# URBAN GREEN INFRASTRUCTURE

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# CONTENTS

- Urban are areas facing multiple pressures
- Green infrastructure can help reduce these pressures
- How do you know you have done enough?

↑ temperatures
Moderate winters, hot summers

Warm, wet & dry

Winter: ↑ (extreme) rainfall
Summer: ↑ extreme rainfall, thunderstorms and hail

Sea level rise at accelerating pace



http://www.klimaatscenarios.nl/scenarios_samengevat/

https://static.wixstatic.com/media/541b11_49f40786b25c4989a4b1e990edfebce4~mv2.jpg/v1/fit/w_800%2Ch_450%2Cal_c%2Cq_80/file.jpg
https://www.klimaatakkoord.nl/klimaatakkoord/vraag-en-antwoord/wat-is-het-doel-van-het-klimaatakkoord
https://www.deltaprogramma.nl/themas/ruimtelijke-adaptatie/deltaplan

# POLICY GOALS

| Policy name | Climate Agreement | Delta Plan Spatial Adaptation |
|---|---|---|
| National goals | By 2030: Reducing emissions to 49% of the levels of 1990.<br>By 2050: Reducing emissions to 90% or more of the levels of 1990. | By 2050: Create a robust and climate proof country, reducing the impacts of waterlogging, floods, drought and heat. |
| Affected sectors/ goals | • Electricity 20,2 Mton<br>• Industry 14,3 Mton<br>• Built environment 3,4 Mton<br>• Mobility 7,3 Mton<br>• Agriculture and land use 3,5 Mton | • Energy transition<br>• New construction challenges<br>• Infrastructure maintenance<br>• Circular economy<br>• Biodiversity |


# WHAT IS URBAN GREEN INFRASTRUCTURE?

"A strategically planned **network** of natural and semi-natural areas with other environmental features designed and managed to **deliver** a wide range of **ecosystem services**" (European Commission, 2013).

GI are landscape elements that need to be planned for with the **same priority** as communications, sanitation, roads, and other infrastructure. Mell, I.C. (2010) Green infrastructure: concepts, perceptions and its use in spatial planning. PhD thesis, Newcastle University. https://theses.ncl.ac.uk/jspui/handle/10443/914

https://greensurge.eu/products/planning-governance/ UGI_Planning_Guide_Sep_2017_web.pdf

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*Green space typology, made up of 44 green space types clustered in eight groups.*
*Image credits: Rieke Hansen*

# NEED FOR DESIGN AND MANAGEMENT

# Green infrastucture can help solve everything

What is it GI is intended to achieve and how do we know if we have achieved the desired outcomes?

reduce flood peaks

serve as a food source

increase social cohesion

remove water pollutants

sequester carbon

provide recreation

reduce energy use for heating and cooling buildings

connect people to nature

increase aesthetic value

- Improved mental and physical health
- Reduced climate pressures
- Increased biodiversity
- Good economic investment

provide habitat for pollinators and fauna

improve cognitive recovery, faster healing from illness

improve speed dispersal

extend life of materials and surfaces

improve air quality

create green jobs

protect from UV radiation

modify wind speeds

cheaper than alternatives in capital and operational costs

https://degroenestad.nl/geen-categorie/nieuw-logo-voor-de-groene-stad
10.1080/03721426.2015.1035219; 10.1016/j.ecolecon.2012.08.019; 10.1080/03721426.2015.1035219; 10.1016/j.sbspro.2015.12.009

# The 3-30-300 Rule for Healthier and Greener Cities

- 3 trees from every home
- 30 percent tree canopy cover in every neighbourhood
- 300 metres from the nearest public park or green space



Walking distance of 300 meter to a cool location

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https://nbsi.eu/the-3-30-300-rule/

Hogeschool van Amsterdam en KuiperCompagnons (2020) De hittebestendige stad: COOLKIT. Toolkit voor ontwerpers van de buitenruimte

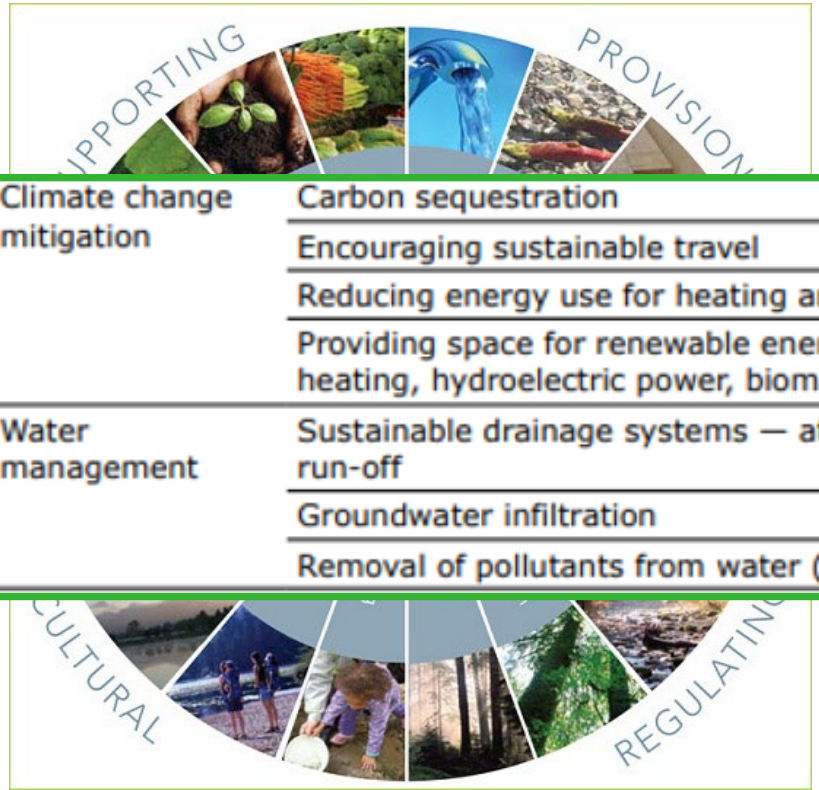
# ECOSYSTEM SERVICES

*'the benefits **people** obtain from ecosystems'*

https://freshwaterwatch.thewaterhub.org/content/ecosystem-services

https://www.eea.europa.eu/publications/green-infrastructure-and-territorial-cohesion

