Urban rainwater harvesting

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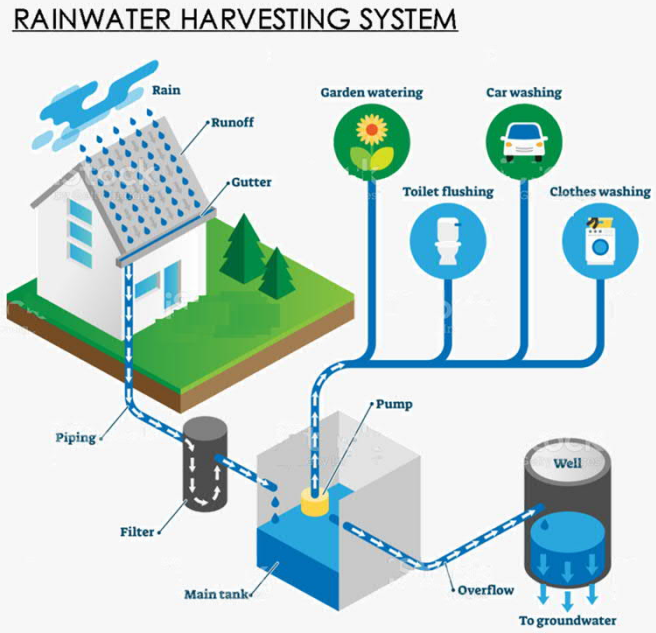
Lecture content

- Rainwater: amount, quality, tends
- Traditional treatment
- Modern harvesting

Lecture contains two types of questions questions:

1) Answer the questions by choosing a correct answer (letter).
2) Write down answers (number from slide). You will need it later.



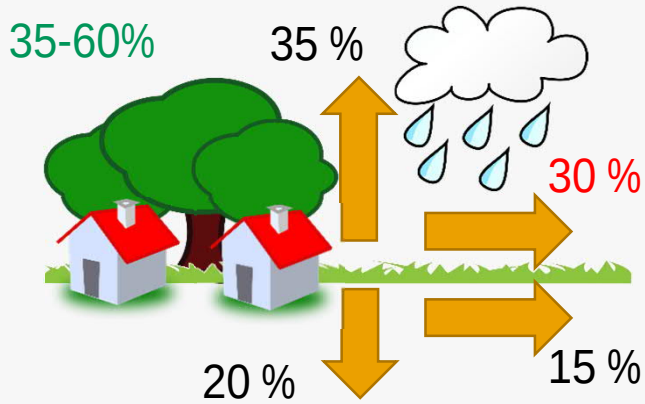
Two main reasons for increased runoff water

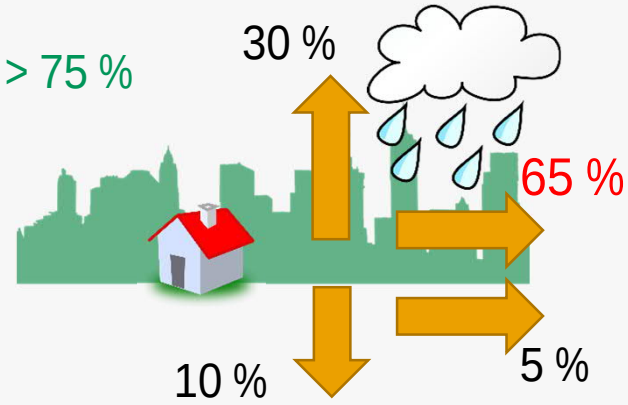
1. Climate Change

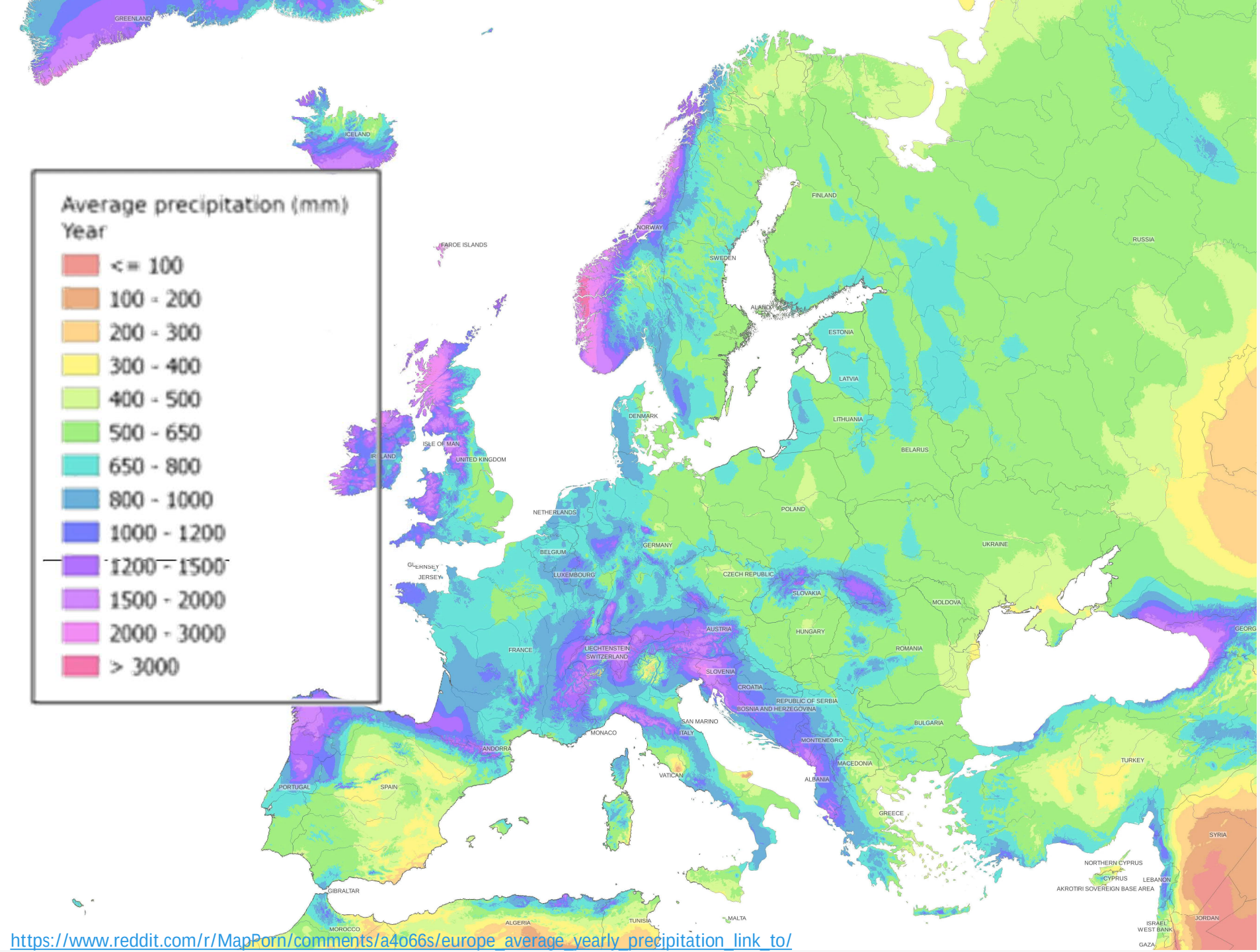
Warmer weather increases heavy raining (it is pouring more), which causes more flooding.

