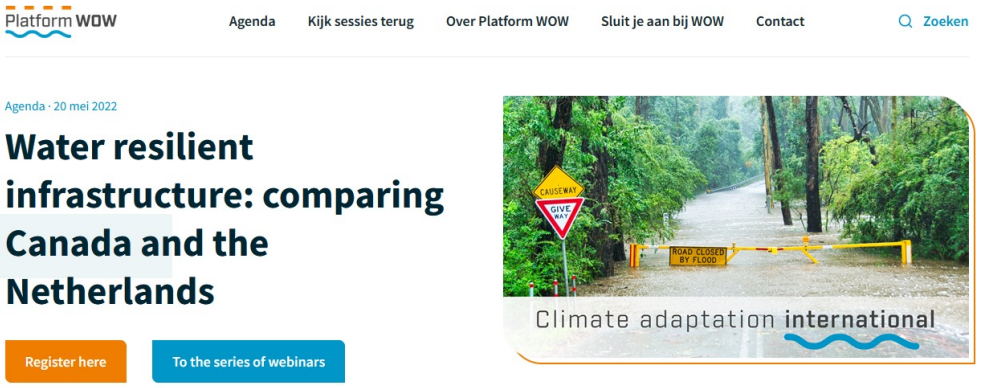
Deltares

Urban Resilient Infrastructure

Climate Adaptation: solutions from different corners of the world is about adapting infrastructure to new conditions caused by climate change in Canada and the Netherlands.

Dr.ir.F.C.Boogaard

May 2022

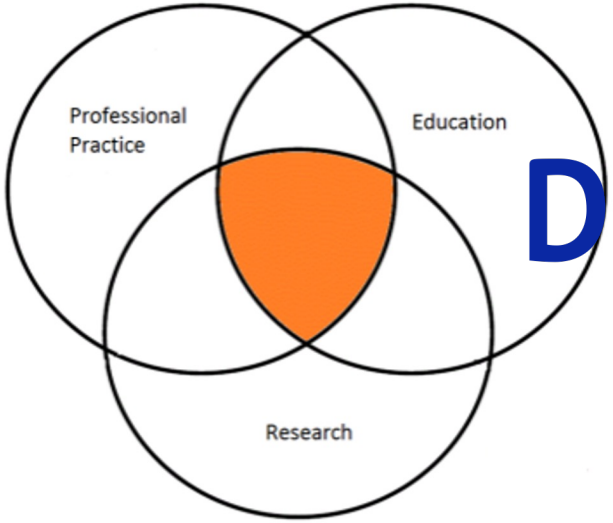


Introduction: Floris Boogaard

GLOBAL CENTER ON ADAPTATION

Hanzehogeschool Groningen
University of Applied Sciences

Kenniscentrum NoorderRuimte



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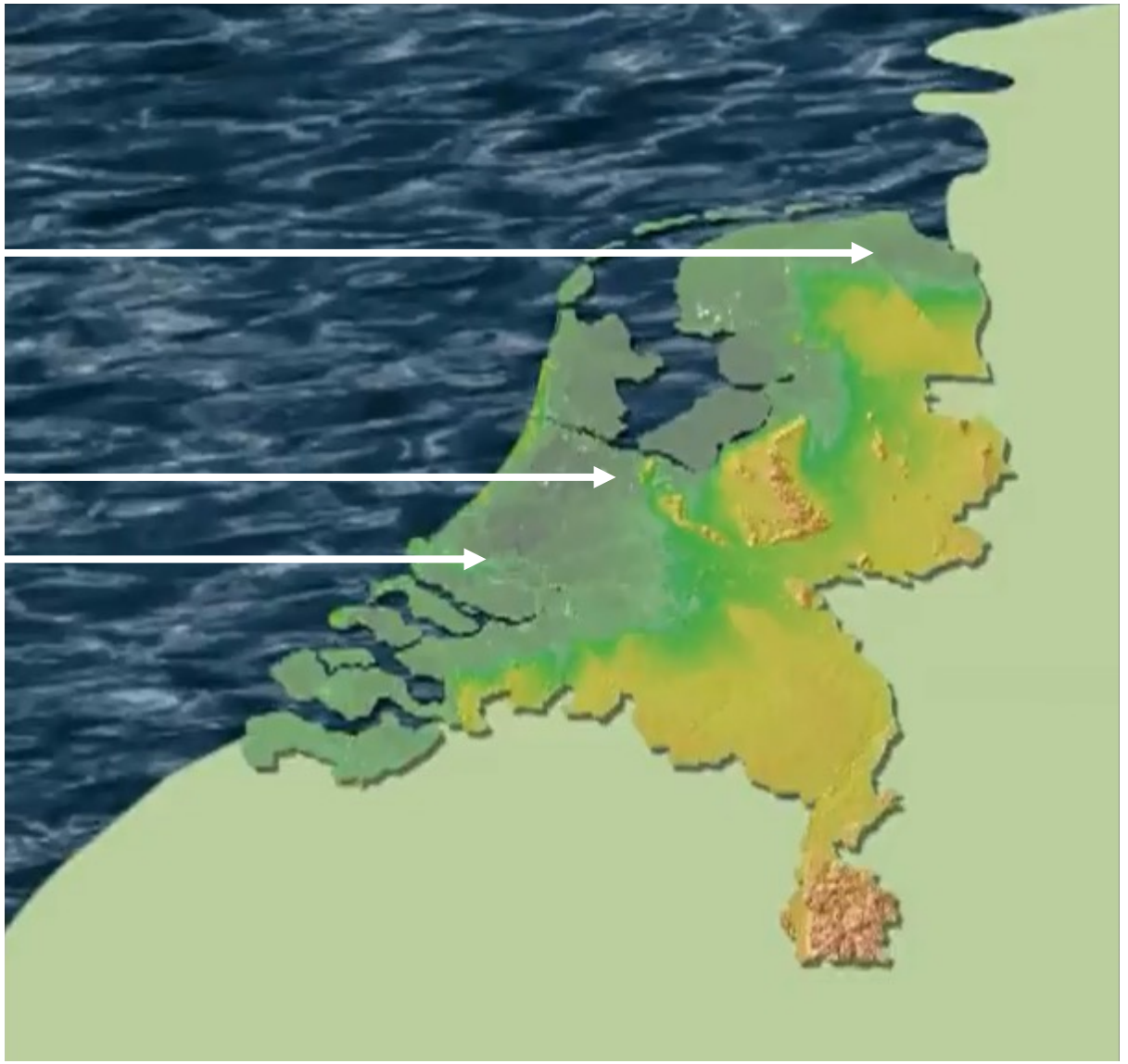

Content: Small scale urban resilient infrastructure in practise: what, where and does it work?

1. Challenges
2. Solutions
    1. The Netherlands
    2. Canada
    3. Global
3. Practical examples of resilient infrastructure
    1. (how) does it work?
4. Tools and information
5. More info

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Analysis

Analysing your area

Ambition

Formulating your ambition

Action

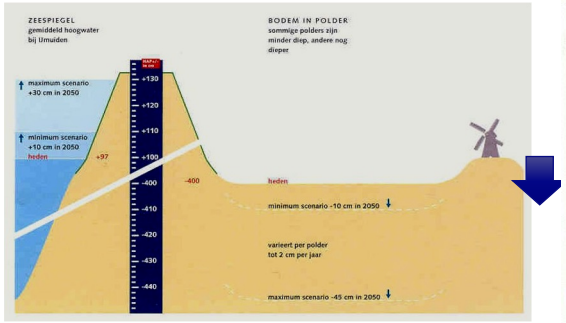
Policy and implementation

Challenges urban climate (Holland)

floodings

heatstress

waterquality



subsidence

drought

Dutch examples of problems in the urban areas: floodings, degradation of waterways, heatstress, drought leading to lower groundwater table and subsidence with results as damage of buildings

Why GI? To face urban challenges

Floods

Credits Port Technology website

Water pollution

Credits Plastic pollution/Zero Waste Conference

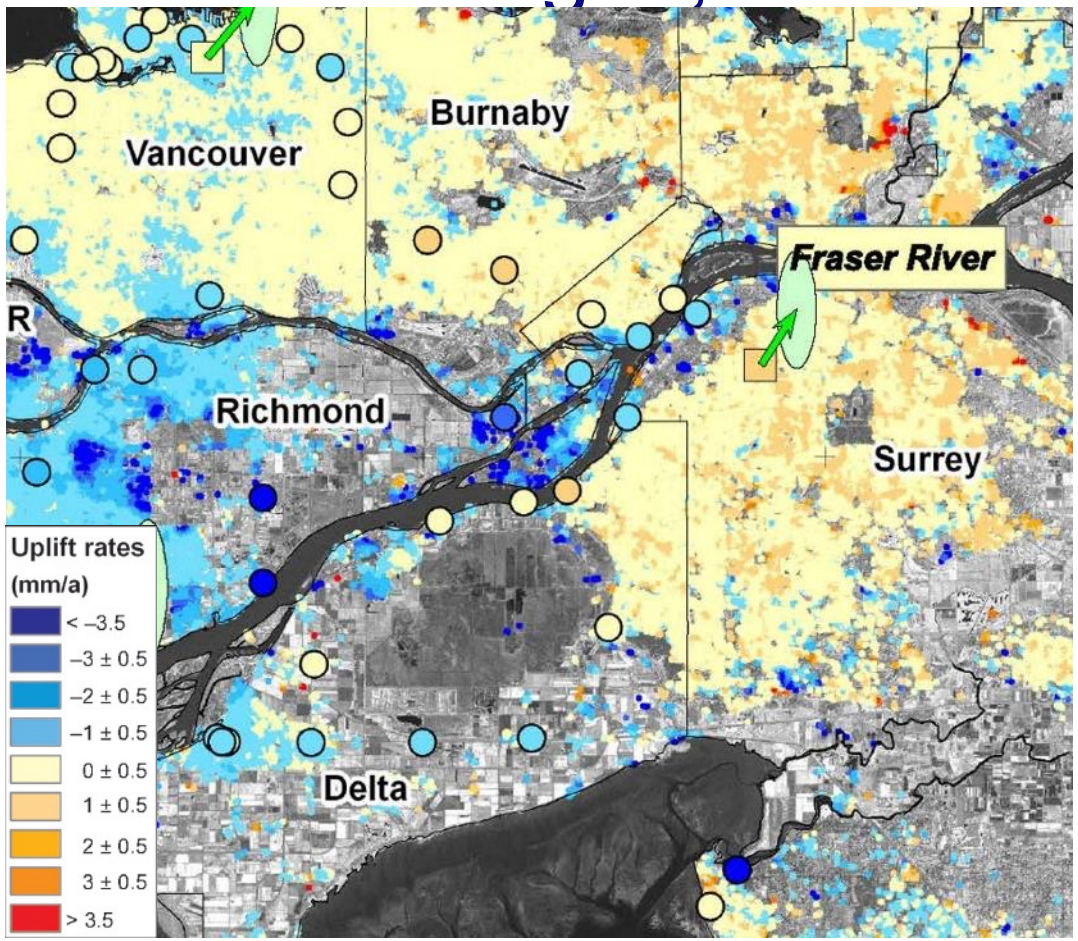
Heat stress

Credits BBC

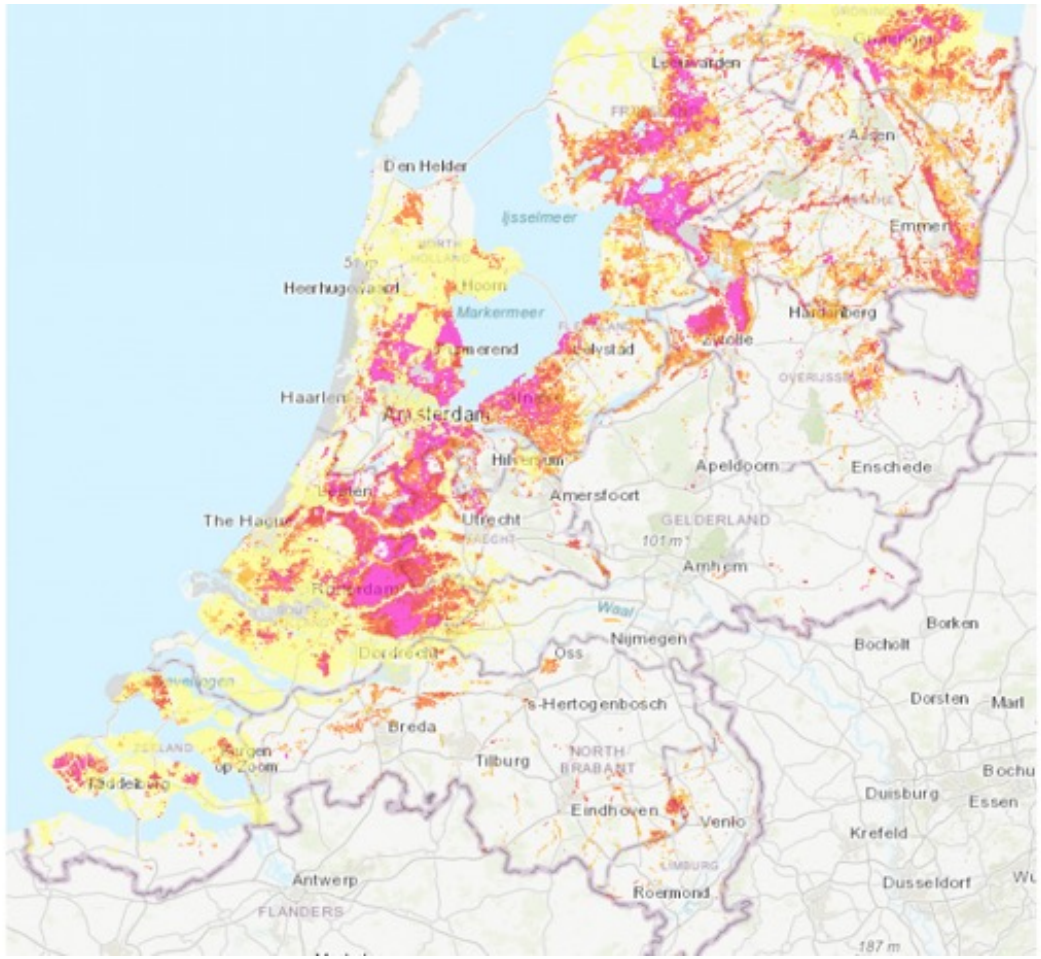
Droughts

Credits Water Canada

The Netherlands and Vancouver face some of the same challenges, like subsidence



Land subsidence in Vancouver



Expected subsidence 2020-2100 in the Netherlands

Verwachte bodemdaling (cm)

	3-10	10-20	20-40	40-60	>60
Geen voorspelling mogelijk	Beperkt	Matig	Vrij sterk	Sterk	Zeer sterk

Deltares

Sinking cities

WORLD ECONOMIC FORUM | Agenda | Platforms | Reports | Events | About | English | TopLink

Global Agenda | Climate Change | Cities and Urbanization | Water

These 11 sinking cities could disappear by 2100

People walk on the water as roads are flooded due to heavy rain in Dhaka, Bangladesh July 26, 2017. Image: REUTERS/Mohammad Ponir Hossain

9. Rotterdam, The Netherlands

Dredgers work to create new land in front of the Europort to create the Europort nr. 2 in Rotterdam September 1, 2009. With scientists predicting that sea levels will rise by about one metre (3.3 feet) this century, the Dutch are reversing centuries of tradition to create natural flood plains for rivers as well as rebuild mangrove swamps as buffers against the sea. Instead of raising dikes, the Dutch want to reclaim land and build public recreation areas that can absorb storm surges. Picture taken September 1, 2009.