De Groot, Functions of Nature: Evaluation of Nature in Environmental Planning, Management, and Decision Making (Groningen, 1992)



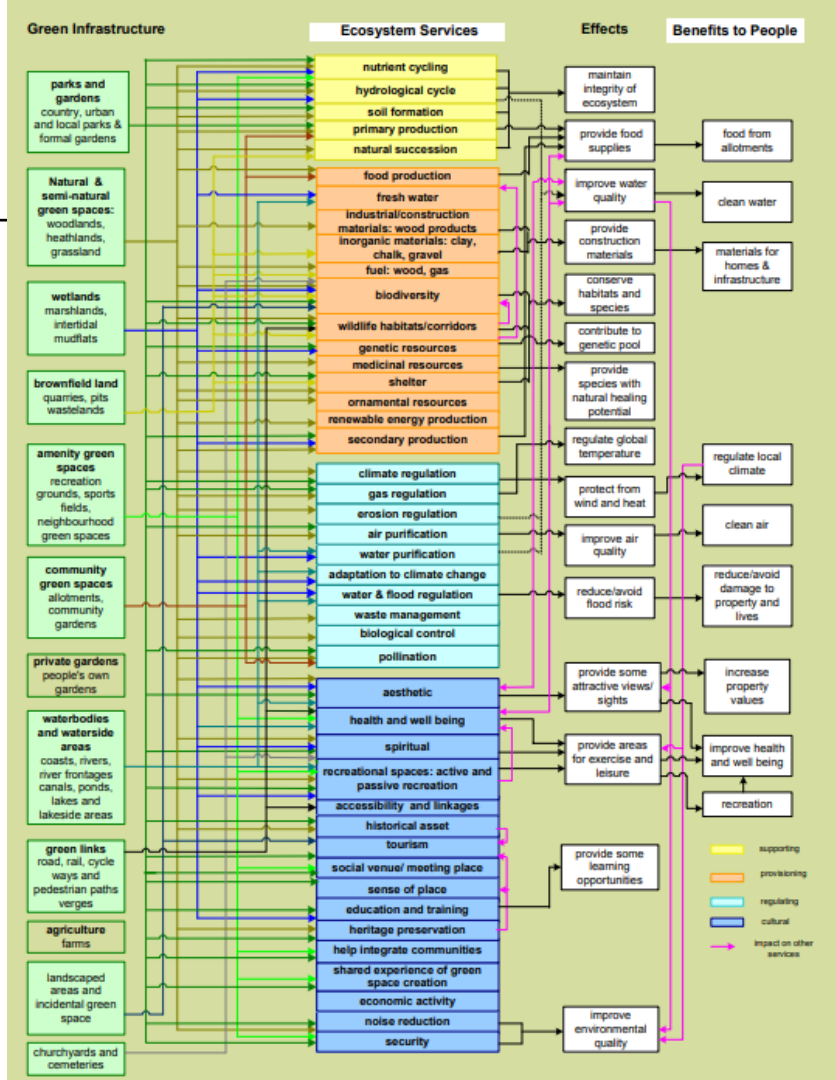

| | |
|---|---|
| Climate change mitigation | Carbon sequestration |
| | Encouraging sustainable travel |
| | Reducing energy use for heating and cooling buildings |
| | Providing space for renewable energy like ground source heating, hydroelectric power, biomass and wind power |
| Water management | Sustainable drainage systems — attenuating surface water run-off |
| | Groundwater infiltration |
| | Removal of pollutants from water (e.g. reed beds) |

| | Main service types |
|---|---|
| **Provisioning services** are products obtained from ecosystems such as food, fresh water, wood, fibre, genetic resources and medicines. | **Provisioning services**<br>1 Food (e.g. fish, game, fruit)<br>2 Water (e.g. for drinking, irrigation, cooling)<br>3 Raw materials (e.g. fibre, timber, fuel wood, fodder, fertiliser)<br>4 Genetic resources (e.g. crop improvement and medicinal purposes)<br>5 Medicinal resources (e.g. biochemical products, models and test organisms)<br>6 Ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion) |
| | **Regulating services**<br>7 Air quality regulation (e.g. capturing (fine) dust, chemicals)<br>8 Climate regulation (including carbon sequestration, influence of vegetation on rainfall)<br>9 Moderation of extreme events (e.g. storm protection and flood prevention)<br>10 Regulation of water flows (e.g. natural drainage, irrigation and drought prevention)<br>11 Waste treatment (especially water purification)<br>12 Erosion prevention<br>13 Maintenance of soil fertility (including soil formation)<br>14 Pollination<br>15 Biological control (e.g. seed dispersal, pest and disease control) |
| pools. | **Habitat services**<br>16 Maintenance of life cycles of migratory species (including nursery services)<br>17 Maintenance of genetic diversity (especially gene pool protection) |
| **Cultural services** include non-material benefits that people obtain from ecosystems such as spiritual enrichment, intellectual development, recreation and aesthetic values. | **Cultural services**<br>18 Aesthetic information<br>19 Opportunities for recreation and tourism<br>20 Inspiration for culture, art and design<br>21 Spiritual experience<br>22 Information for cognitive development |

