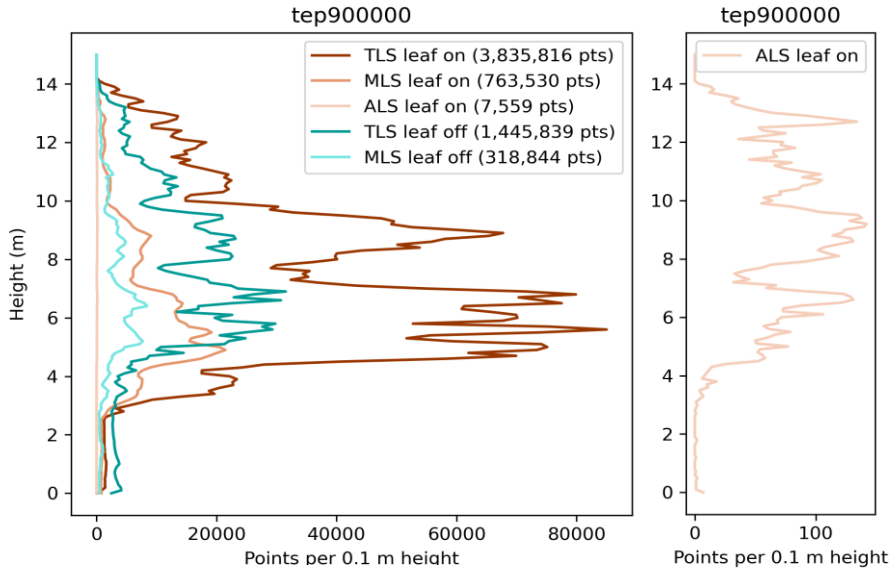

Crown Area
10 m²
50 m²
100 m²
200 m²
Height (m)
30
25
20
15
10
5
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DBH (m)
6000
5000
4000
3000
2000
1000
Crown Volume (m³)