Change in rain Europe are estimated +/-25 % by 2100.

2. Building of larger cities







Annual precipitation in Europe is typically 400-800 mm.

Q1:

According to this map: What is the annual precipitation in your city? ____ mm

https://www.reddit.com/r/MapPorn/comments/a4o66s/europe_average_yearly_precipitation_link_to/

https://www.eea.europa.eu/data-and-maps/indicators/european-precipitation-2/assessment

Change in rainfall average 1971-2000 vs 2071-2100

Fig. 2: Projected change in annual and summer precipitation

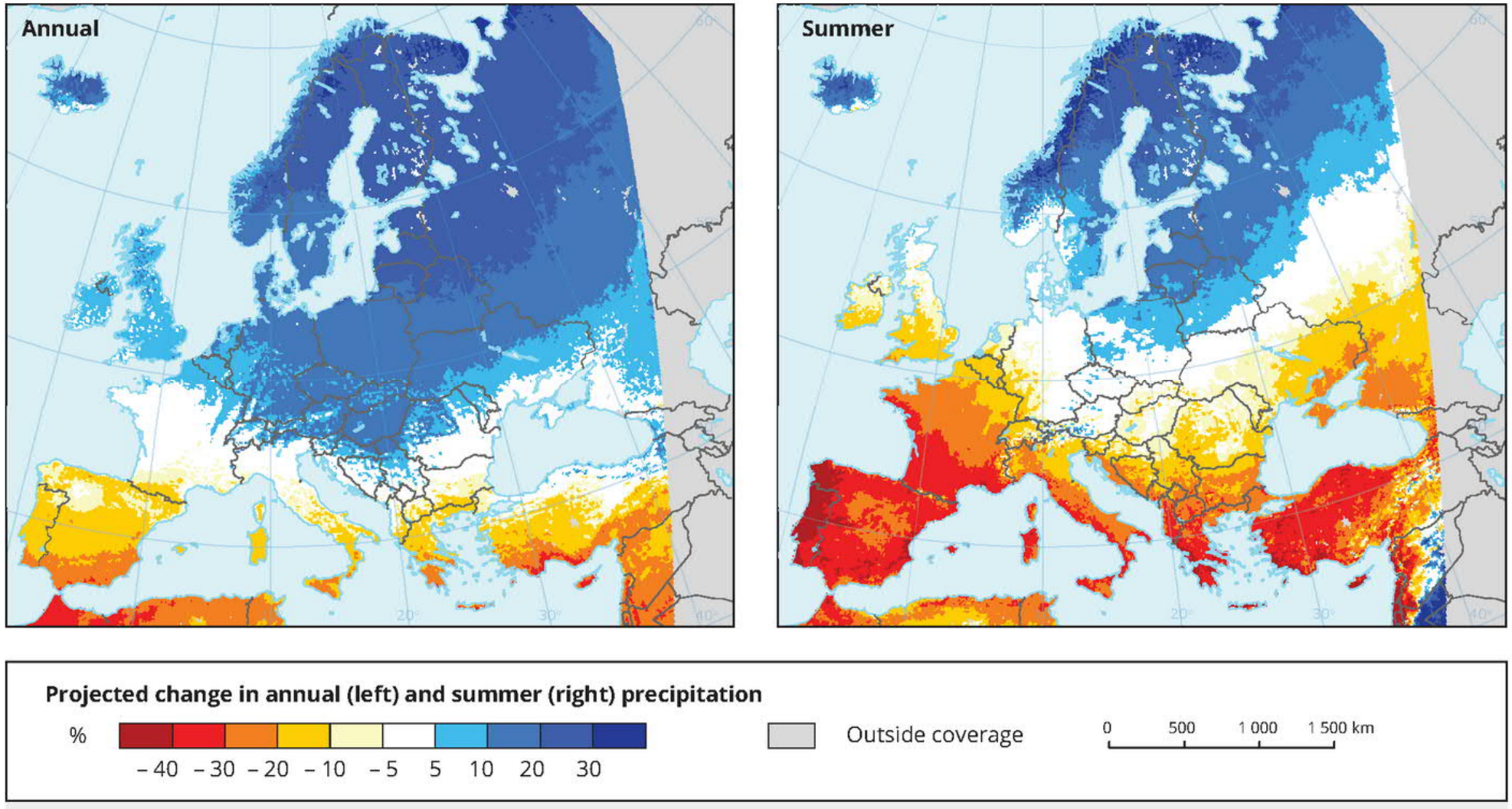
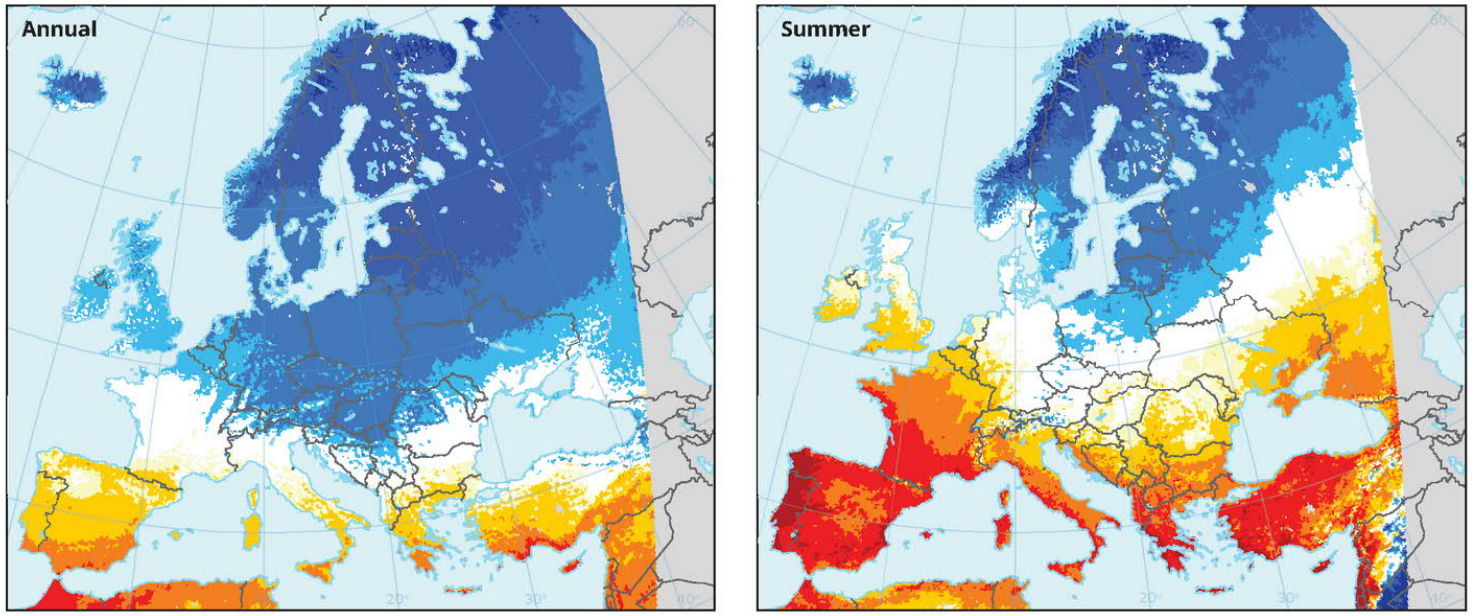