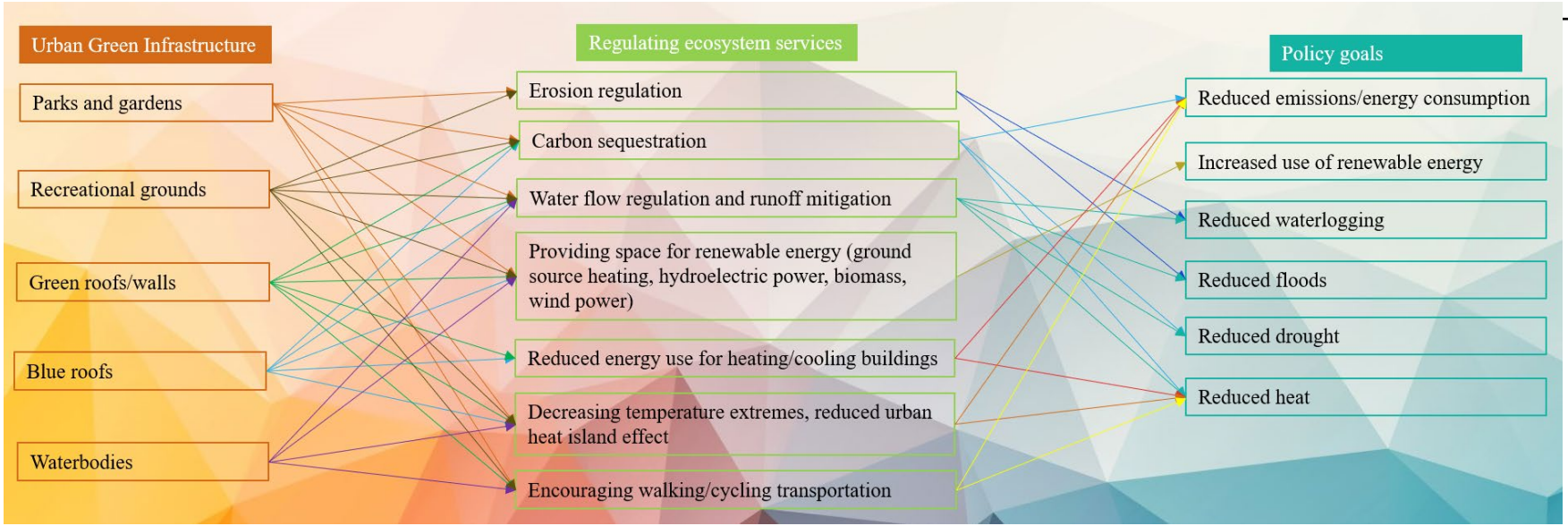
https://www.eea.europa.eu/publications/green-infrastructure-and-territorial-cohesion

# LINKING SERVICES TO UGI

| ES | Benefits |
|---|---|
| Biodiversity/ species protection | Habitats for species |
| | Permeability for migrating species |
| | Connecting habitats |
| Climate change adaptation | Mitigating urban heat island effect with evapotranspiration, shading and keeping free corridors for cold air movement |
| | Strengthening ecosystems' resilience to climate change |
| | Storing flood water and ameliorating surface water run-off to reduce the risk of flooding |
| Climate change mitigation | Carbon sequestration |
| | Encouraging sustainable travel |
| | Reducing energy use for heating and cooling buildings |
| | Providing space for renewable energy like ground source heating, hydroelectric power, biomass and wind power |
| Water management | Sustainable drainage systems — attenuating surface water run-off |
| | Groundwater infiltration |
| | Removal of pollutants from water (e.g. reed beds) |
| Food production and security | Direct food and fibre production on agricultural land, gardens and allotments |
| | Keeping potential for agricultural land — food security (safeguarding of soil) |
| | Soil development and nutrient cycle |
| | Preventing soil erosion |
| Recreation, well-being and health | Recreation |
| | Sense of space and nature |
| | Cleaner air |
| Land values | Positive impact on land and property |
| Culture and communities | Local distinctiveness |
| | Opportunities for education, training and social interactions |
| | Tourism opportunities |