According to The New York Times, 90% of the city of Rotter level. As ocean levels rise, the risk of flooding increases.

Like Bangkok's Chulalongkorn University Centenary Park, th "water parks" that double as reservoirs for the swelling wate called Room for the River, as well as enormous storm surge

1. Jakarta, Indonesia

A man d fishing p

Jakarta pumpi sink).

The In miles a million cost $

Read more: Inc hundreds of miles. He

2. Lagos, Nigeria

People capital

Lagos warm

A 201 to nin regior

3. Houston, Texas

Inter seen REU

Part grou

The disa disp

4. Dhaka, Bangladesh

Vehicl Bangl

Bang but t acco

Ocea citize

5. Venice, Italy

Tourist walk REUTERS/G

Venice is

Italy bega 2003. It's but will lik

6. Virginia Beach, Virginia

Virgi facto

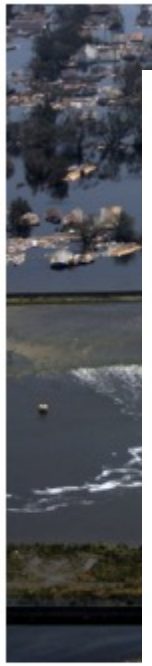
The Beac

7. Bangkok, Thailand

Imag

Ban sea

8. New Orleans, Louisiana



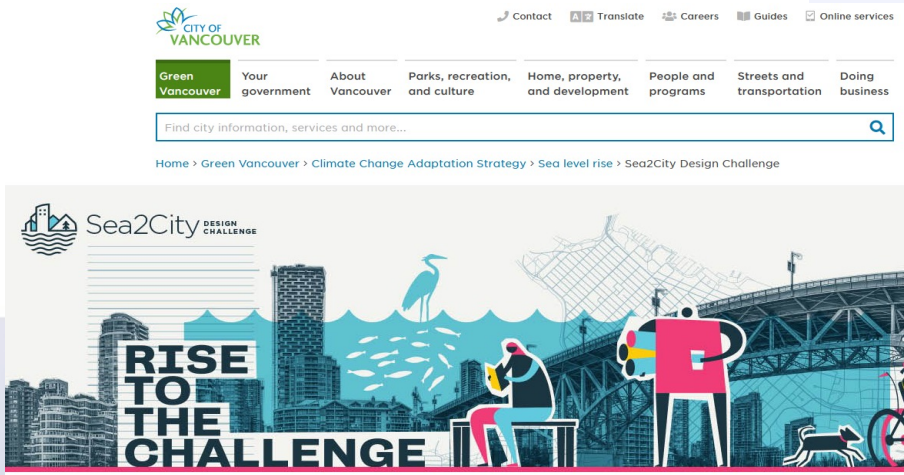
A levee gives v Katrina struck top-ranked stc

10. Alexandria, Egypt

11. Miami, Florida

https://www.weforum.org/agenda/2019/09/11-sinking-cities-that-could-soon-be-underwater/

Solutions Canada-Netherlands



Sea2City Design Challenge

Dutch: Floating urbanisation, room for the river

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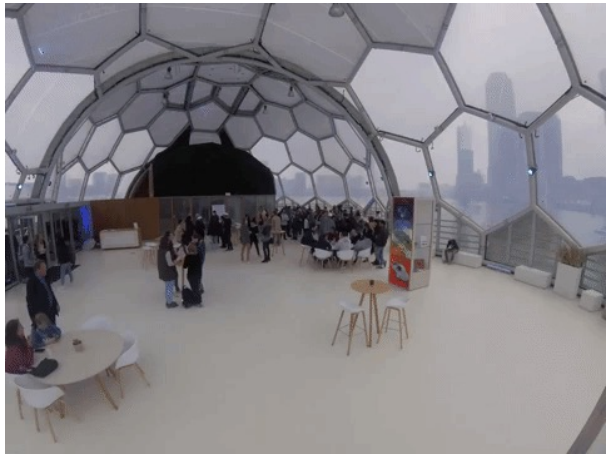
Challenges urban climate (change)



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Where to find: Floating urbanisation

https://www.climatescan.org/#filter-1-2

Interactive map | About ClimateScan | JOIN US | Focus topics | Events | Contact | Login

Start typing here to search for projects

Legend

Click on a focus group to filter the markers on the map. You can get more information on a specific focus topic by clicking the ℹ-sign.

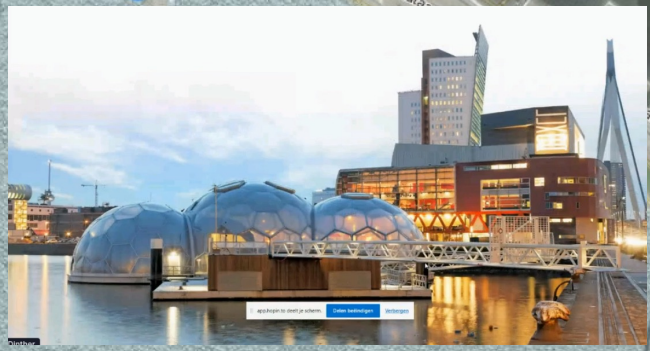
- Water
  - (bio) swale
  - Floating urbanisation
  - Permeable pavement
  - Green roofs and walls
  - Subsurface infiltration
  - Gully free roads
  - Problem area
  - Constructed wetland
  - Water quality improvement
  - Other categories
  - Stormwater on private property
  - Watersquare
  - Storage for water
  - surfacewater storage & infiltration
  - Rainwater harvesting
  - Urban bathing water
  - Australian (eg bio retention, rainwater ha...
  - Raingarden
  - Retention pond

Global Centre on Climate Adaptation Headquarter in Rotterdam

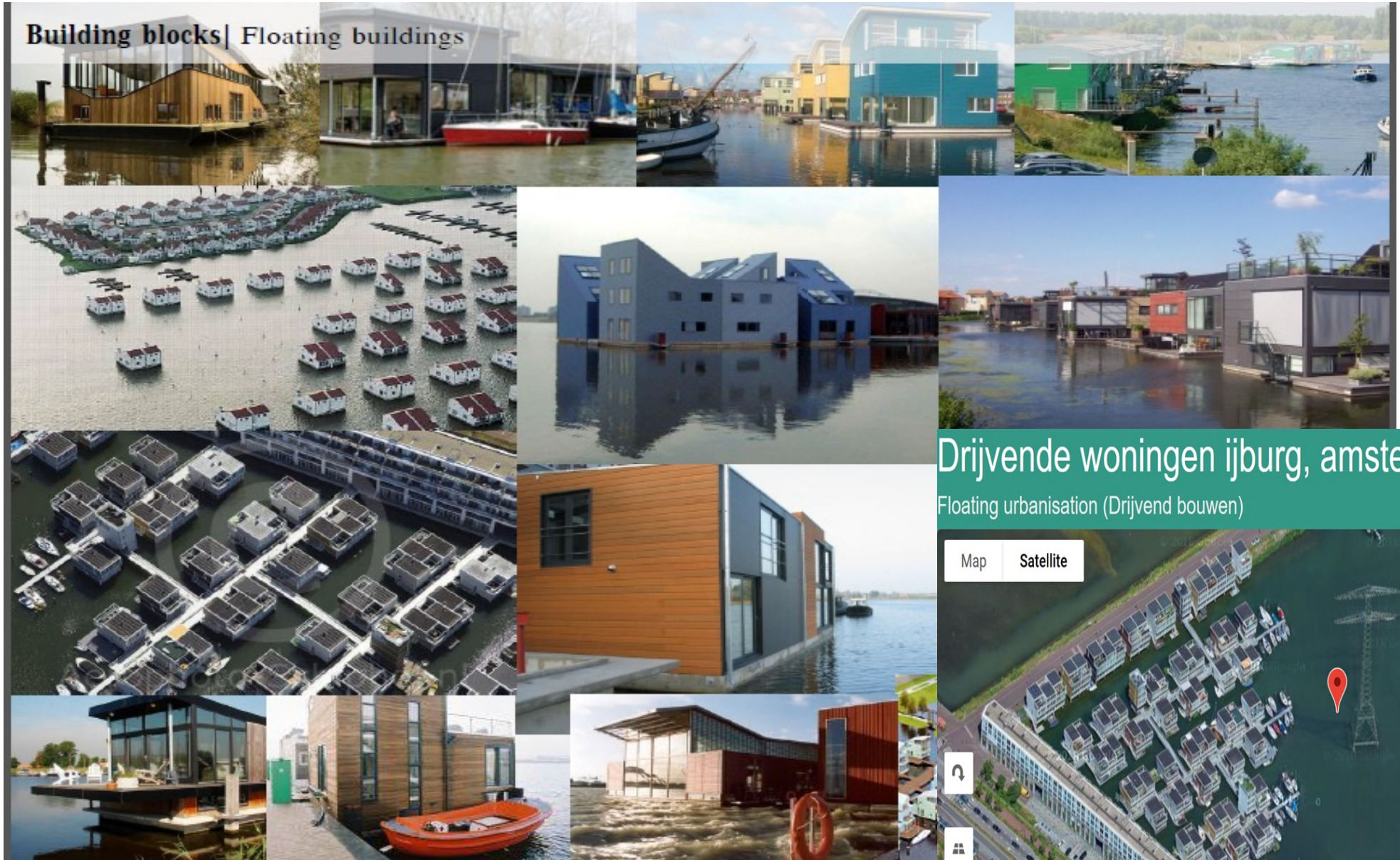
Focus topic: Water
Category: Floating urbanisation