Fig. 2: Projected change in annual and summer precipitation



Note: Projected changes in annual (left) and summer (right) precipitation (%) in the period 2071-2100 compared to the baseline period 1971-2000 for the forcing scenario RCP 8.5. Model simulations are based on the multi-model ensemble average of RCM simulations from the EURO-CORDEX initiative.

Choose one correct claim (pick up a letter):

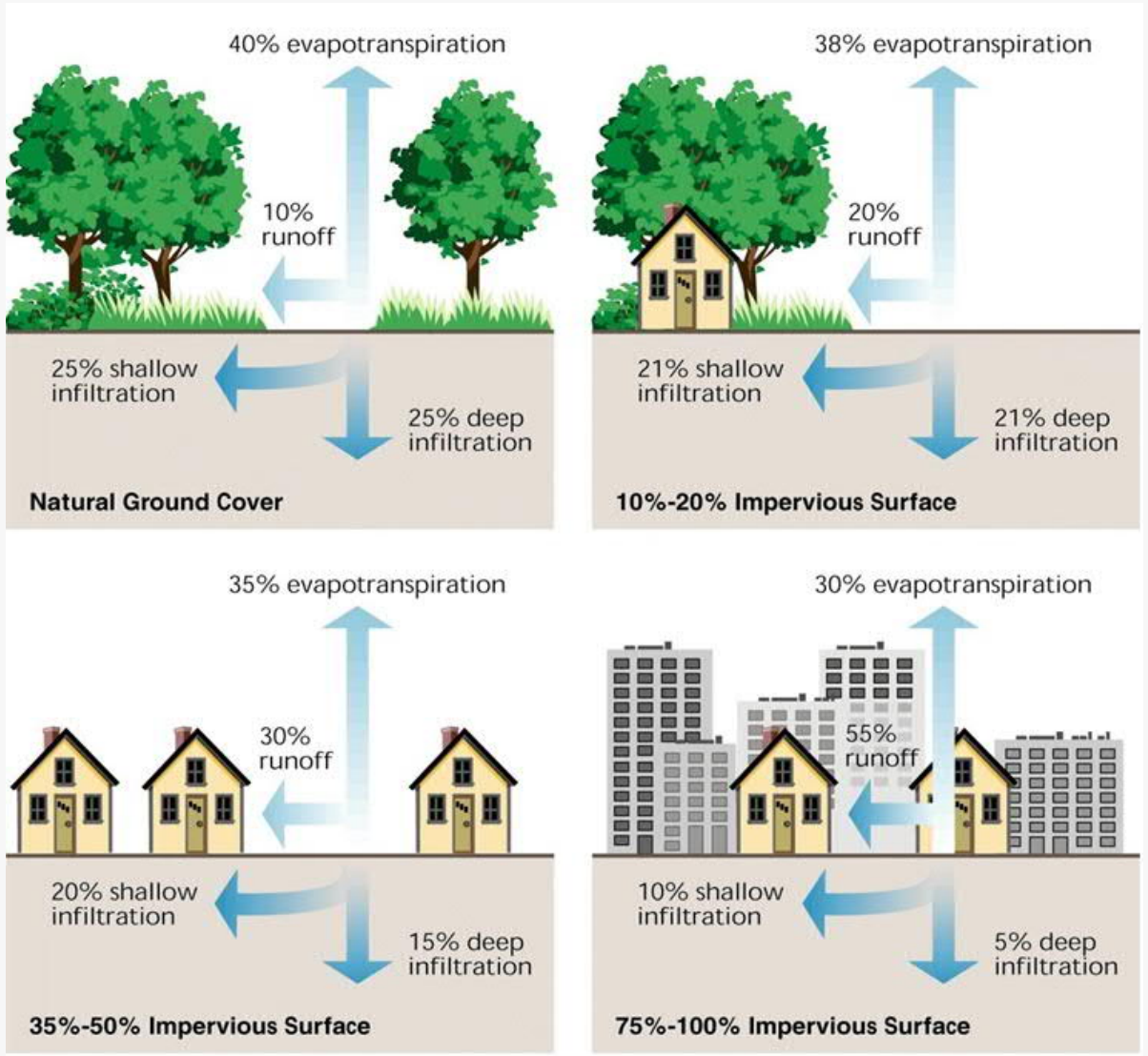
F. Amount of rain will increase in south Europe