# UGI – ECOSYSTEM SERVICES – DUTCH POLICY GOALS



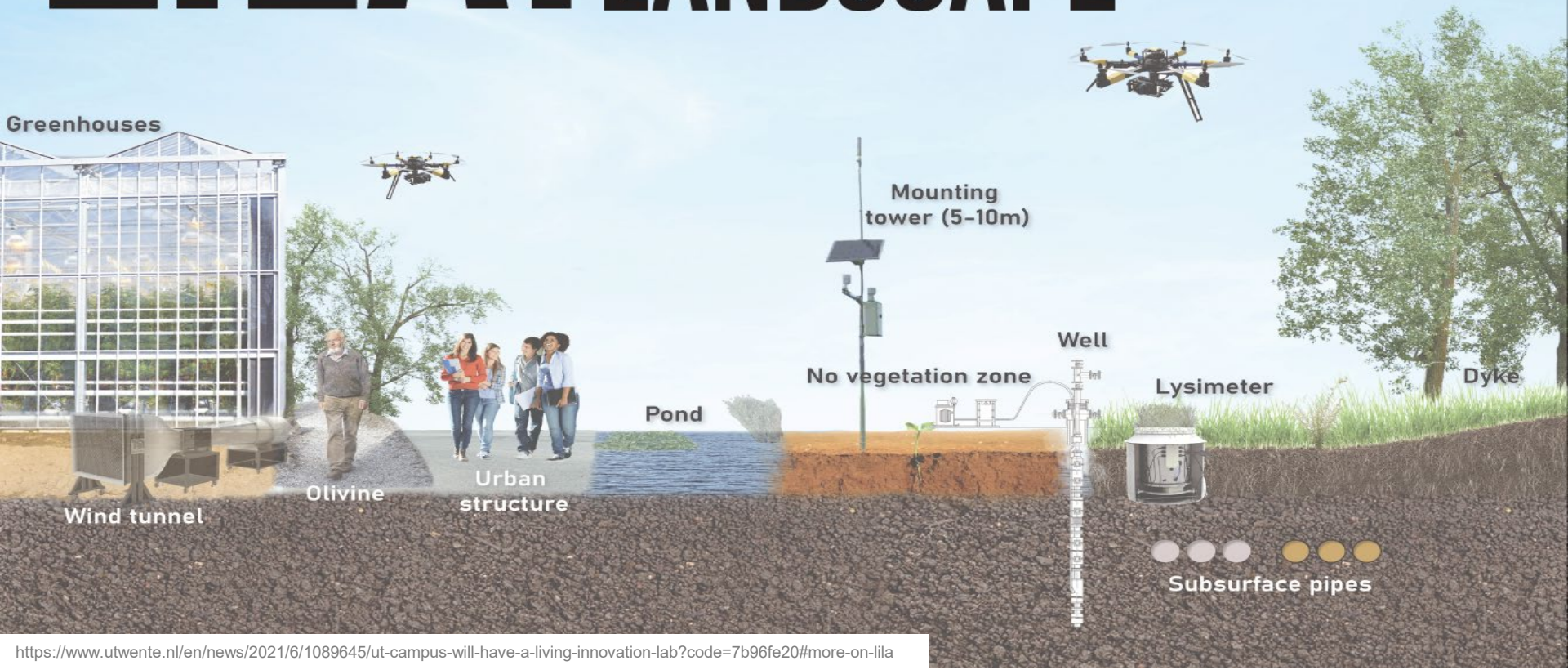

- only one service, providing space for renewable energy, helps to achieve the goal of increased use of renewable energy, and this service does not help achieve any other goal
- reduced emissions/energy consumption can be achieved by four different services
- water flow and runoff mitigation is relevant for four of the six policy goals



Implementing climate change adaptation and energy transition policies simultaneously through urban green infrastructure, K Vink, A A Gul, M Miyamoto, (2023), ICFM9 conference Tsukuba, Japan.