More information →

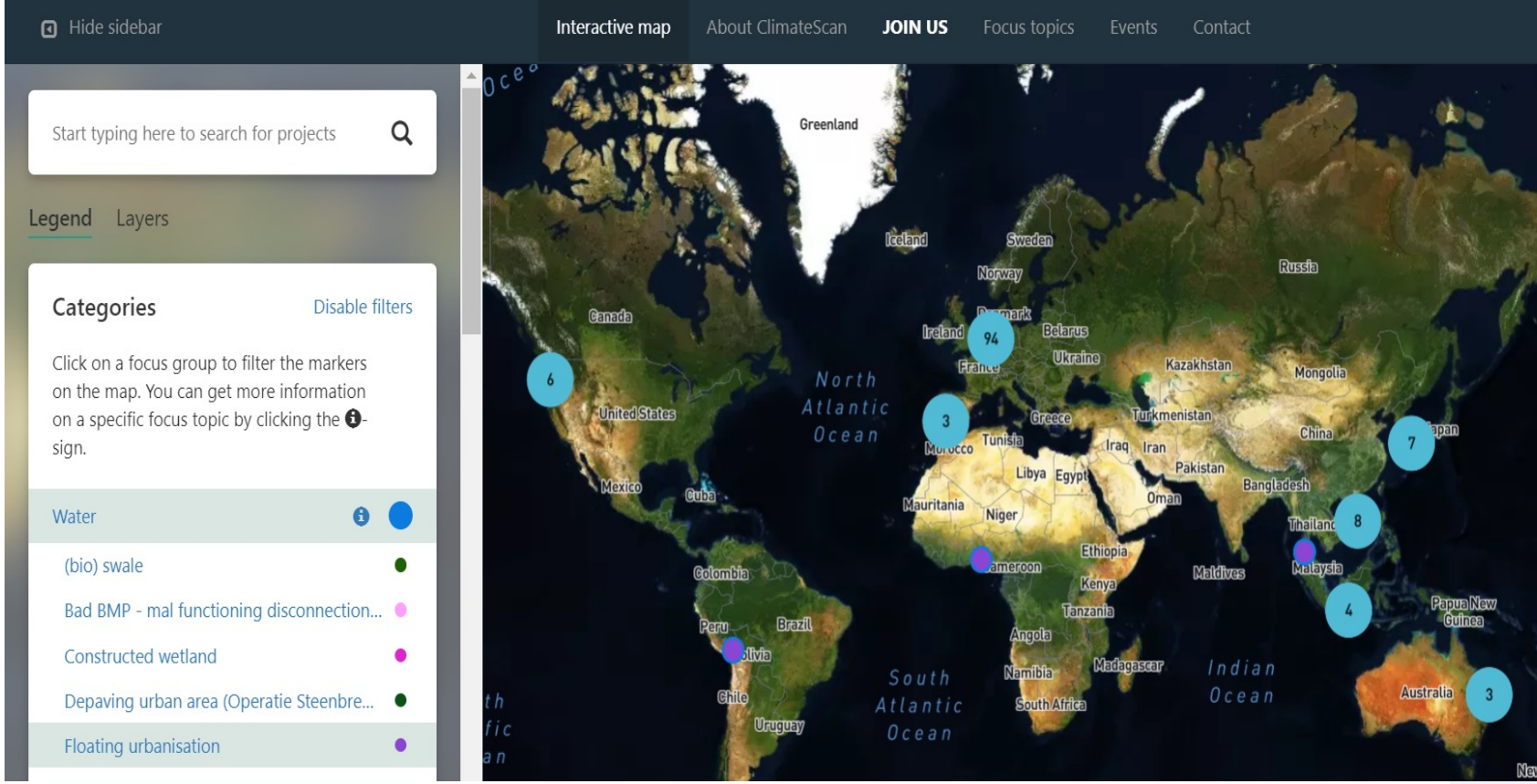
GLOBAL CENTER ON ADAPTATION



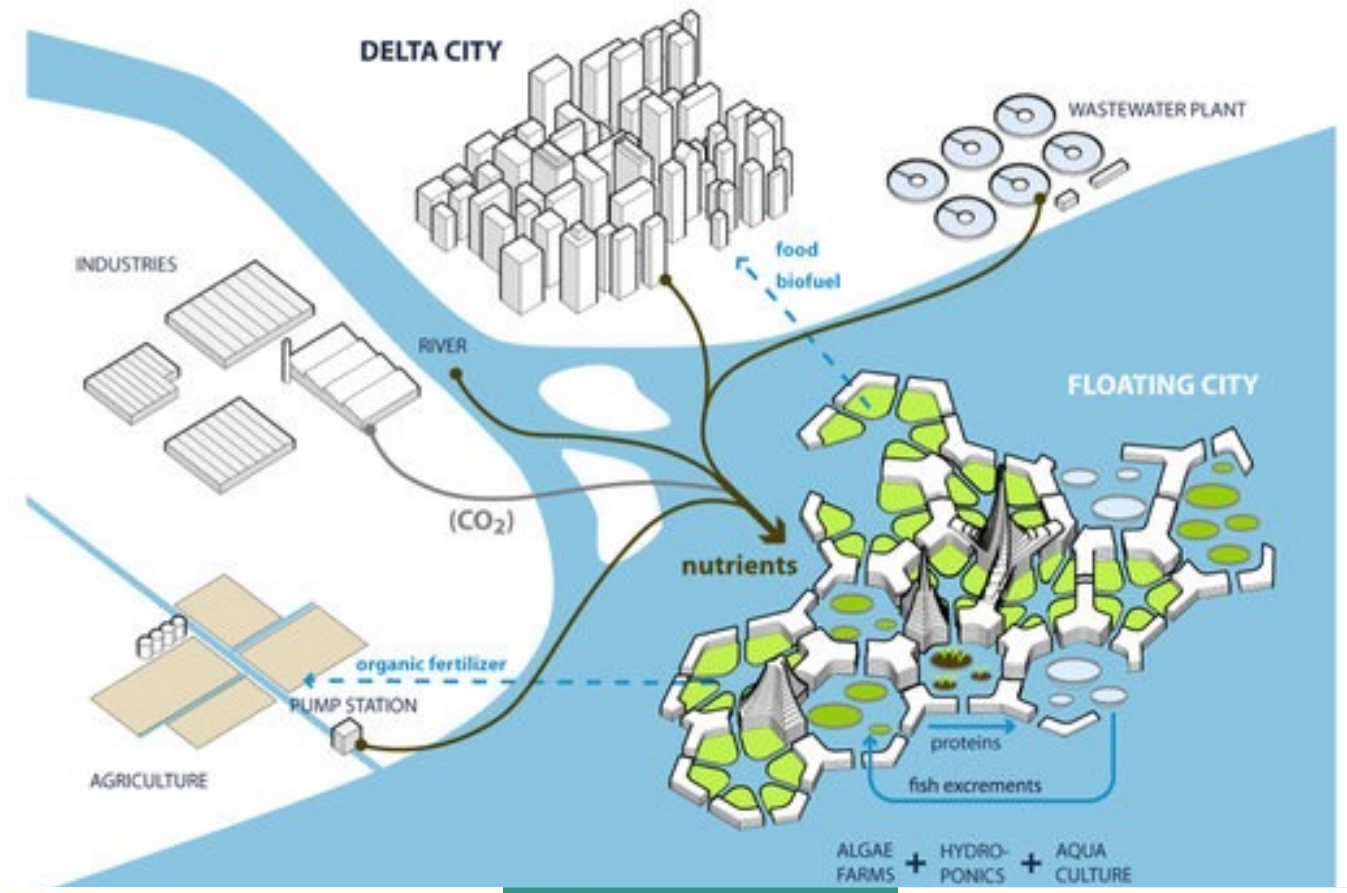
Floating and amphibious life



Tools and examples
Floating urbanisation
Climatescan.org



Future? New floating cities




DAGBLAD NOORDEN

ACHTERGROND

Dromen van wonen op drijvend afval

Studenten van de Hanzehogeschool maakten al bootjes van drijvend afval. Nu richten ze zich op complete drijvende woningen.

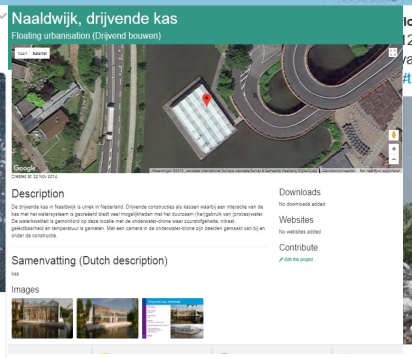
'Als er geen ruimte meer is, ga je het water op'

De Green Quest


Weinig invloed op ecosysteem onder drijvende objecten


Rutger De Graaf @degraaf_e · 28 feb.
Delftse architecten helpen bij bouw eerste drijvende stad ter wereld
owst.nl/XFm5 @Blue21Float @KarinaDeltasync @FlorisBoogaard

Delftse architecten helpen bij bouw eerste drijvende stad ter wereld
Een Delfts architectenbureau Blue21 werkt mee aan een bijzonder project. Zij onderzoeken op dit moment de bouw van 's werelds eerste drijvende st...


Naaldwijk, drijvende kas
Floating urbanisation (Drijvend bouwen)
Description
Samenvatting (Dutch description)
Images
Downloads
Websites
Contribute

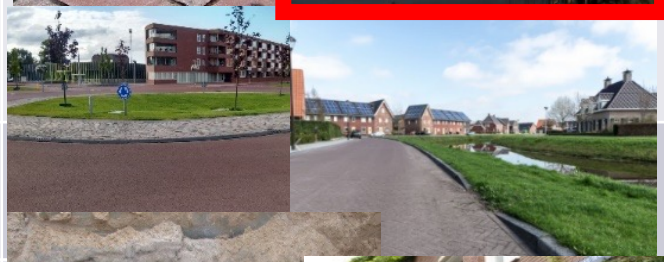

loris boogaard @FlorisBoogaard · 18 u
12 @hanze studenten willen drijvende (studenten)woningen bouwen van plastic afval na Manilaproject youtube.com/watch?v=8Cfbir… #thegreenquest
GIF

Deltar

Flexible small urban Resilient infrastructure

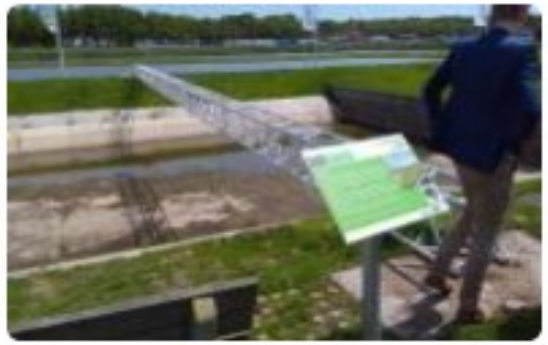
I have no interest in who built the drain system... I want to know who built the fence!

Deltares

	name	definition	Visual (source: wwclimatescan.nl)
1	Swale	A shallow vegetated channel designed to conduct and retain water, but may also permit infiltration. The vegetation filters particulate matter.	
2	Constructed wetland	Wetland: flooded area in which the water is shallow enough to enable the growth of bottom-rooted plants. Wetlands are constructed in urban areas to store water after stormwater events and improve waterquality.	
3	Waterharmonica	Ecological engineering treating waste water into usable surface water. The Waterharmonica focusses on integrated ecological engineering processes, by optimising multifunctional constructed wetland processes.	
4	Green roofs (and walls)	A roof with plants growing on its surface, which contributes to local biodiversity. The vegetated surface provides a degree of retention, attenuation and treatment of rainwater, and promotes evapotranspiration.	
5	Floating urbanization	Floating or amfibious constructions as floating homes will adapt to variation of waterlevels (flooding, drought). Floating homes are constructed around the world to adapt to climate adaptation.	
6	Permeable pavement	A permeable surface that is permeable and drains through voids between solid parts of the pavement. A permeable surface is a surface that is formed of material that is itself impervious to water, but has a pattern of voids formed through the surface, allows infiltration of water to the subbase through the pattern of voids, for example concrete block paving.	
7	Opportunities for adaptation	This category shows projects that provide opportunities for climate adaptation. Uploaded projects can be implementation of nature based solutions or locations that are suited for adaptation.	
8	Hollow gully free roads	Roads that are designed for drainage. An example is a surface flood pathway: routes in which excess stormwaterflows are conveyed on the ground. Also referred to as ‚hollow gully free' roads.	
9	Sub-surface infiltration	A sub-surface structure into which storm water is conveyed, designed to promote infiltration.	
10	Flexible small urban Resilient infrastructure	An upcomming categorie linked to flexible flood walls to protect infrastructure	

Flood barriers






https://www.climatescan.nl/projects/2239/detail

And what about drought (and flood & heatstress)

This second webinar from the series Climate Adaptation: solutions from different corners of the world is about adapting infrastructure to new conditions caused by climate change in Canada and the Netherlands. Floris Boogaard and Darren Swanson will specifically discuss the drought and extreme rainfall.

Smart cities: a Green Blue strategy

Solutions

Green infrastructure

[GI is] ‘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’ in both rural and urban settings.

European Commission

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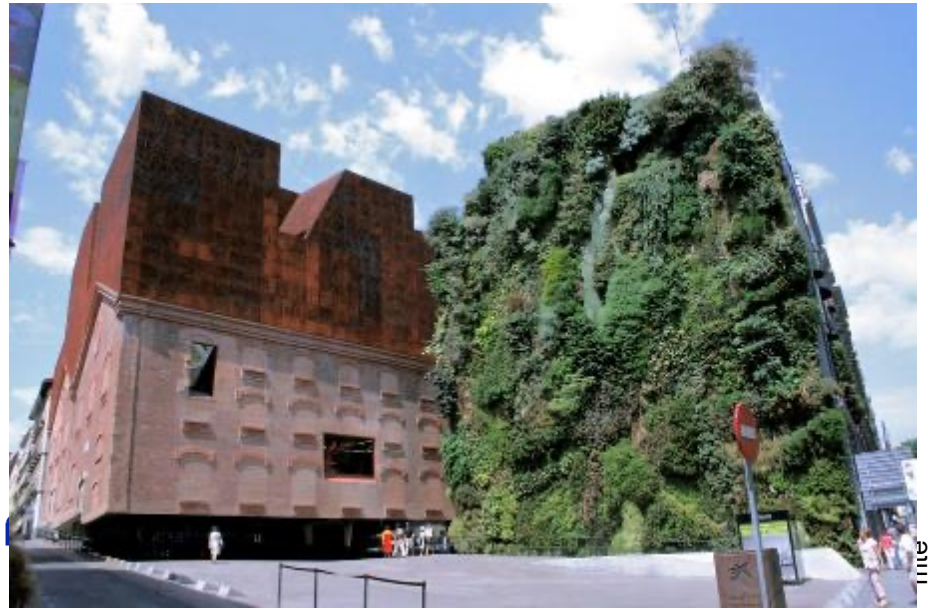
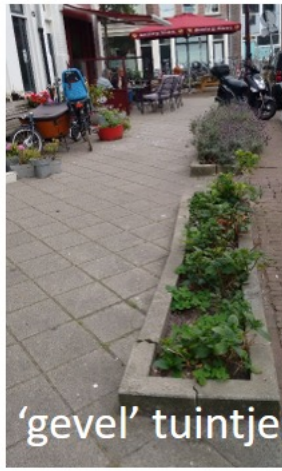
International multifunctional inspiration/solutions