R. By year 2100 the precipitation will increase 20-30 % in Scandinavia

M. Climate change will not influence precipitation or number of storms

Tighter construction increases impervious surfaces and decreases vegetation, trees and topsoil.
The amount of ground water decreases and runoff water increases.

Most cities in Europe have 35-50 % of impervious surfaces (roads, houses, etc). Metropoles might have >75 %.



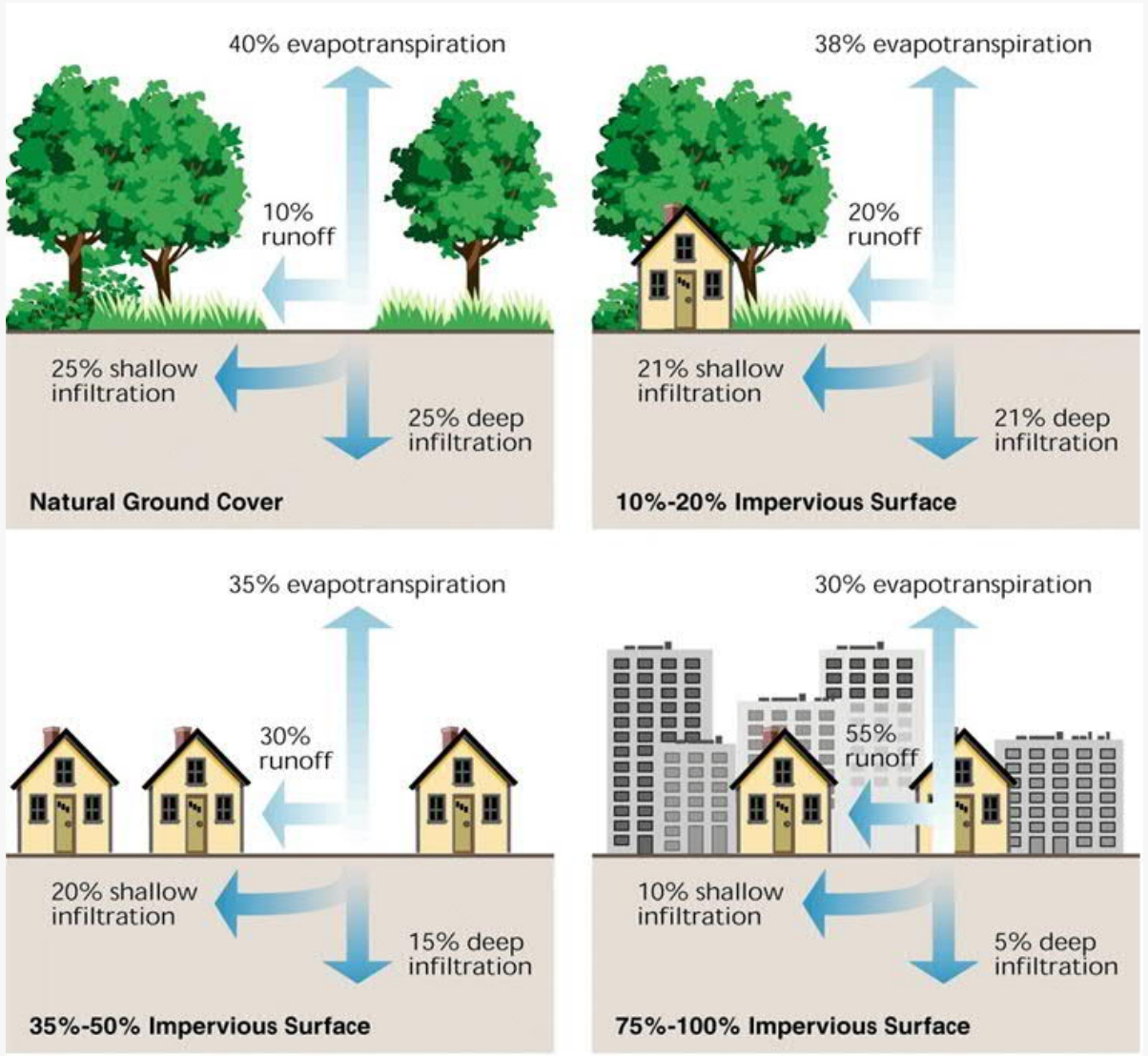
https://megamanual.geosyntec.com/npsmanual/sectionintrourbanstormwaterrunoff.aspx

Choose one incorrect claim:

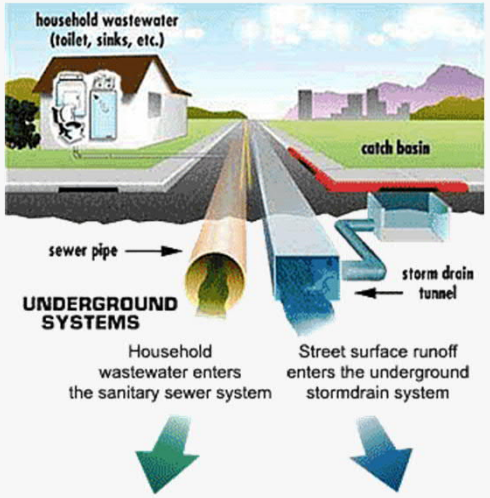
A. When impervious surfaces cover 50 %, the deep infiltration has decreased from 25 % to 15 % of rainfall.