# LILA. LANDSCAPE

*Living Innovation-Lab at the UT*



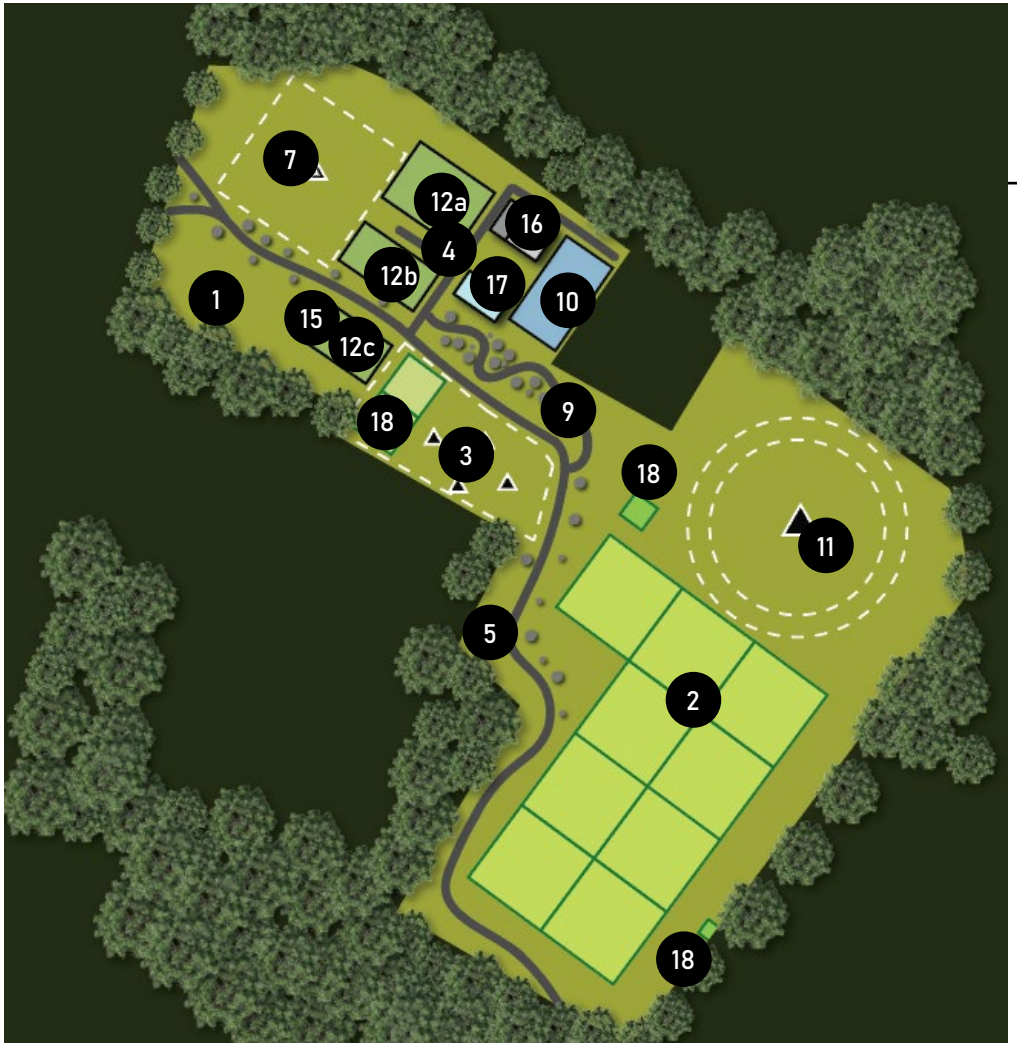

https://www.utwente.nl/en/news/2021/6/1089645/ut-campus-will-have-a-living-innovation-lab?code=7b96fe20#more-on-lila

# LIVING INNOVATION LAB – GREEN INFRASTRUCTURE


What is the living innovation lab?

LILa aims to:

1. give the public insight into current UT research
2. create an environment for observation, monitoring and experiments
3. support training and education by means of challenge-based learning on large societal challenges of urban resilience, climate change, and the energy transition




# Various experiments from 2 faculties (ITC & ET)

1. Soil mechanics
2. Subsurface infra
3. Geophysical testsite
4. Urban infra
5. Soil moisture (throughout)
6. Discontinued
7. Insar corner/ geodesic pole
8. Combined with 4, to be confirmed
9. Rock garden
10. Water quality
11. Climate (meteo) tower
12. Vegetation
    a. Vegetation monitoring with beam
    b. Vegetation growth
    c. Root-soil interaction
13. Combined with 12,17
14. Geo-information processing (no location)
15. Combined with 5
16. Coastal defence
    a. windtunnel
    b. Coastal dynamics/aquatic vegetation (possibly combined with 10,17)
17. Greenhouse
18. Biodiversity monitoring


Soil mechanics
Water and energy basics
incl. climate scaffold tower
Green garden

# LIVING INNOVATION LAB – GREEN INFRASTRUCTURE


What green infrastructure will be built?

North

South

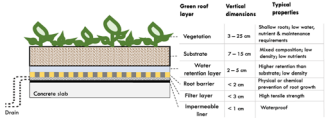
# LIVING INNOVATION LAB – GREEN INFRASTRUCTURE

## Green roof types

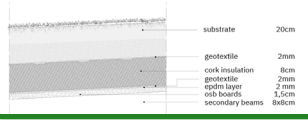
4 sections of 5x5m flat green roof

control

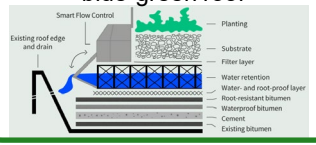
extensive green roof




corkboard/intensive green roof




blue-green roof




## Green wall types

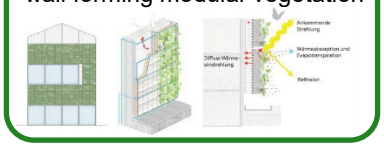
4 sections of 3m wide and at least 2m tall

control

free climbing soil bound plants

scaffolding climbing plants

wall forming modular vegetation



Electricity/dataloggers required for sensors, water for irrigation system.

# LIVING INNOVATION LAB – GREEN INFRASTRUCTURE

We aim to quantify the potential climate resilience benefits:

- reduced urban floods and runoff peaks
- reduced heating/cooling
- carbon sequestration

and quantify the potential tradeoffs:

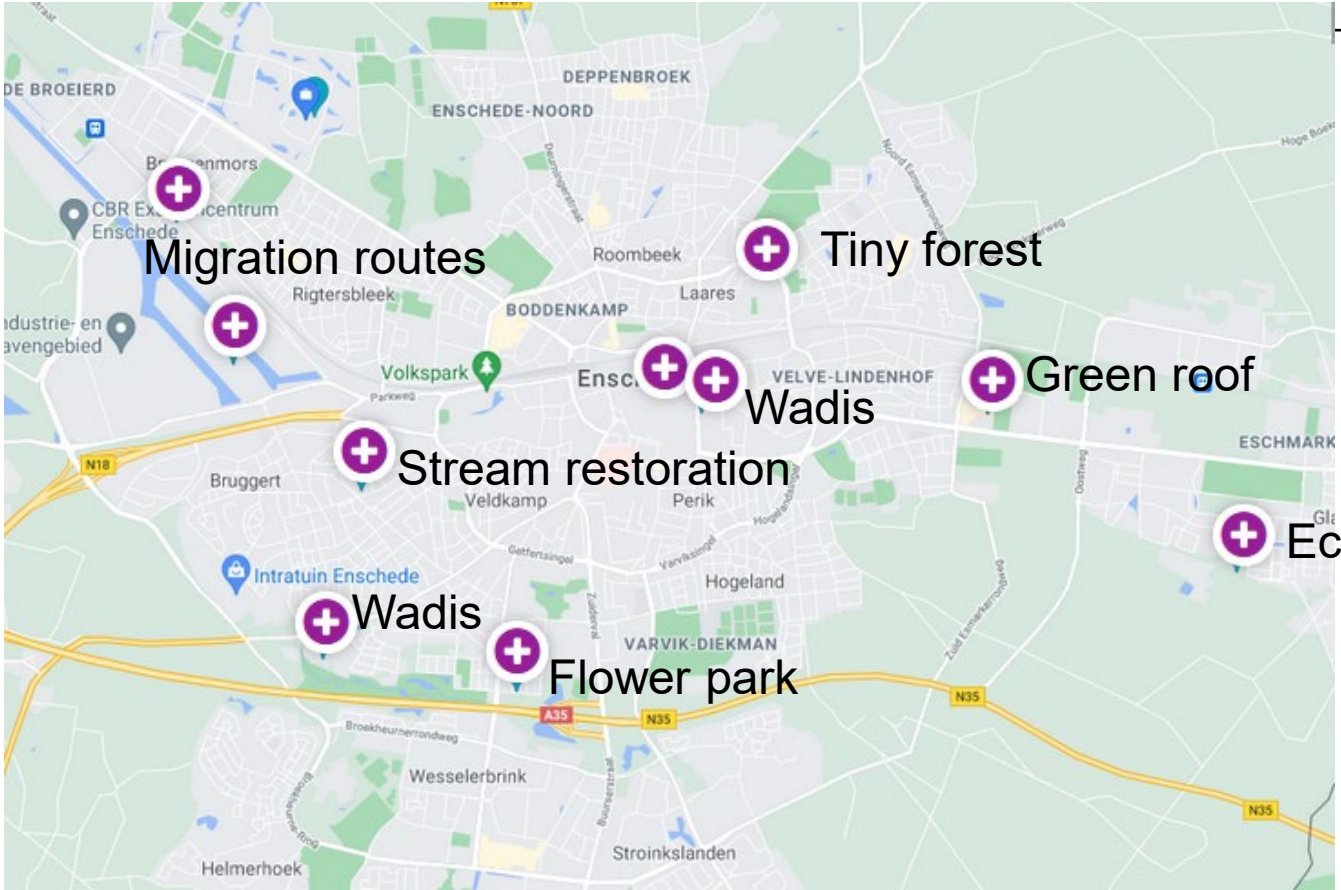
- CO2 emissions during production, maintenance (for irrigation and pumping), and end of life
- required irrigation and stored precipitation