Groene infrastructuur,
Amsterdam


(Doorgroeibare) verharding


Sheet flow
Deventer


‘gevel’ tuintje


Speelplaats en waterberging


Participerend onderzoek
Groenblauw oplossing
Groningen


Tree box
Zutphen


Groene
rotonde
Winschoten


Raingarden
Nijverdal


Bio-filtratie
Purmerend


Wetlands


Bodempassage
Enkhuizen

	name	definition	Visual (source: wwclimatescan.nl)
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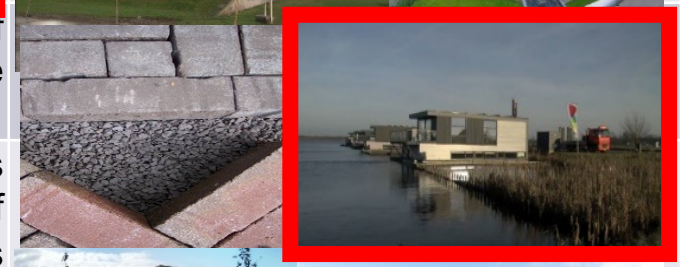
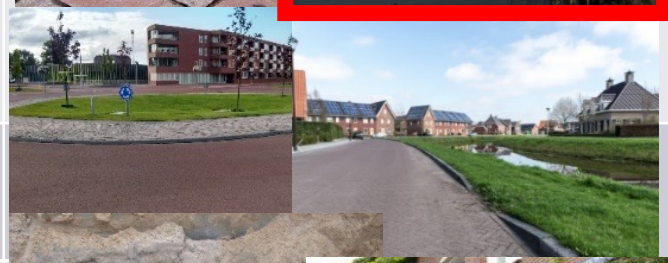
5	Floating urbanization	Floating or amfibious constructions as floating homes will adapt to variation of waterlevels (flooding, drought). Floating homes are constructed around the world to adapt to climate adaptation.	
6	Permeable pavement	A permeable surface that is paved and drains through voids between solid parts of the pavement. A permeable is a surface that is formed of material that is itself impervious to water but, by virtue of voids formed through the surface, allows infiltration of water to the sub-base through the pattern of voids, for example concrete block paving.	
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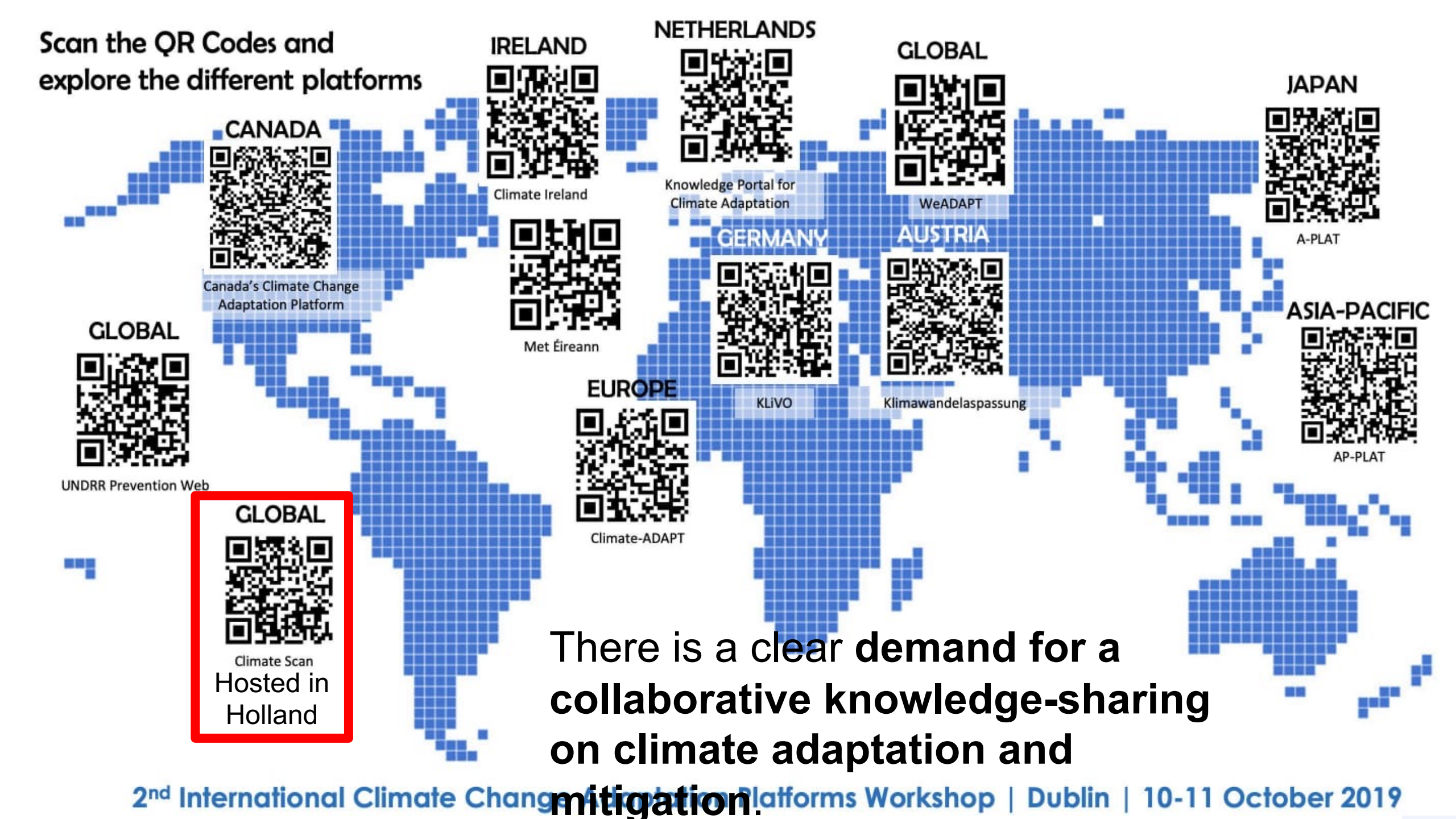

Scan the QR Codes and explore the different platforms
IRELAND
Climate Ireland
NETHERLANDS
Knowledge Portal for Climate Adaptation
GLOBAL
WeADAPT
JAPAN
A-PLAT
CANADA
Canada's Climate Change Adaptation Platform
Met Éireann
GERMANY
KLiVO
AUSTRIA
Klimawandelaspassung
ASIA-PACIFIC
AP-PLAT
GLOBAL
UNDRR Prevention Web
EUROPE
Climate-ADAPT
GLOBAL
Climate Scan
Hosted in Holland
There is a clear **demand for a collaborative knowledge-sharing on climate adaptation and mitigation**.
2nd International Climate Change Adaptation Platforms Workshop | Dublin | 10-11 October 2019

Overview of European platforms — content relevant to the core societal challenges

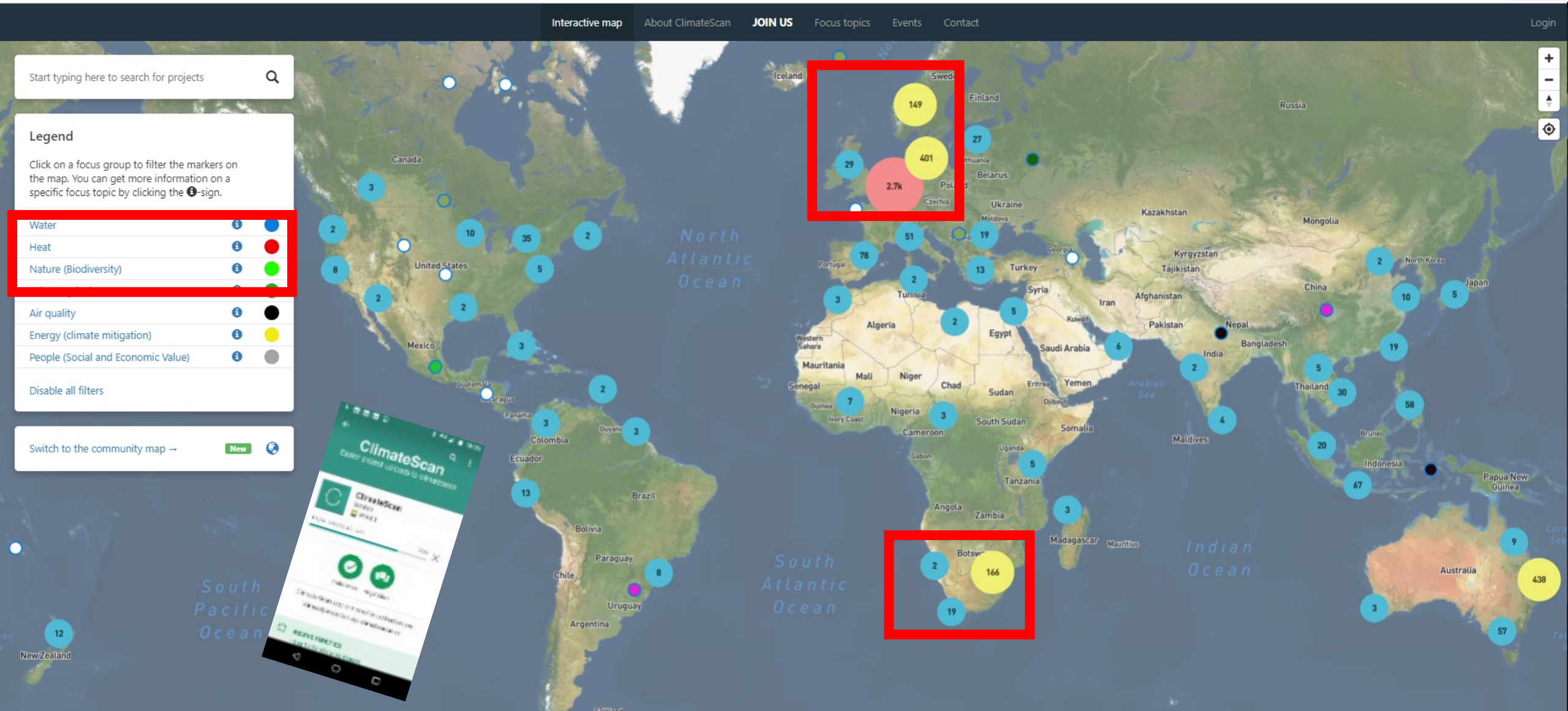
Table A5.3 Overview of European platforms — content relevant to the core societal challenges

	Core societal challenges						
	CSC1	CSC2	CSC3	CSC4	CSC5	CSC6	CSC7
	Improving society's resilience to extreme weather- and climate-related events	Food security, sustainable agriculture and forestry	Preserving habitat, reducing biodiversity loss and increasing green and blue spaces	Water management	Social justice, cohesion and equity and reducing risk for groups of society highly vulnerable to climate change	Public health and well-being (related to climate change impacts)	Make cities and human settlements inclusive, safe, resilient and sustainable
BISE	✓	✓	✓				
Climatescan	✓	✓	✓	✓	✓	✓	✓
Climate-ADAPT	✓				✓	✓	
DRMKC	✓						
Natural Hazards — Nature-based Solutions platform	✓	✓	✓	✓	✓	✓	✓
Nature-based Solutions Initiative	✓	✓	✓	✓	✓	✓	✓
Naturvation Urban Nature Atlas	✓		✓	✓	✓		
NWRM	✓			✓			
OPPLA	✓	✓	✓	✓	✓	✓	✓
Panorama	✓	✓	✓	✓	✓	✓	✓
ThinkNature	✓	✓	✓	✓	✓	✓	✓
weADAPT	✓				✓	✓	

Note: Tick-boxes were selected in consultation with platform managers, except the entries for NWRM and OPPLA.

Source: EEA.