I. In natural non-urban environment 40 % of precipitation evaporates to air.

E. Shallow infiltration cannot be harvested.



Traditional harvesting of rainwater



Sanitary sewer and rainwater drainage are not totally separate systems. About 30-40 % of influent to purification plant is rainwater.

Volume of rainwater is huge. Example from Lappeenranta

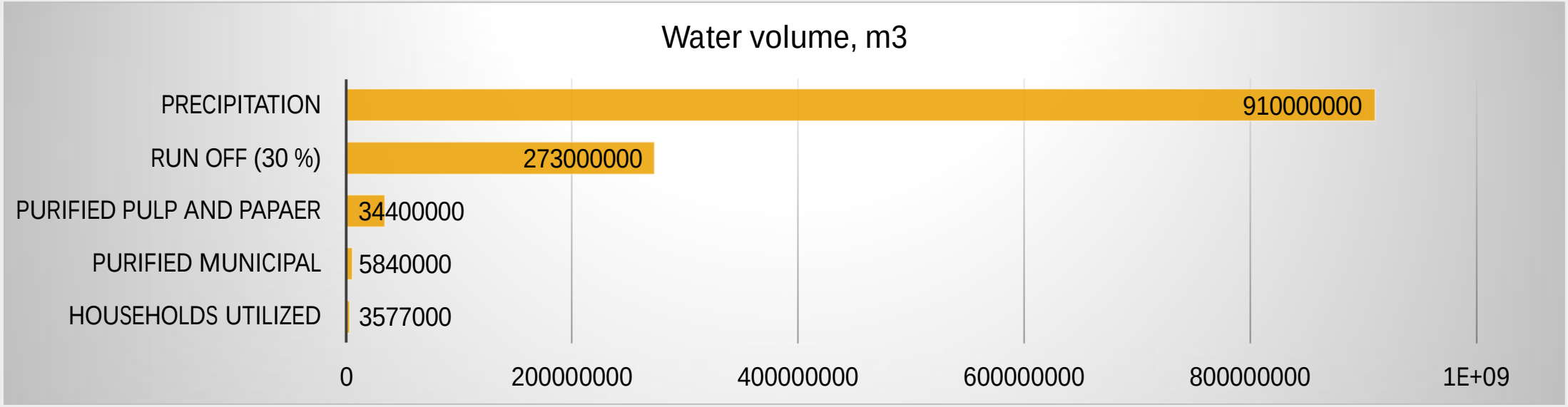
Population 72,000,

Area: total 1,723.56 km^2 , land 1,433.36 km^2

Annual Precipitation 650 mm

Two purification plants:

1) Effluents from pulp production
2) Domestic and other wastewater flows



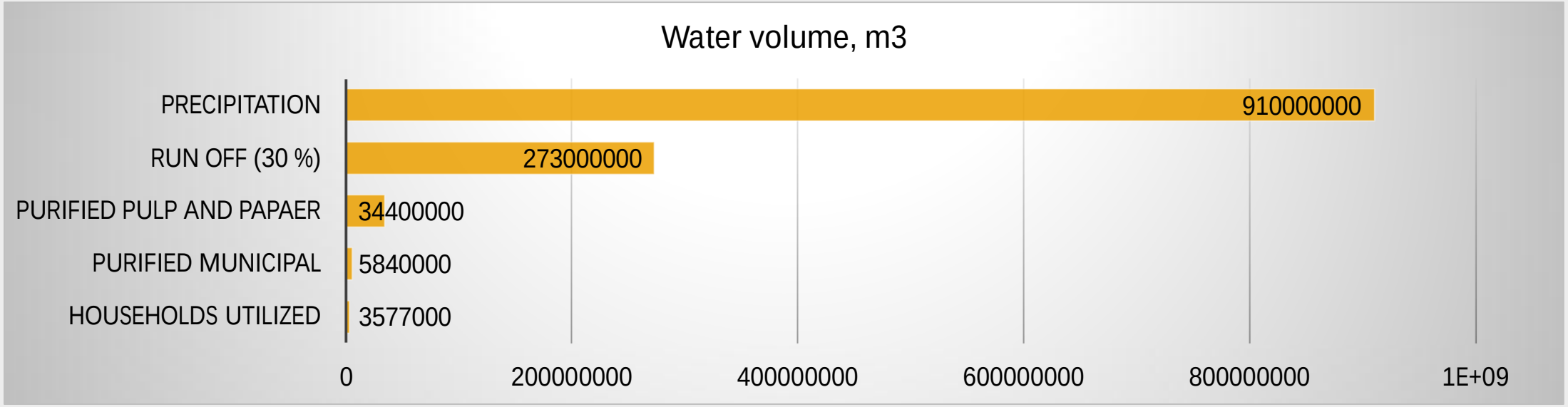
Volume of rainwater is huge. Example from Lappeenranta

Households utilize 3 577 000 m3/year, and 5 840 000 m3/year is purified in municipal plant. It means that percentage of rainwater in influent can be as high as:

U. 39 %

W. 61 %

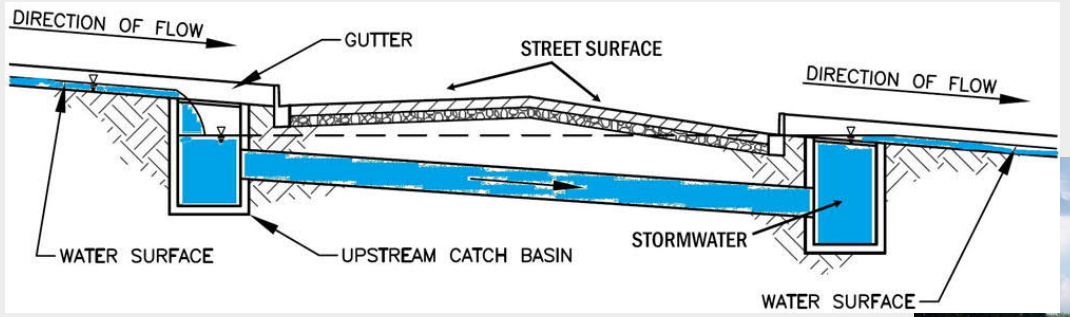
C. 50 %

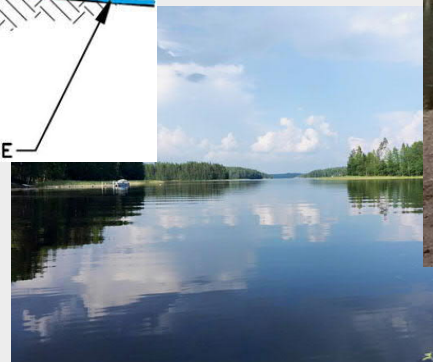


What happens to runoff water: case Lappeenranta

Now

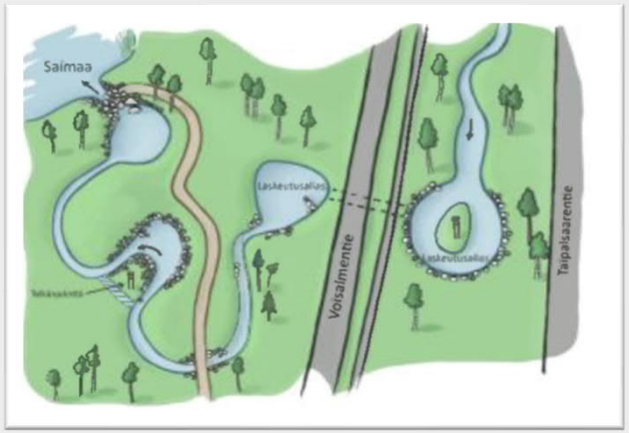
Drainage system to collect rainwater leads to constructed wetlands, or to lake Saimaa via sedimentation chambers in the pipelines.