all through continuous monitoring and modeling.

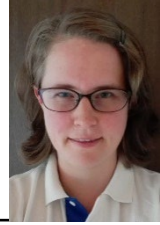
This provides insight into the **water-energy resource tradeoffs** when implementing urban green infrastructure.

What are the research aims?

# Examples of existing UGI in Enschede – contact me :)



Sean Vrielink/Karina Vink
https://people.utwente.nl/k.vink
k.vink@utwente.nl



# Thank you for your kind attention

## GEBÄUDE

| BEDARF | °C Temperatur | Licht | Lüftung | Elektrische Energie | Wasser | Material/ Ökobilanz |
|---|---|---|---|---|---|---|
| MASSNAHME | Adiabate Kühlung; Wärmehaltung/ Pufferwirkung | Außen liegender Sonnenschutz | Vorkonditionierung natürliche/kontrollierte Lüftung | Umweltenergie | Grauwassernutzung/ -reinigung | UV ΔT; $CO_2$-Bilanz |
| WIRKUNG GEBÄUDE-BEGRÜNUNG | + Vermeidung Aufheizung Gebäudeoberflächen/ Innenraum/Absorber durch Verschattung/ Verdunstungsleistung der Pflanzen<br>+ Reduktion Wärmeverluste der Gebäudehülle<br>+ geringere Windbelastung<br>+ geringere Feuchte | + Blendschutz durch Verschattung<br>+ Funktionsübernahme technischer Systeme<br>+ Pflanzenabhängig transluzent | + Luftreinigung<br>+ Luftbefeuchtung<br>+ Kühlung der Zuluft im Sommer<br>+ ggf. Pufferwirkung der Zuluft im Winter | + Wirkungsgradsteigerung technischer Systeme<br>+ Unterstützung aktiver und passiver Energiegewinnung | + Trinkwasserersparnis<br>+ Kühlwirkung<br>+ Schadstoff-Filterung<br>+ Gestaltungselement | + Kohlenstoff - Speicherung<br>+ $O_2$-Produktion<br>+ Energiebedarfsreduktion<br>+ Filterung von Feinstäuben<br>+ Bauteilschutz/Verlängerung der Lebensdauer |
| EINSPARUNG/ ZUGEWINN | Einsparung Kühlkosten | Reduktion Wärmedurchgang | Reduktion Primärenergie, Einsparung Wartungskosten technischer Systeme | Unterstützung/ Entfall Klimageräte | Leistungssteigerung Photovoltaik, Einsparung Kühlenergie, Biomassegewinnung | Einsparung systemabhängig | Einsparung Fassaden-/ Dachmaterialien, Lebensdauerverlängerung |



Ministerium für Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen

https://www.umwelt.