ClimateScan.org
Mapping climate adaptation solutions

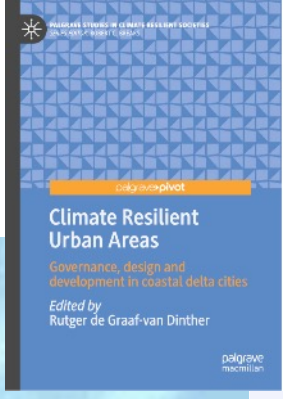


Opportunity: relating GI to urban typologies

1900-1940

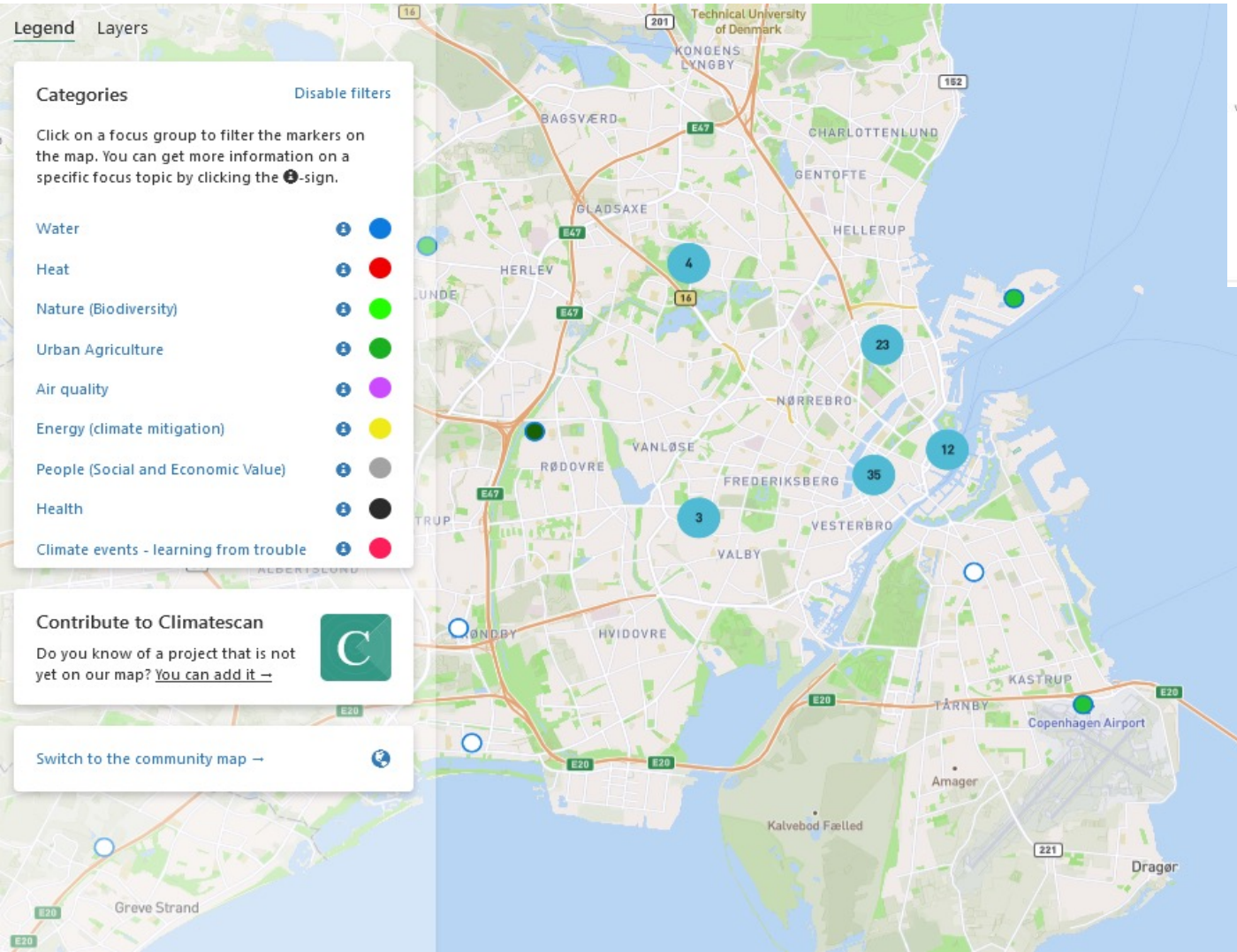
1950-1970

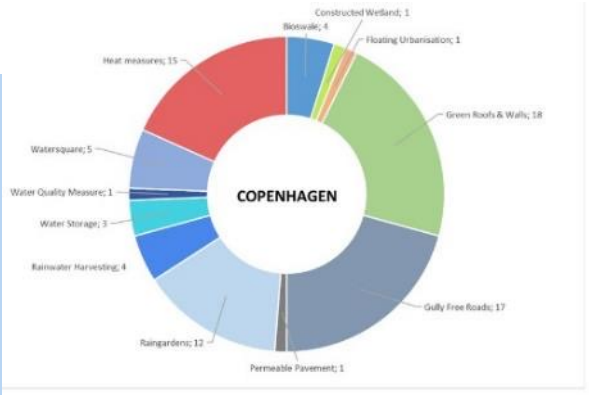
1970

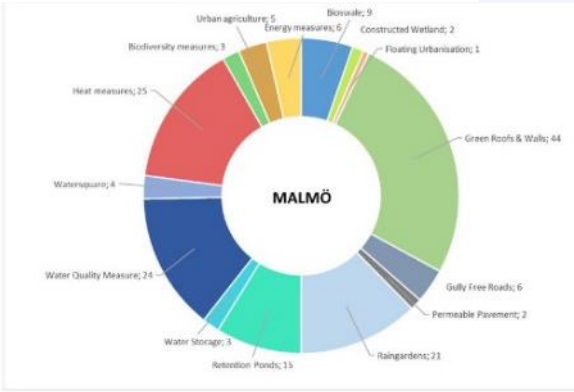


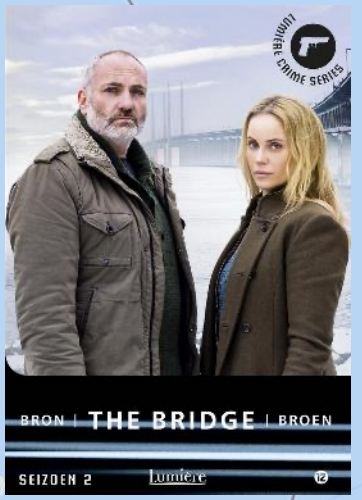
Strategy: Climate city approach

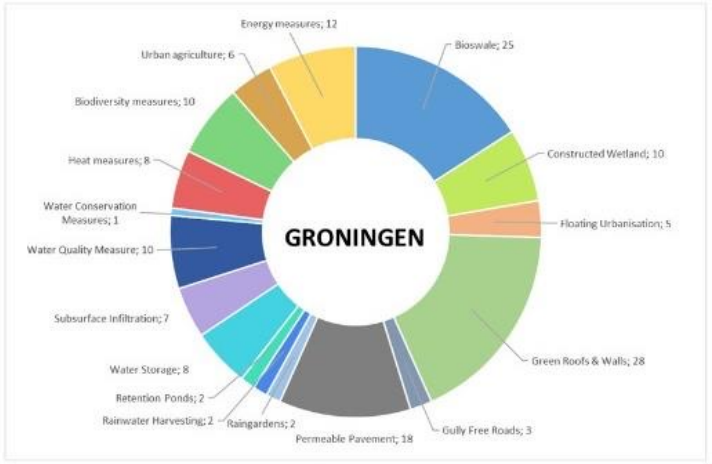
Status 2022 GI > 500 locations in climatescan.org