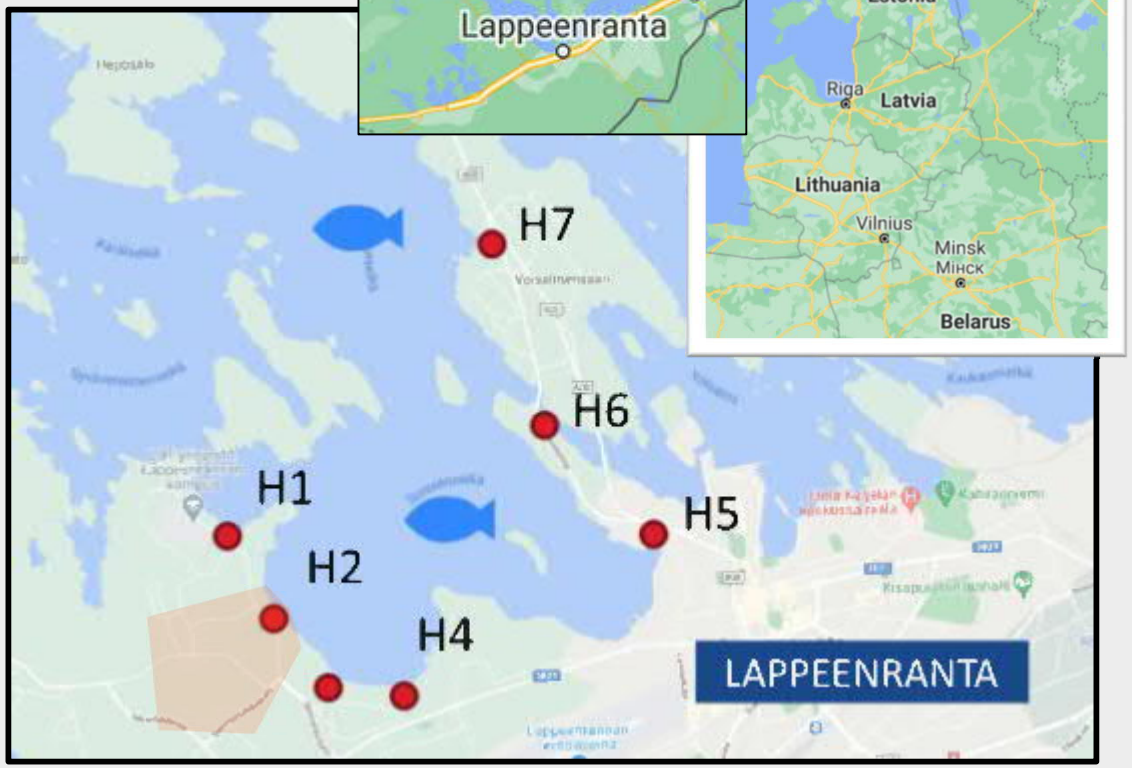


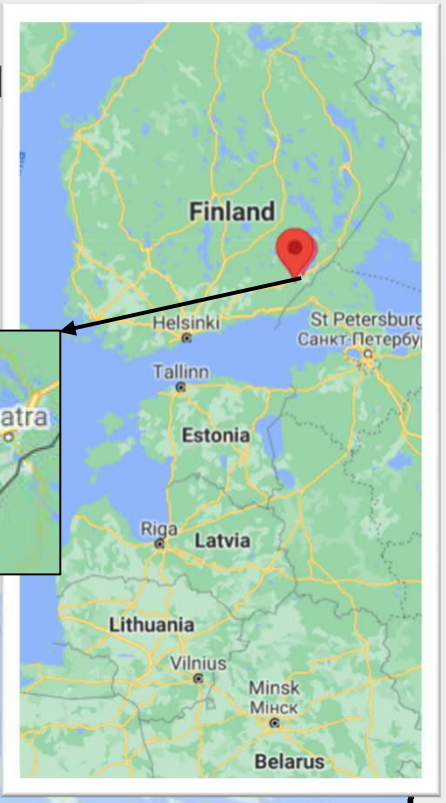


Urban wetlands look like parks

Constructed wetlands in city of Lappeenranta



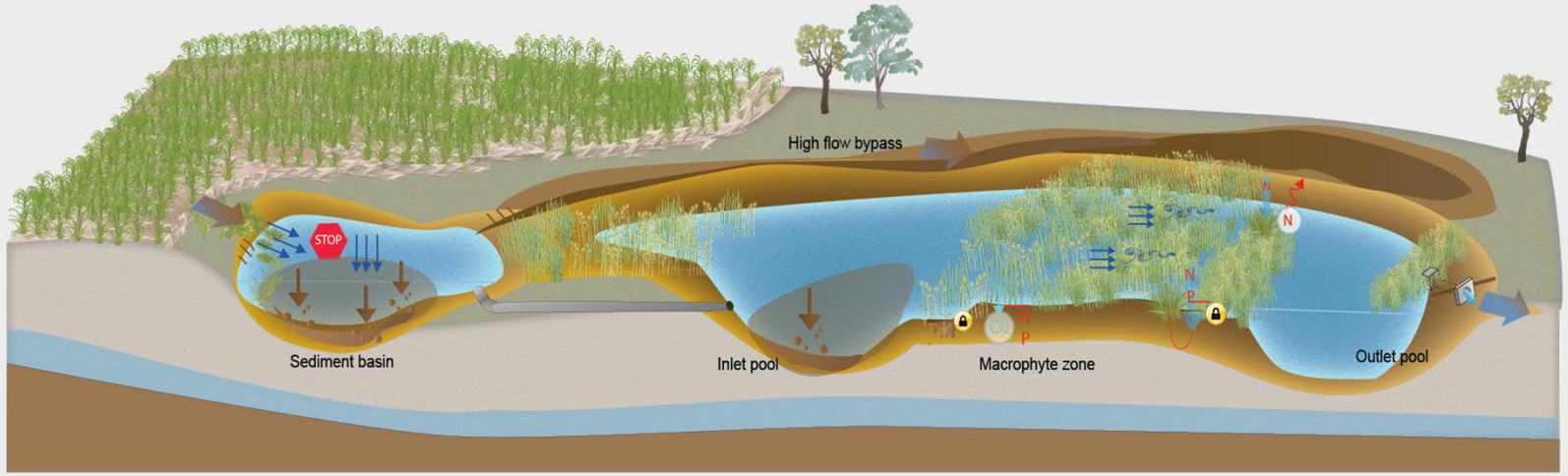




Improving wetlands efficiency

Land construction and vegetation

Filtering and biological organisms



Water run-off, carrying sediment particles (coarse and fine) and dissolved pollutants (nutrients and pesticides)

Slowing of run-off. Holding water on site increases sediment deposition rate.

Multi stemmed vegetation, slowing run off velocity, reducing erosion and increasing infiltration

Processing of nutrients into wetland vegetation and biofilms

Wetting and drying of sediments leads to fixation of pollutants in sediments

Deposition of coarse (and some fine) sediment particles

Wetland vegetation inhibits the release of deposited nutrients by pumping oxygen into the soil.

Vegetation provides a carbon source and a surface for biofilms to undertake denitrification, removing nitrogen from the water column.

Water leaving treatment system with reduced sediment and nutrient loads

Main mechanisms in pollutant removal are sedimentation, filtering trough soil, bacteria in sediment and algae, other vegetation growing.

Improved removal can be gained via flood water control, filtering, and micro-organisms.

CBC 2014-2020
SOUTH-EAST FINLAND - RUSSIA

Filters

Mineral filters (chemical free)

- Natural mineral that can be reused and recycled for example shungite, zeolite or lava minerals
- Activated char from biomaterials
- Good in removal metals, odors, microplastics, oil compounds and other organic matter.
- Poor in removal of nutrients

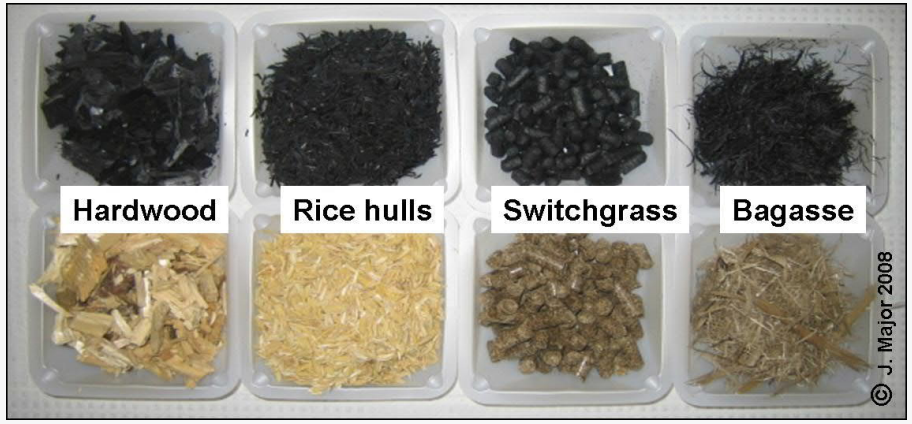
Nutrient removal

- Effective microorganisms: photosynthesizing bacteria, lactic acid bacteria, yeasts, actinomycetes and fermenting fungi (& enzymes)
- Chemicals (Al or Fe)
- Artificial minerals such as Polonite

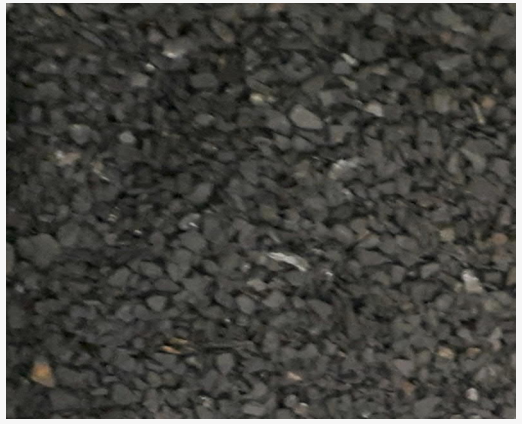
Filtering materials

Feasible for removal of organic compunds, metals, odours, small particles, … but nutrient removal might be poor.