UMFELD

| BEDARF | Wasser | Vermeidung von Überhitzung | Reduktion der Luftbelastung | Akzeptanz | Minderung der Lärmbelastung | Biodiversität |
|---|---|---|---|---|---|---|
| MASSNAHME | Regenwasser-Rückhalt<br>Regenwasser-verdunstung | Adiabate Kühlung und Verschattung | Photosynthese und Feinstaubbindung | Aufwertung von Gebäuden und Freiraum | Schallreflektion und -absorption | Erweiterung Lebensraum für Flora und Fauna |
| WIRKUNG GEBÄUDE-BEGRÜNUNG | + Wasserrückhalt durch Minderung des Abflussbeiwerts<br>+ Verhinderung hoher Belastung der Kanalisation<br>+ Reduktion versiegelter Flächen<br>+ Erhöhung der Verdunstungsrate<br>+ Umgebungskühlung | + Kühlung durch Verdunstung und Verschattung<br>+ Minderung städtischer Wärmeinseln | + Kohlenstoffspeicherung<br>+ Sauerstoffproduktion<br>+ Feinstaubbindung und Verstoffwechselung von Luftschadstoffen<br>+ Oberflächenschutz | + Verbesserung der Aufenthaltsqualität<br>+ Steigerung der Akzeptanz<br>+ Corporate Identity<br>+ Fernwirkung | + Lärmminderung durch Reflexions- und Absorptionsleistung<br>+ Reduktion Transmission Gebäude | + trägt zur lokalen Artenvielfalt bei<br>+ Erweiterung Nahrungs- und Lebensraum |
| EINSPARUNG/ ZUGEWINN | reduzierte Niederschlag-wassergebühr | Reduktion Starkregen-ereignisse / Sturm und Hagelschäden, Kanalentlastung | Schutz Material/ Klima/Gesundheit | Schutz Material/ Gesundheit | Attraktivität | Gesundheit, Sicherheit, Aufenthalts- und Kommunikationsqualität | Artenschutz |



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# HOW TO MEASURE AND VALUE GI BENEFITS

Monetary value = ?

The monetary costs of implementing and maintaining the measures?

The monetary savings of avoided costs, e.g. water treatment or health?

Include potential co-benefits e.g. improved aesthetic quality or social cohesion?

Include disservices, e.g. displacement of prior residents or an increased risk of pollen-related allergies?

Keeler, B.L., Hamel, P., McPhearson, T. et al. Social-ecological and technological factors moderate the value of urban nature. Nat Sustain 2, 29–38 (2019). https://doi.org/10.1038/s41893-018-0202-1

# INDICATOR-BASED ASSESSMENT

Parisa Pakzad, Paul Osmond, Developing a Sustainability Indicator Set for Measuring Green Infrastructure Performance, Procedia - Social and Behavioral Sciences, Vol. 216, 2016, https://doi.org/10.1016/j.sbspro.2015.12.009.

| Categories | Performance indicators |
|---|---|
| Ecological indicato | Climate and microclimatic modifications (e.g. Urban Heat Island effect mitigation; temperature moderation through evapotranspiration and shading; wind speed modification) |
| | Air quality improvement (e.g. Pollutant removal; Avoided emissions) |
| | Carbon Emissions (e.g. direct carbon sequestration and storage; avoided greenhouse gas emissions through cooling) |
| | Reduced building energy use for heating and cooling (through e.g. shading by trees; covering building by green roof and green walls) |
| | Hydrological regulation (e.g. flow control and flood reduction; regulation of water quality; water purification) |
| | Improved soil quality and Erosion prevention (e.g. soil fertility; soil stabilization) |
| | Waste decomposition and nutrient cycling |
| | Noise level attenuation |
| | Biodiversity-protection and enhancement (e.g. Communities; species; genetic resources; habitats) |
| Health indicators | Improving physical well-being ( e.g. physical outdoor activity; healthy food; healthy environments ) |
| | Improving social well-being (e.g. social interaction; social integration; community cohesion) |
| | Improving mental well-being (e.g. reduced depression and anxiety; recovery from stress; attention restoration; positive emotions) |

# INDICATOR-BASED ASSESSMENT

Parisa Pakzad, Paul Osmond, Developing a Sustainability Indicator Set for Measuring Green Infrastructure Performance, Procedia - Social and Behavioral Sciences, Vol. 216, 2016, https://doi.org/10.1016/j.sbspro.2015.12.009.

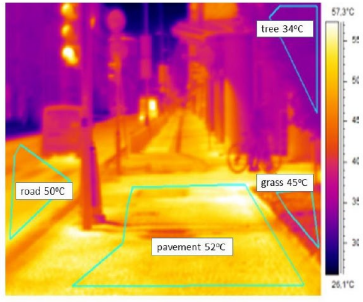
| Categories | Performance indicators |
|---|---|
| Socio-cultural indicators | Food production (e.g. urban agriculture; kitchen gardens; edible landscape and community gardens) |
| | Opportunities for recreation, tourism and social interaction (community livability) |
| | Improving pedestrian ways and their connectivity (e.g. increasing safety; quality of path; connectivity and linkage with other modes) |
| | Improving accessibility |
| | Provision of outdoor sites for education and research |
| | Reduction of crimes and fear of crime (comfort; amenity and safety) |
| | Attachment to place and sense of belonging (cultural and symbolic value) |
| | Enhancing attractiveness of cities (e.g. enhancing desirable views; restricting undesirable views ) |
| Economic indicators | Increased property values |
| | Greater local economic activity (e.g. tourism, recreation, cultural activities) |
| | Healthcare cost savings |
| | Economic benefits of provision services (e.g. raw materials; timber; food products; biofuels; medicinal products; fresh water etc.) |
| | Value of avoided $CO_2$ emissions and carbon sequestration |
| | Value of avoided energy consumption (e.g. reduced demands for cooling and heating) |
| | Value of air pollutant removal/avoidance |
| | Value of avoided grey infrastructure design (construction and management costs) |
| | Value of reduced flood damage |
| | Reducing cost of using private car by increasing walking and cycling (e.g. shifting travel mode) |

C.M. Raymond et al. A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas, Environmental Science & Policy, Vol. 77, 2017, https://doi.org/10.1016/j.envsci.2017.07.008.