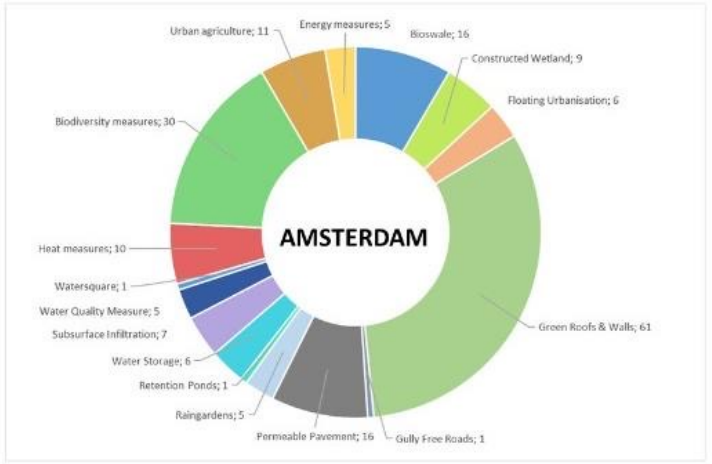


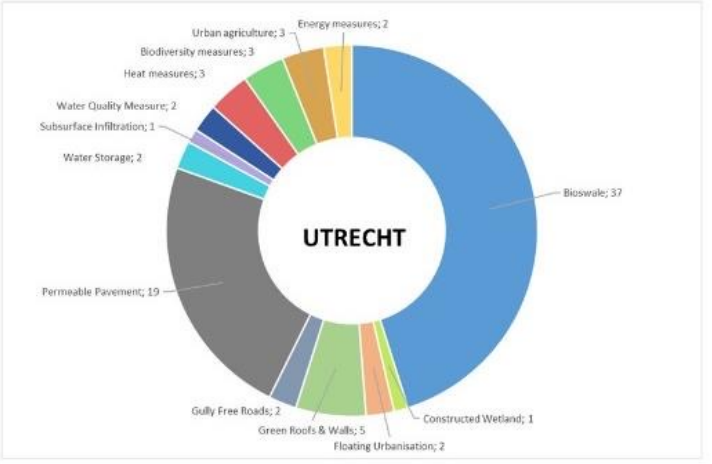


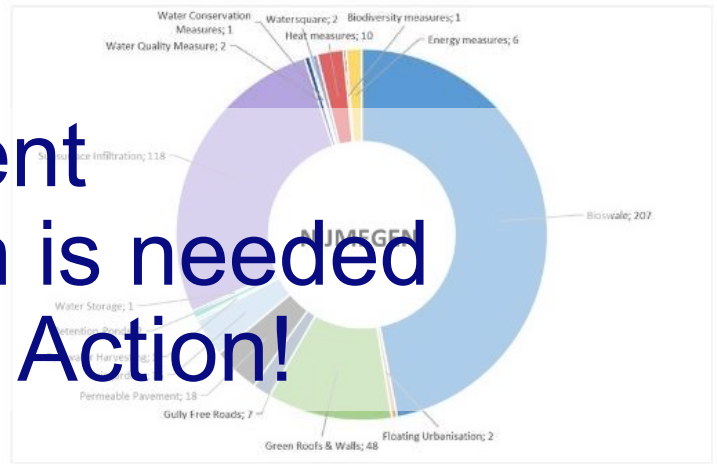


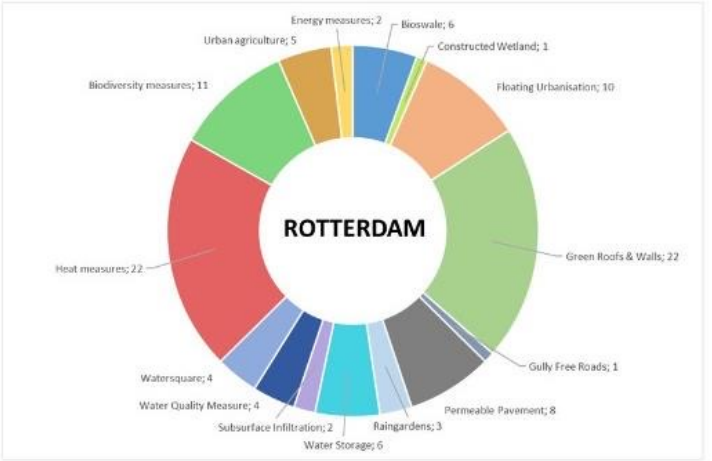


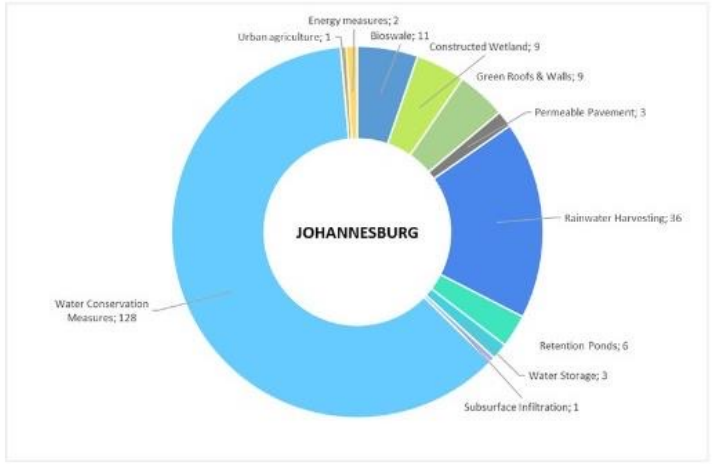


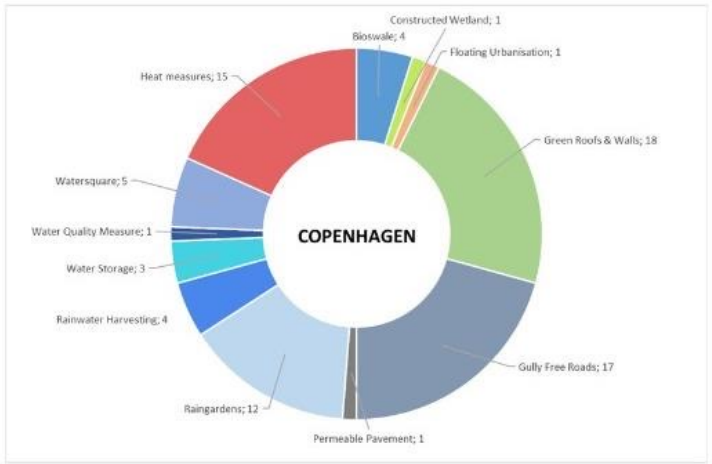


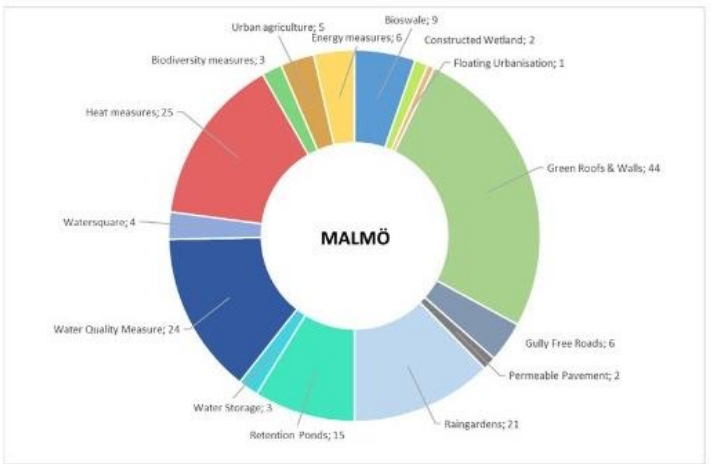






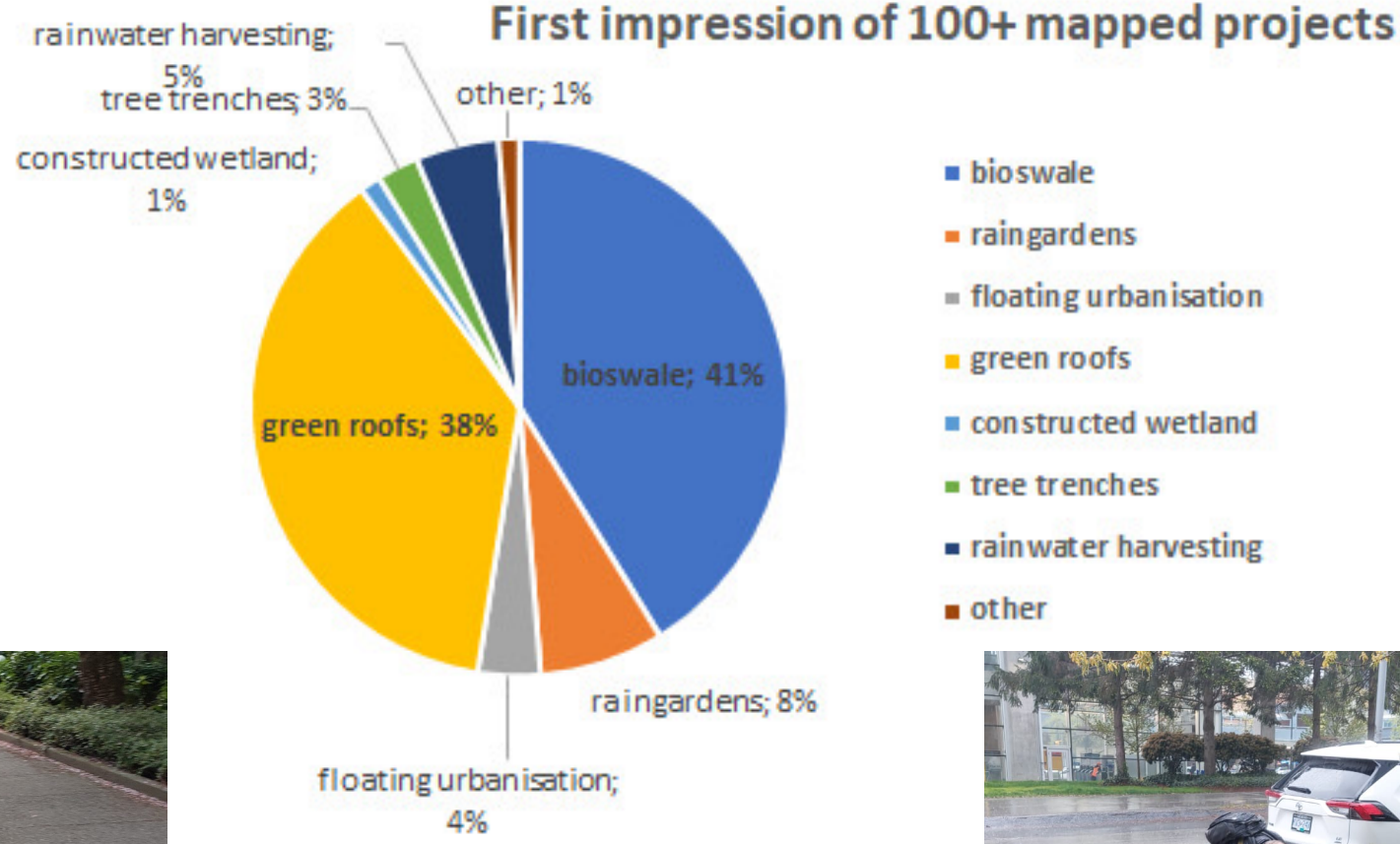




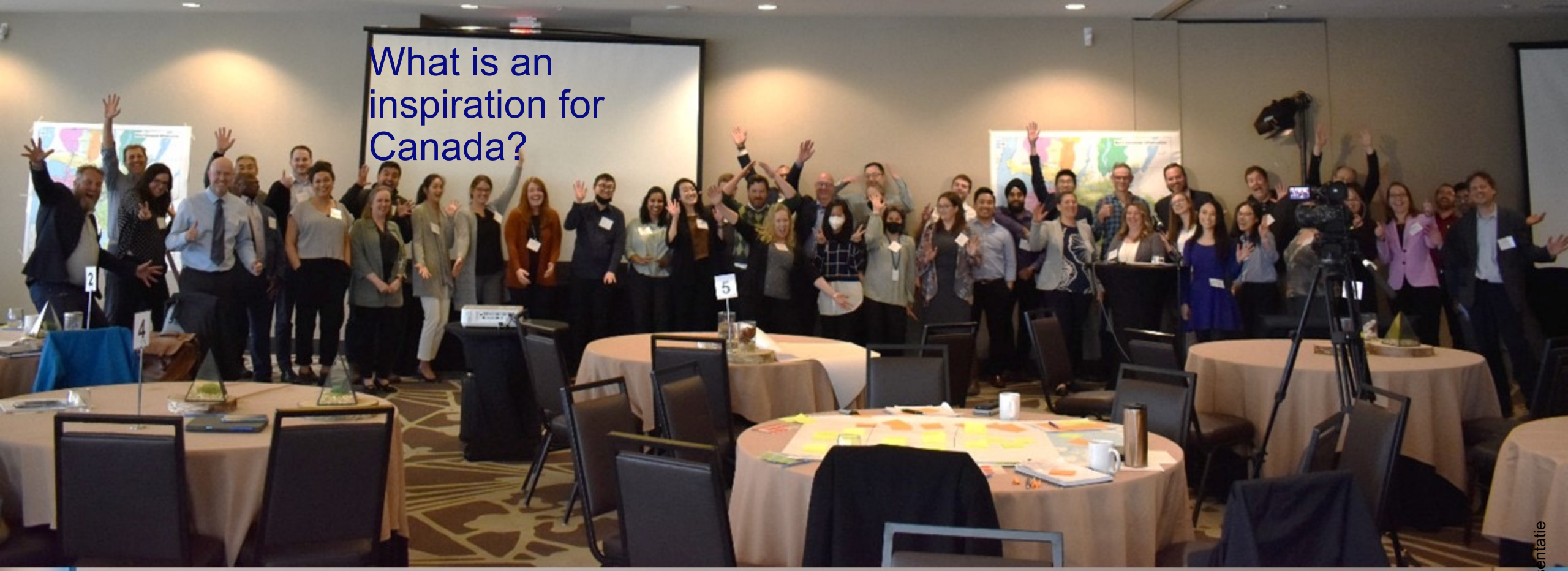


Every city is different
A holistic approach is needed
Analyze, Ambition, Action!

GI Vancouver
First impression of 100+ mapped projects



What is an inspiration for Canada?



Daily Functions

Wednesday, May 11th, 2022

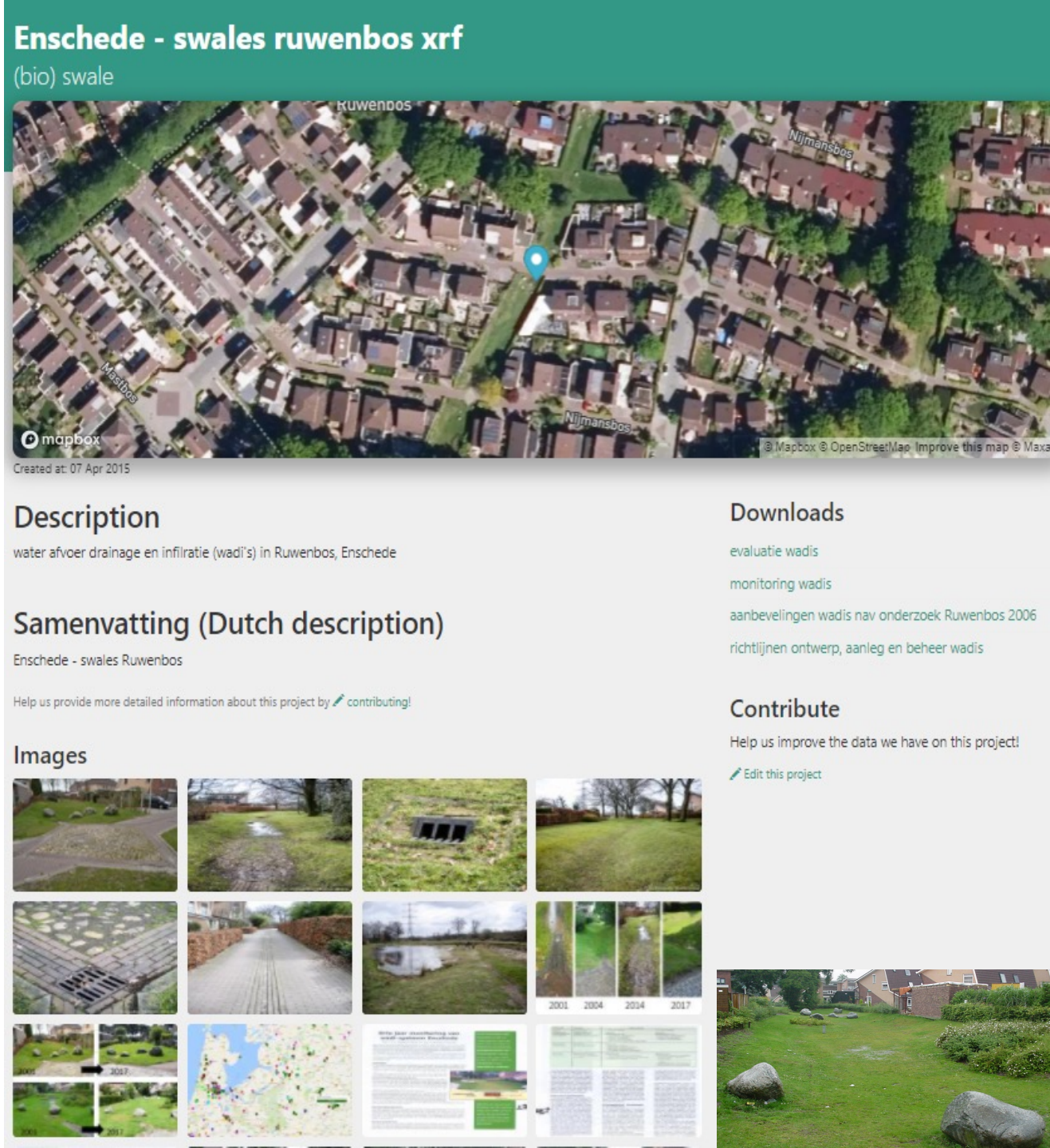
Metro Vancouver Green Infrastructure Workshop

07:00am – 5:00pm Meeting Evergreen Ballroom 3rd Floor

What is an inspiration for Canada?

- NBS since 1997… looking in the future
- Maintenance and monitoring: long term efficiency

Deltares



1 Swale & playground Dalfsen

2 Grid Pavers Someren

3 bio Swale Harkstraat Amsterdam

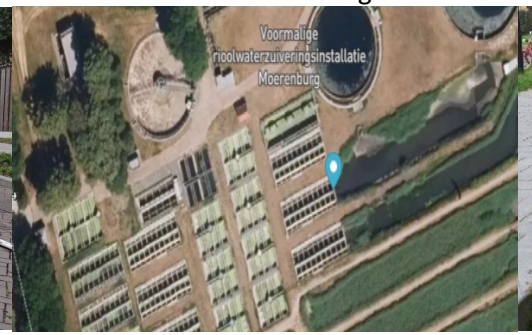
4 bio Swale Veldbiezenweg Zwolle

5 bio Swale Alphen

6 Gully free road to swale Almelo

7 Grid Pavers Zoeterwoude

8 Raingardens & DV Reestraat Arnhem



9 Waterharmonica Moerenburg

10 Raingarden Amsterdam

11 Raingarden Irenestraat Amsterdam

12 subsurface road storage Zoeterwoude

13 Swale Paddepoel Groningen

14 Swale Ruwenbos Enschede

15 bio Swale Euvelgunne Groningen

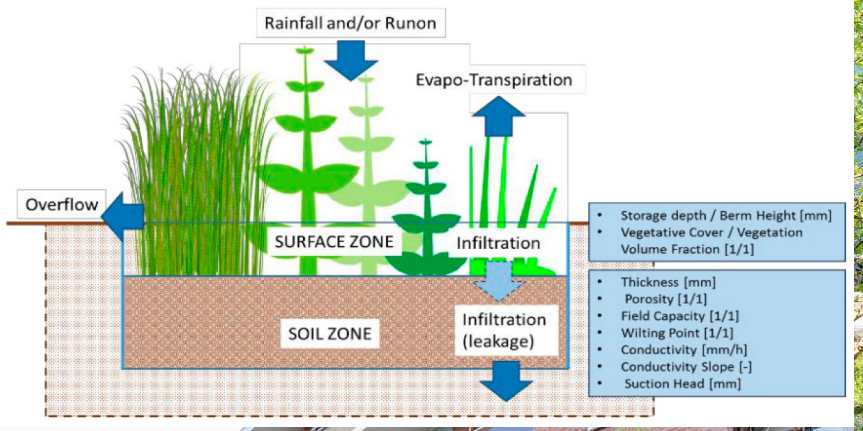
16 Raingarden Azuurweg TIlburg

17 bio Swale Veenweg Deventer

18 Infiltrating sewer Boddenkamp Enschede

19 subsurface road storage Zwolle

20 Swale Vasaliplantsoen Utrecht


Rainfall and/or Runon
Evapo-Transpiration
Overflow
SURFACE ZONE
Infiltration
SOIL ZONE
Infiltration (leakage)
Storage depth / Berm Height [mm]
Vegetative Cover / Vegetation Volume Fraction [1/1]
Thickness [mm]
Porosity [1/1]
Field Capacity [1/1]
Wilting Point [1/1]
Conductivity [mm/h]
Conductivity Slope [-]
Suction Head [mm]


Amsterdam


Zeewolde


Delft

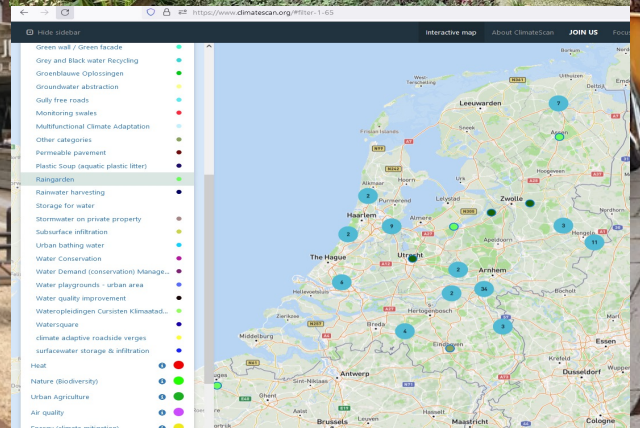

Tilburg


Leiden


Arnhem


Groningen


Raingarden
Nijverdal


Hide sidebar
Interactive map
About ClimateScan
JOIN US
Green wall / Green facade
Grey and Black water Recycling
Groenblauwe Oplossingen
Groundwater abstraction
Gully free roads
Monitoring swales
Multifunctional Climate Adaptation
Other categories
Permeable pavement
Plastic Soup (aquatic plastic litter)
Raingarden
Rainwater harvesting
Storage for water
Stormwater on private property
Subsurface infiltration
Urban bathing water
Water Conservation
Water Demand (conservation) Manage...
Water playgrounds - urban area
Water quality improvement
Wateropleidingen Cursisten Klimaatad...
Watersquare
climate adaptive roadside verges
surfacewater storage & infiltration
Heat
Nature (Biodiversity)
Urban Agriculture
Air quality
Leeuwarden
Zwolle
Haarlem
Amsterdam
Utrecht
Arnhem
The Hague
Antwerp
Brussels
Maastricht
Cologne
Essen
Dusseldorf

Top views on climatescan

Deltares

Top views on climatescan

Goot- en kolkloze klinkerweg, westerbouwlanden te nieuwleusen

Hollow gully free roads (Dutch: kolkloze wijk)

Created at: 03 Apr 2017

Description

In de nieuwbouwwijk Westerbouwlanden wordt hemelwater zichtbaar afgevoerd over de weg. Deze weg heeft geen goot, geen kolken maar ligt alleen iets hol. Bandverlangingen laten het water vrij naar het groen en oppervlaktewater stromen.