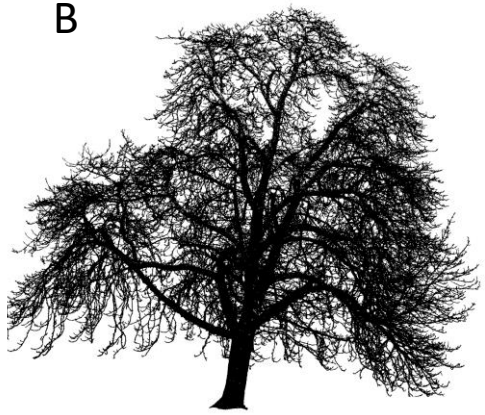


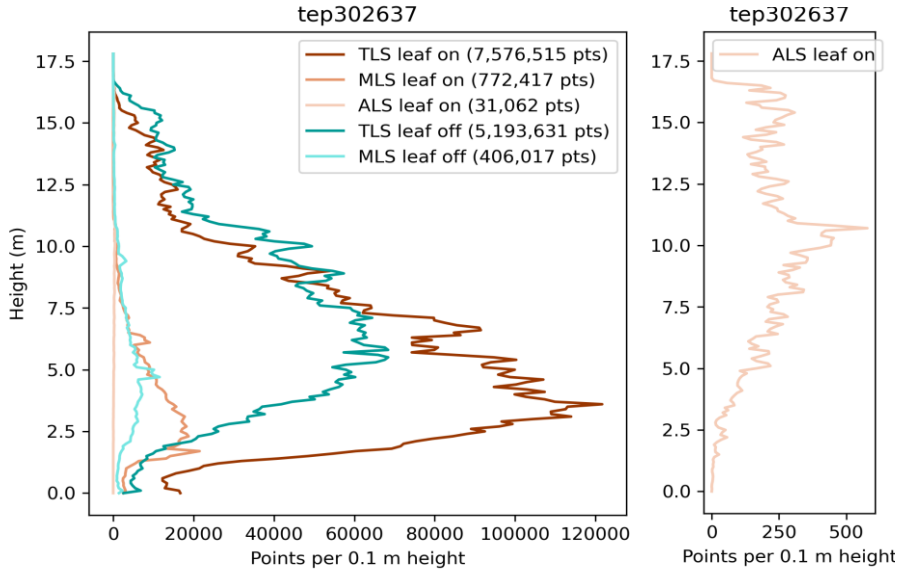
A





B

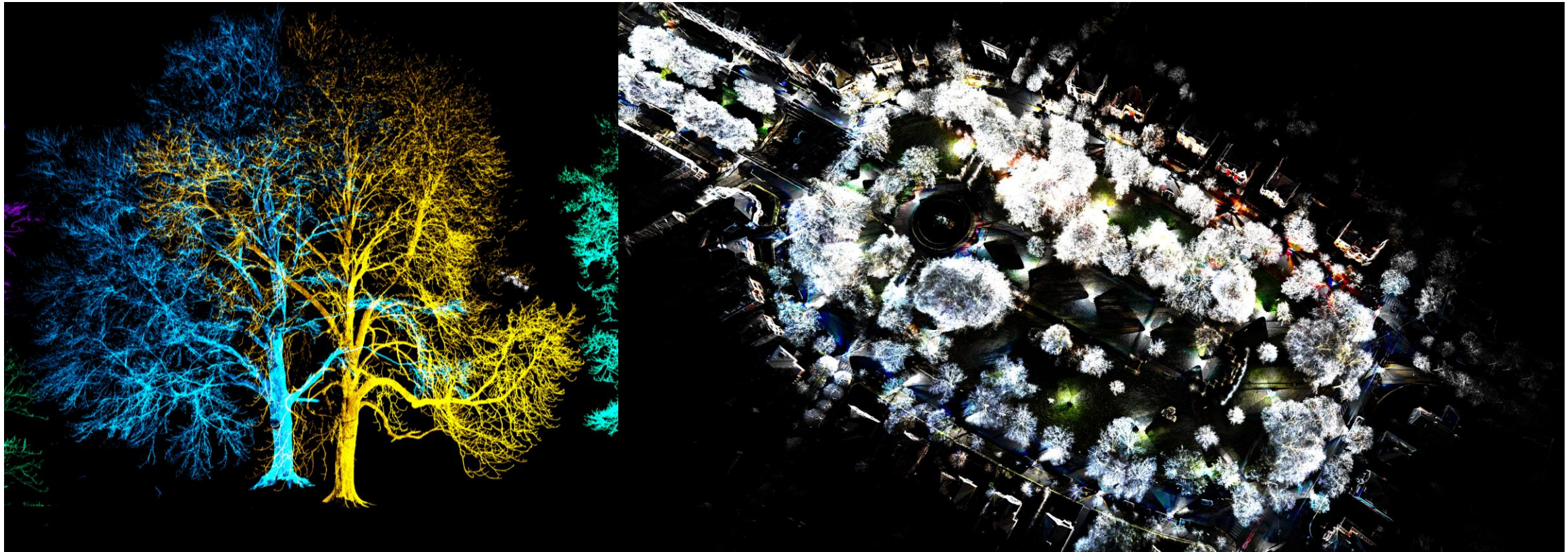




-> main limitations are related to occlusion

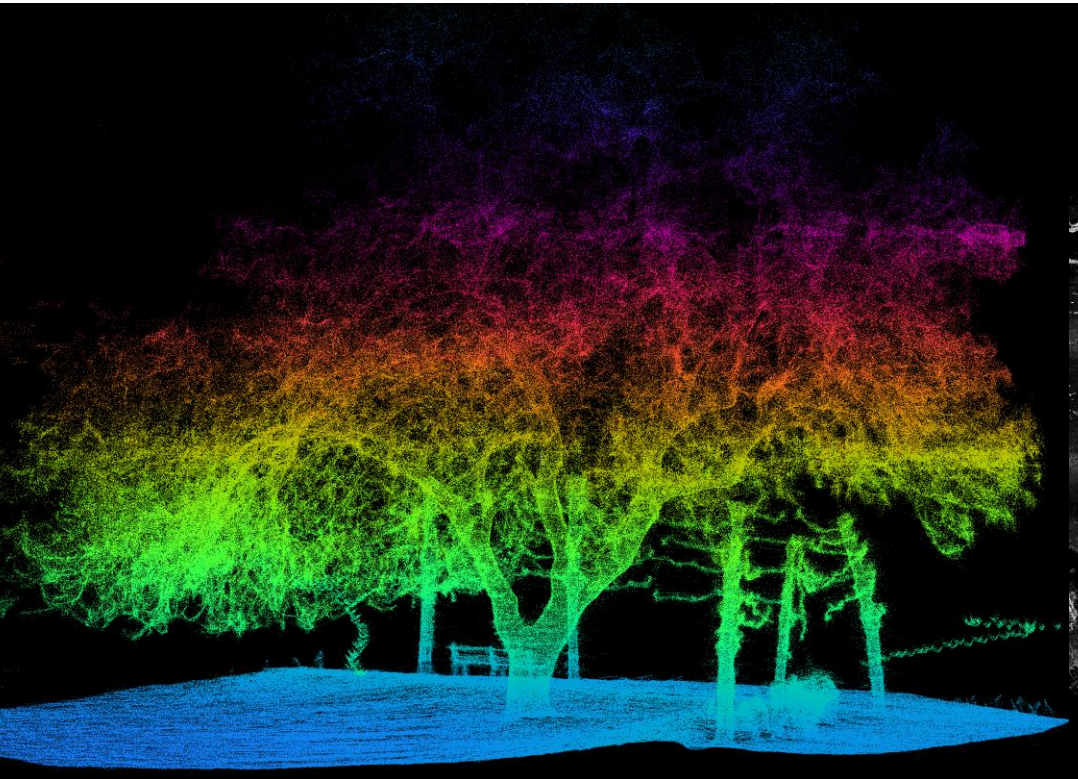
Terrestrial laser scanning