# INDICATOR-BASED ASSESSMENT

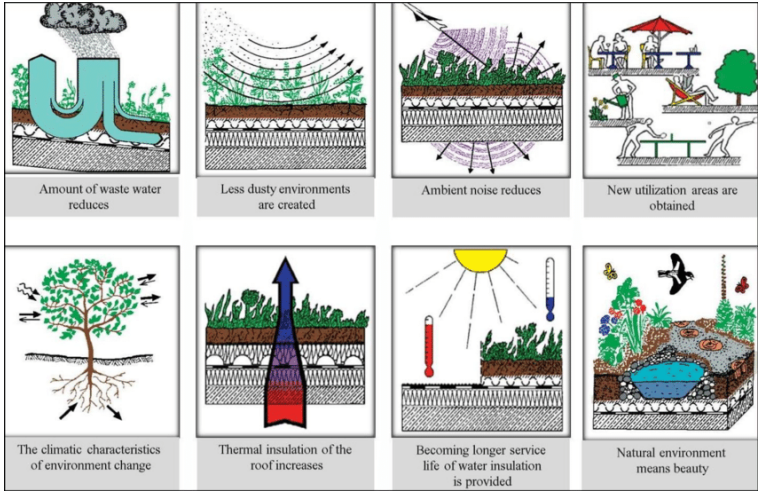
| Challenge area | Example of indicators | Type of indicator | Unit of measurement |
|---|---|---|---|
|  | Net carbon sequestration by urban forests (including GHG emissions from maintenance activities) | Environmental (chemical) | t C per ha/year |
|  | Economic benefit of reduction of stormwater to be treated in public sewerage system | Economic (monetary) | Cost of sewerage treatment by volume (€/$m^3$) |
|  | Area remaining for erosion protection | Environmental (physical) | $km^2$ or $m^2$ |
|  | Species richness of indigenous vegetation | Environmental (physical) | A count, magnitude or intensity score of indigenous species per unit area |
|  | Annual amount of pollutants captured by vegetation | Environmental (chemical) | t pollutant per ha /year |
|  | Index of ecological connectivity (integral index of connectivity | Environmental (physical) | Probability that two dispersers randomly located in a landscape can reach each other |
|  | Quality of the participatory or governance processes | Social (process) | Perceived level of trust, legitimacy, transparency and accountability of process |
|  | Accessibility to public green space | Social (justice) | % of people living within a given distance from accessible, public green space |
|  | Level of involvement in frequent physical activity in urban green spaces | Social (physiological) | Number and % of people being physically active (min. 30 min 3 times per week) in urban green spaces |
|  | Net additional jobs in the green sector enabled by NBS projects | Economic (productivity) | New jobs/specific green sector/year |

# LACK OF QUANTIFICATION




Using project-based education to develop pre-service biology teachers' knowledge of the cooling effect of vegetation. *Ryplova Renata, Pokorny Jan.* In: M.Rusek, K.Vojíř (Eds.): PROJECT-BASED EDUCATION AND OTHER ACTIVATING STRATEGIES IN SCIENCE EDUCATION XVI. Proceeding from the international conference PBE 2018, 8. – 9.11. 2018, Prague,CZ, p. 105 – 113. ISBN 978-80-7603-066-4

**Fig.1. Street without trees on a summer day. Surface temperature of pavement 52°C, a tree on a side 34°C. (Pokorny et al., 2018)**




The Effects of Green Roofs on Urban Ecosystems
Murat Özyavuz, Beste Karakaya, Deniz Gözde ERTİN.
GreenAge Symposium, Mimar Sinan Fine Arts, University
Faculty of Architecture 15-17 April 2015, Istanbul, Türkiye

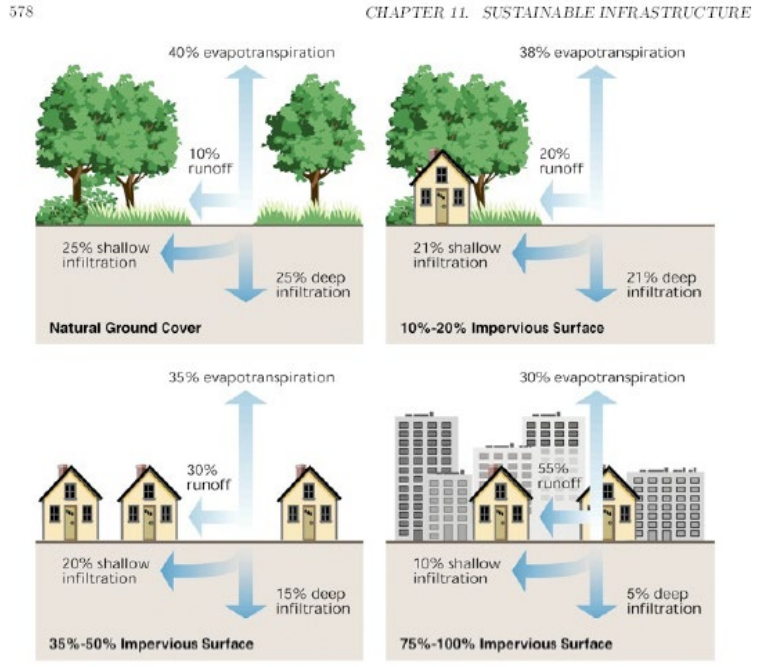



**Figure 11.31: Degrees of Imperviousness and its Effects on Stormwater Runoff** These four images show increasing amount of stormwater runoff as the area becomes developed with more impervious surfaces. *Source: In Stream Corridor Restoration: Principles, Processes, and Practices (10/98) By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)*[112]

Sustainability: A comprehensive foundation. Theis & Tomkin, 2015. OpenStax CNX. Chapter 11. https://open.umn.edu/opentextbooks/textbooks/96