Images

Downloads

No downloads added

Websites

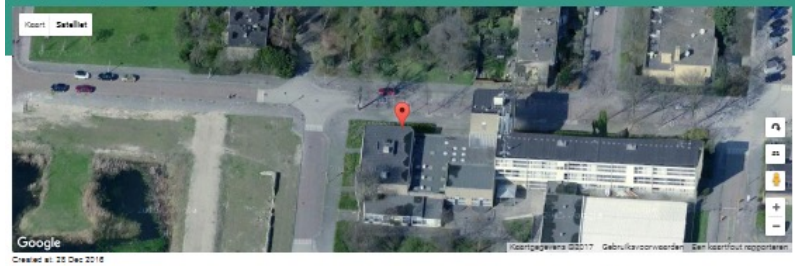
No websites added

Contribute

Edit this project

Green infiltration zone/ rainwatergarden amsterdam

(bio) swale (Wadi)



Created at: 28 Dec 2016

Description

Een primeur voor Amsterdam: een waterbergende groenstrook, die nu 66.000 liter en straks zelfs 130.000 liter water kan opvangen, en er zo voor zorgt dat bewoners geen wateroverlast hebben bij hoosbuien. Vandaag opent wethouder Udo Kock de groenstrook in een woonwijk op de Zuidas. Het is de eerste in zijn soort in Nederland. Wethouder Udo Kock (Water): "We zien dat het steeds vaker hard regent, en dat leidt tot wateroverlast zoals ondergelopen kelders. Deze groenstrook ziet er simpel uit, maar zorgt ervoor dat de kelders in deze buurt niet meer onderlopen. Een prachtig initiatief, helemaal omdat het relatief weinig kost. " Omdat de groenstrook 35 centimeter lager ligt dan de omgeving, kan hij regenwater opvangen van de wegen en de daken in de buurt. De groenstrook kan bij een hoosbui zelfs even in een beek veranderen. Het water blijft maximaal 24 uur in de berging en daarna stroomt het langzaam weg naar het oppervlaktewater en infiltreert het in de bodem. Als bij een zware bui de strook dreigt te overstromen, stroomt het via een overstort het riool in. Dit voorkomt dat het water de huizen in stroomt. Het unieke aan de strook is dat het opvangen van water wordt gecombineerd met een hoogwaardige inrichting van het groen. De groenstrook is beplant met planten die tegen veel water kunnen en het hele jaar groen zijn. De planten kunnen zelfs een tijdje onder water staan. De gemeente en Waternet willen deze groenstrook op meerdere plekken in de stad aanleggen. De waterbergende groenstrook wordt vanmiddag om vier uur officieel geopend. Hij ligt op de Zuidelijke Wandelweg, op de kruising met de Gaasterlandstraat. De opening is openbaar.

Images

Downloads

No downloads added

Websites

Waterbergende groenstrook voor droge voeten op de Zuidas

rainproof: infiltratiestroken met bovengrondse opslag

Waterbergende groenstrook voor droge voeten op de Zuidas

rainproof: infiltratiestroken met bovengrondse opslag

Contribute

Edit this project

De

(Dutch) green roofs 2.0

- Green roof programs in most Dutch municipalities
- For existing buildings:
  - Co-funded by municipalities from waste water taxes paid by citizens
  - private investments from real state owners
- For new buildings:
  - Fully funded by private owners

First Polderdak, Amsterdam
Green roof 2.0 mitigation and adaptation
Reacting on weather forecast, RTControl
https://www.climatescan.nl/projects/920/detail

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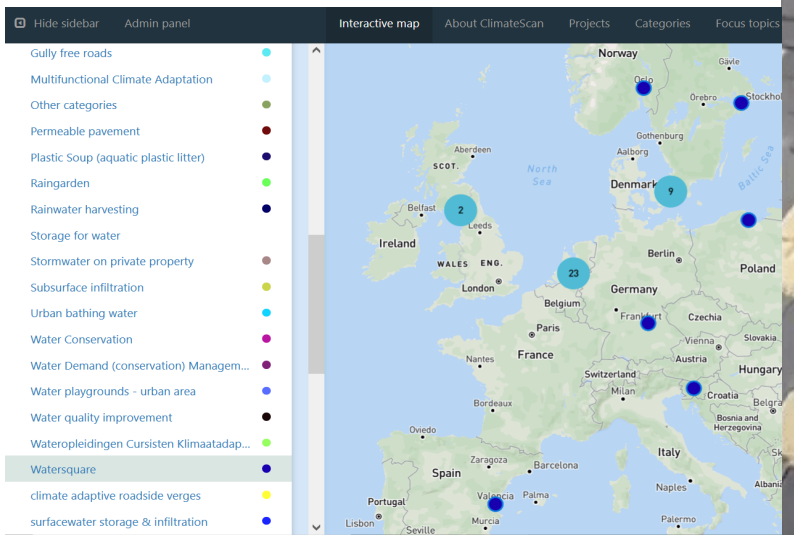
Water square in Rotterdam 2013

- Multifunctional square
- Combines a space for recreation and sports with temporary water storage
- Square acts as a buffer
- Filtered water is returned to the water system
- Twofold strategy:
  - Money invested in water storage facilities becomes enjoyable and visible
  - Opportunities to create environmental quality and identity to central spaces in neighborhoods.



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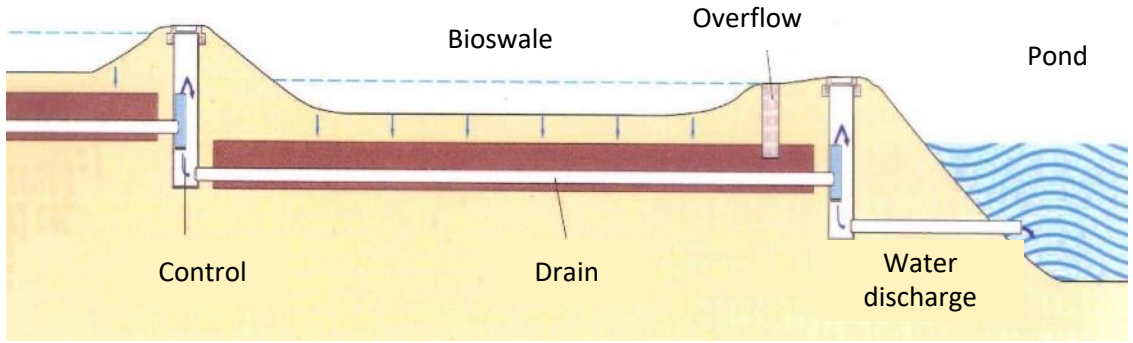
Multifunctional Bio-swales

- Naturally designed buffer and infiltration filter, can be a shallow ditch or depression in the field
- It detaches rainwater runoff from streets and rooftops from the traditional sewer system.
- Most of the year the bioswale remains dry. Only during heavier rain events it will be filled with water.
- This way clean water is infiltrated into the soil it can be used during drier periods.
- The overflow risk of the sewage system is limited as rainwater is separated from the sewer system.
- This leads to a higher water quality of the surface waters.



Innovation, there is more!

Factor Time

Water storage

Permeable pavement

Swales

phytoremedition

Delta

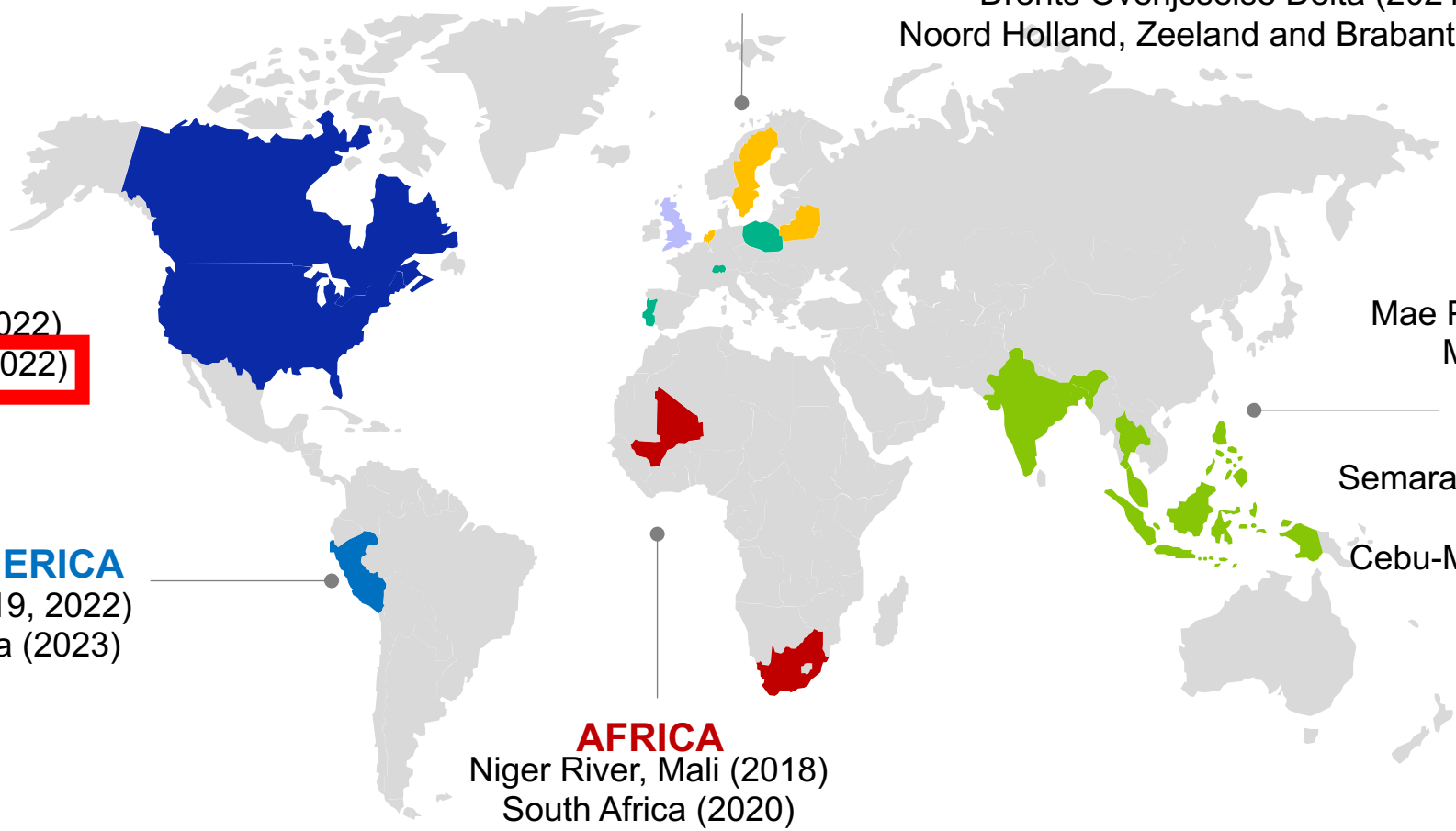
ClimateCafe

www.climatecafe.nl

Riga, Latvia (2019)
Oldenburg, Germany (2020)
Malmo, Sweden (2019)
Chur, Switzerland (2019)
Gdansk, Poland (2021)
Coimbra, Portugal (2022)

The Netherlands
Cities:
Groningen (2014,2017-2022)
Rotterdam (2017-2019,2022)
Leeuwarden, Hoogeveen, Kampen, Apeldoorn, Arnhem, Tilburg, Nijmegen, Eindhoven (2015-2022)
Regions:
GrensMaas (2020, 2022)
Drents Overijsselse Delta (2021)
Noord Holland, Zeeland and Brabant(2021)

EUROPE



North AMERICA

New Orleans, USA (2022)
Vancouver, Canada (2022)

ASIA

Mae Phaem, Thailand (2014, 2015)
Manila, Philippines (2016)
Tainan, Taiwan (2016)
Kanpur, India (2016)
Semarang-Surabaya-Ambon, Indonesia (2017-2020)
Cebu-Manila, Philippines (2017, 2018, 2019)

SOUTH AMERICA

Peru (2019, 2022)
Colombia (2023)

AFRICA

Niger River, Mali (2018)
South Africa (2020)

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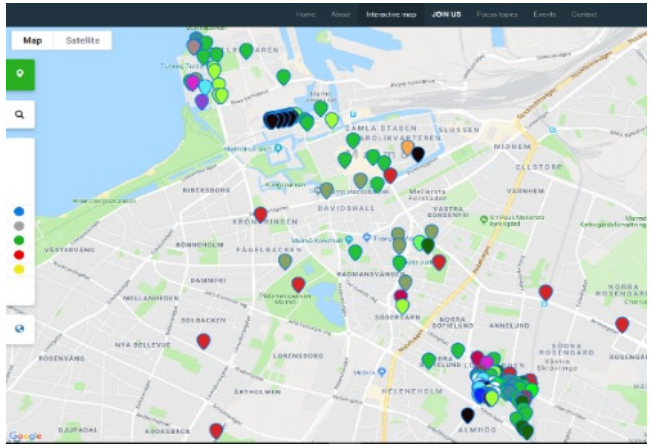
ClimateCafé: sustainable climate adaptation and lessons learnt: https://www.mdpi.com/2071-1050/12/9/36

ClimateCafe Vancouver

Engaging the community, even in monitoring GI



Mapping GI and characteristics

Dynamic Monitoring (heatstress and air pollution)

Waterquality

Monitoring micro pollution

Story telling

Hydraulic performance


TU Delft TV
FLOOD FIGHTER
However, now we face a new challenge; Global Warming flooding our streets.
SUB SCRIBE
0:23 / 2:09

Floodfighting:

Sponge cities after 20 years?

https://www.youtube.com/watch?v=R14BajCwU6w

Challenges in monitoring and Maintenance of GI

challenges

- Cost and capacity of monitoring and maintenance
- Do we want to know? Experience
- As GI often require different types of maintenance, different expertise is required
- Involvement from different departments is required
- Funding agencies need to be convinced of or at least informed on the corresponding maintenance cost

opportunities

- Partnering with education institutes to make monitoring more affordable to municipalities
- Learn from others' experiences and other sites
- Use citizen science and participation
- Raising awareness, capacity building: climatecafe
- Make monitoring more attractive!