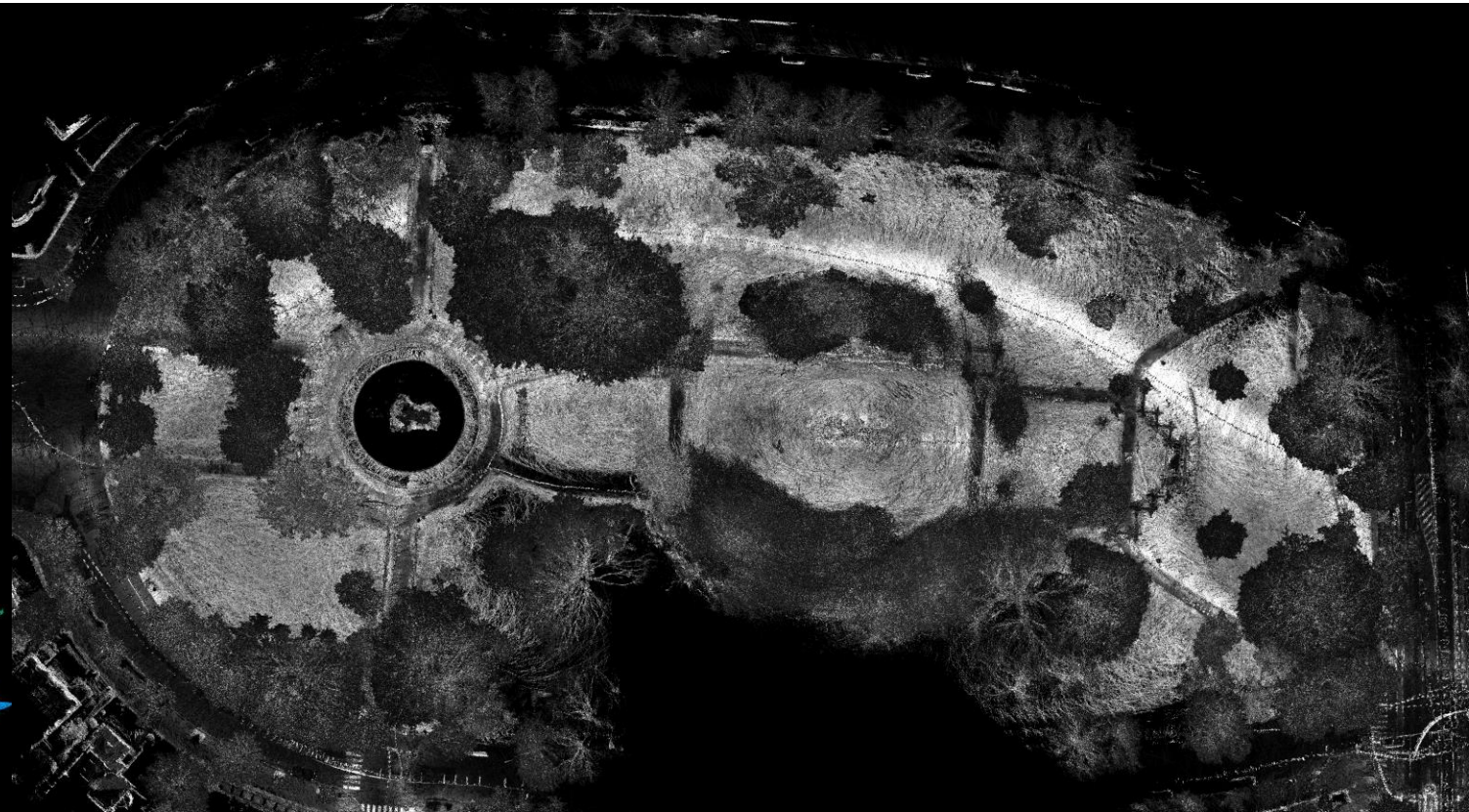
- DBH, height, crown dimensions
- Slow acquisition



Mobile laser scanning

- DBH, height, crown dimensions of large trees can be underestimated
- Faster acquisition





Airborne laser scanning

- Height and crown dimensions but no DBH
- City wide