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sustainability

MDPI

Article

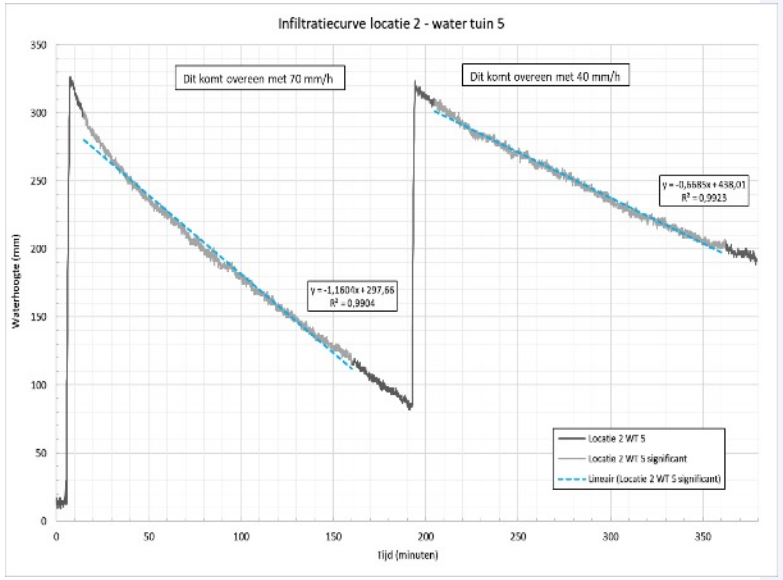
Rapid Assessment and Long-Term Monitoring of Green Stormwater Infrastructure with Citizen Scientists

Thomas Meixner [1,*], Alan R. Berkowitz [2], Alisen E. Downey [3], Jose Pillich [3], Reese LeVea [3], Brianne K. Smith [3], Mark Chandler [4], Neha Gupta [1], Stan Rullman [5], Anna Woodroof [5] and Jennifer Cherrier [3]

1 Department of Hydrology and Water Resources, University of Arizona, Tucson, AZ 85721, USA; nehagupta@email.arizona.edu
2 Cary Institute of Ecosystem Studies, Millbrook, NY 12545, USA; berkowitza@caryinstitute.org
3 Earth and Environmental Sciences, Brooklyn College, City University, New York, NY 11210, USA; Alisen.Downey26@bcmail.cuny.edu (A.E.D.); pillich@gmail.com (J.P.); rlevea@gmail.com (R.L.); briannekellysmith@gmail.com (B.K.S.); Jennifer.Cherrier18@brooklyn.cuny.edu (J.C.)
4 Citizen Science and Planetary Health, Boston College, Boston, MA 02467, USA; markchandlerw@gmail.com
5 Earthwatch Institute, Boston, MA 02135, USA; srullman@earthwatch.org (S.R.); awoodroof@earthwatch.org (A.W.)
* Correspondence: tmeixner@email.arizona.edu

Rain garden: centralized or decentralized at street and house level

Note that infiltration capacity is depending on vegetation, clogging, bio activity more than the engineered soil: maintenance and saturation

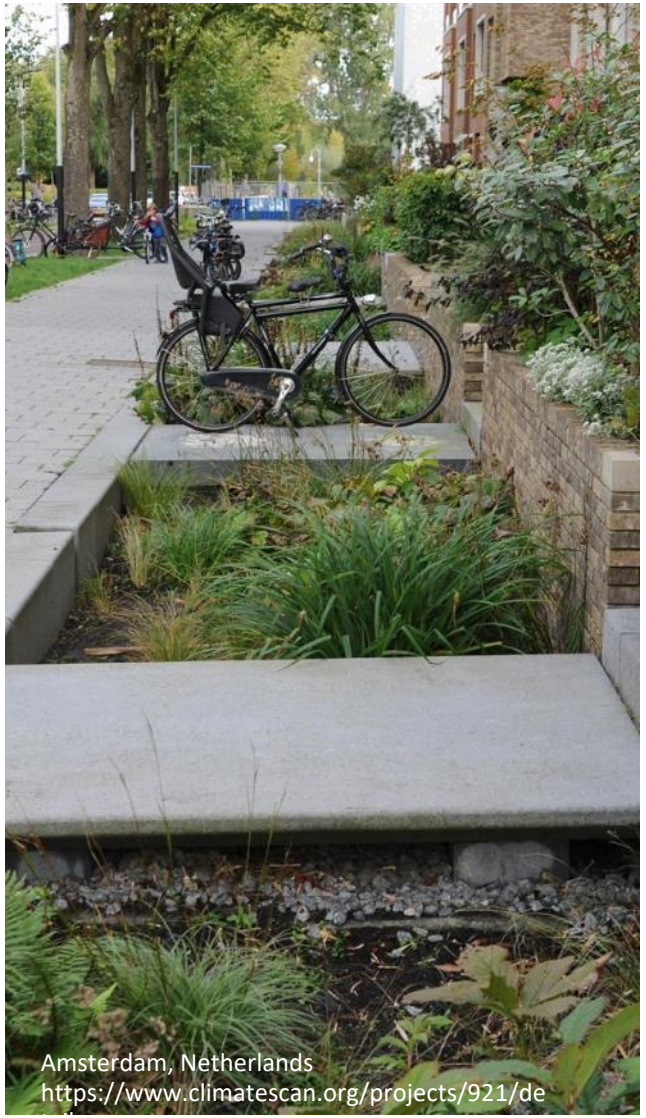


Veld (Arnhem), The Netherlands

Rain gardens: scientific results international knowledge exchange

Bergen, Norway
https://www.climatescan.org/projects/1068/d

Gdansk, Poland
https://www.climatescan.org/projects/4224/d



Amsterdam, Netherlands
https://www.climatescan.org/projects/921/de

Velp, The Netherlands
https://www.climatescan.org/projects/1109/d

Poland: Magda Kasprzyk, Wojciech Szpakowski, Eliza Poznańska, Floris C. Boogaard, Katarzyna Bobkowska, Magdalena Gajewska, Technical solutions and benefits of introducing rain gardens – Gdańsk case study, Science of The Total Environment, 2022, 155487, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2022.155487

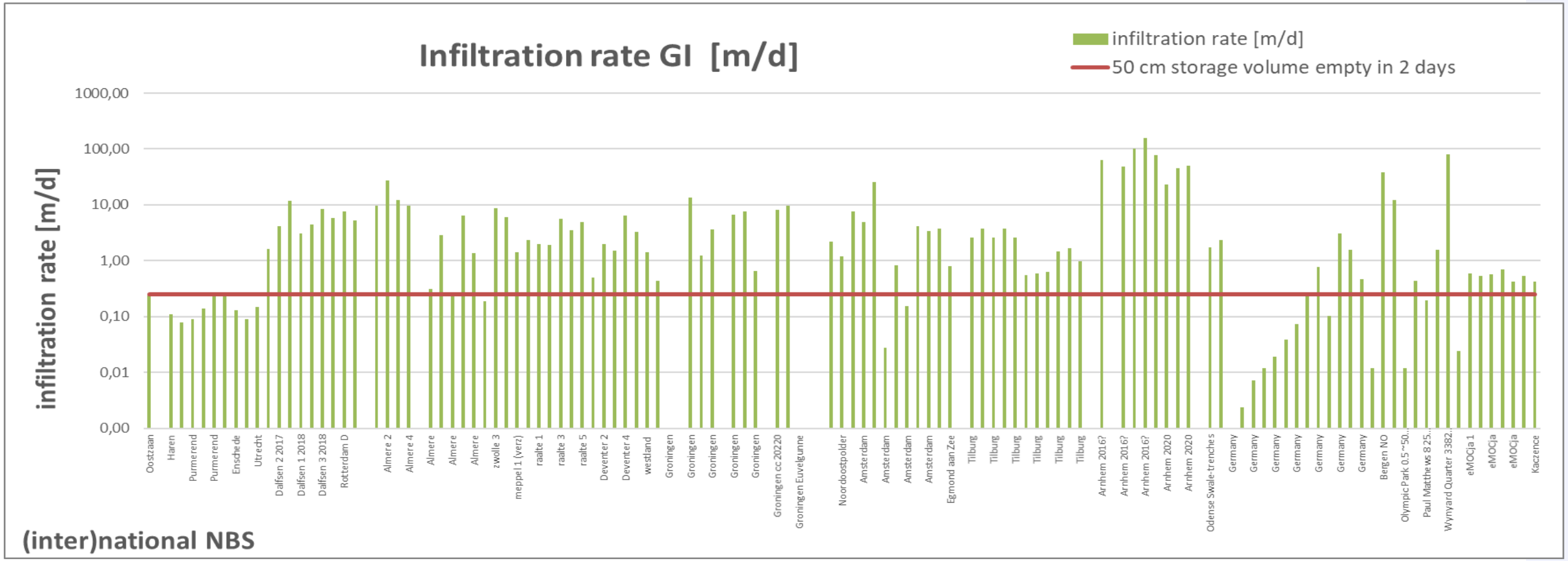
Norway: Venvik, G.; Boogaard, F.C. Infiltration Capacity of Rain Gardens Using Full-Scale Test Method: Effect of Infiltration System on Groundwater Levels in Bergen, Norway. Land 2020, 9, 520. https://www.mdpi.com/2073-445X/9/12/520

Thailand: Majidi, A.N.; Vojinovic, Z.; Alves, A.; Weesakul, S.; Sanchez, A.; Boogaard, F.; Kluck, J. Planning Nature-Based Solutions for Urban Flood Reduction and Thermal Comfort Enhancement. *Sustainability 2019, 11(22), 6361; https://doi.org/10.3390/su11226361*.

Sweden: Boogaard, F.C.; Venvik, G.; Pedroso de Lima, R.L.; Cassanti, A.C.; Roest, A.H.; Zuurman, A. ClimateCafé: An Interdisciplinary Educational Tool for Sustainable Climate Adaptation and Lessons Learned. Sustainability 2020, 12, 3694.

Netherlands: Kennisportaal klimaatadaptatie, De raingarden biedt net als de wadi veel kansen voor Nederland, Gepubliceerd 10 februari 2022

But we need to conduct long-term monitoring and share results



Open Access Article

Spatial and Time Variable Long Term Infiltration Rates of Green Infrastructure under Extreme Climate Conditions, Drought and Highly Intensive Rainfall

by Floris Cornelis Boogaard [1,2]

[1] Research Centre for Built Environment NoorderRuimte, Hanze University of Applied Sciences, 9747 AS Groningen, The Netherlands

[2] Deltares Daltonlaan 600, 3584 BK Utrecht Postbus, 85467 3508 AL Utrecht, The Netherlands

Boogaard, F.C. Spatial and Time Variable Long Term Infiltration Rates of Green Infrastructure under Extreme Climate Conditions, Drought and Highly Intensive Rainfall. Water 2022, 14, 840. https://doi.org/10.3390/w14060840

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From monitoring results of local GI to international guidelines

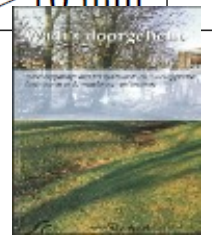
Table 2: General international design guidelines for swales

Design Parameter	Unit	Netherlands	Germany	UK	Belgium
Organization		(RIONED)	(ATV)	(CIRIA)	(VLARIO)
Distance ground water	m	> 0.5	>1	--	--
Swale area/drained area	Ratio	5 – 10	> 7	--	5 – 10
Distance to houses	m	>1	1.5 depth		
Swale water depth	m	<0.3	<0.3	<0.1	<0.3
Spare capacity	m	0.1	--	0.15	--
Width of bottom	m	>0,5	0.6	--	0.5 - 1
Longitudinal slope	V:H	1 : 3 or less	1:4 or less	--	1:3 or less
Max velocity	m/s	--	--	1 - 2	--
Thickness of filter soil	m	0.3 – 0.5	>0.1	--	0.3 – 0.5
Humus in top layer	%	3-5		--	
Infiltration capacity	m/day	> 0.5	0.86 < Kd < 86.4	--	> 0.086
Overflowing frequency	n/yr	1 to 2	0.2	--	0.2 – 0.5
Time to empty	hour	<24	<24	> 10 min	<24

Vancouver

3- 5 meter
& ‘15 cm rule’



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Content: Small scale urban resilient infrastructure in practise: what, where and does it work?

1. We share Challenges
2. So lets share Solutions
3. Practical examples of resilient infrastructure
4. **Tools and information**
5. More info

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Analysis

Analysing your area

Ambition

Formulating your ambition

Action

Policy and implementation

Thank you

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facebook.com/deltaresNL