BioCHAR



Mineral CHAR

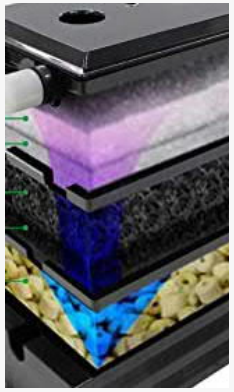


Clays, soils

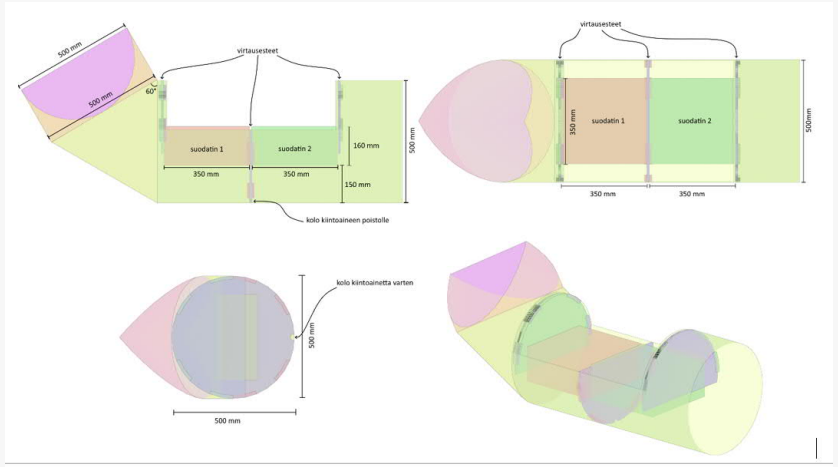
FIBERS

Shungite

Lava

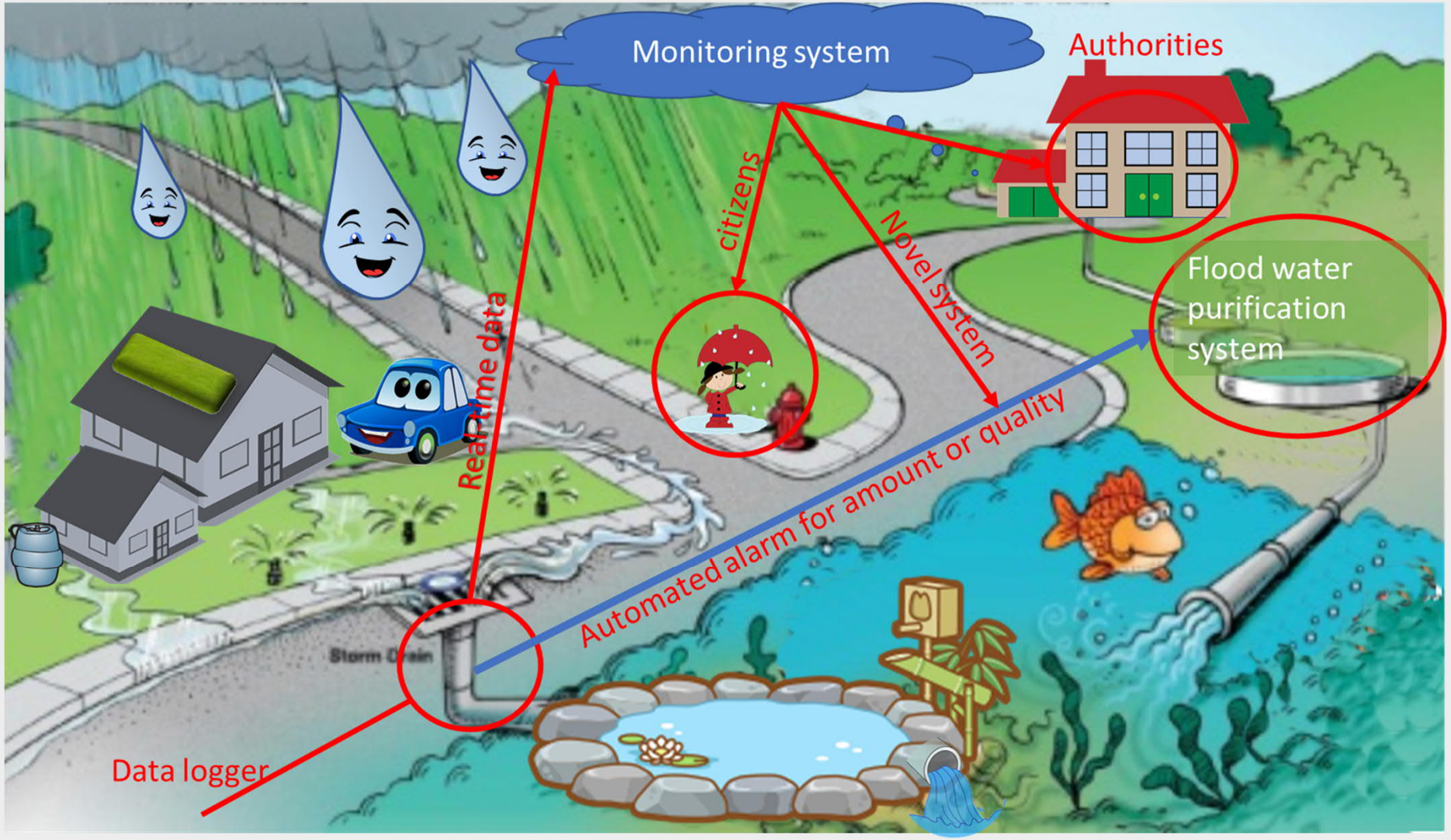


Filters


500 mm
500 mm
60°
virtausesteet
suodatin 1
suodatin 2
160 mm
350 mm
350 mm
150 mm
500 mm
kolo kiintoaineen poistolle
virtausesteet
350 mm
suodatin 1
suodatin 2
500mm
350 mm
350 mm
kolo kiintoainetta varten
500 mm
500 mm

Funded by the Horizon 2020 Framework Programme of the European Union

Novel system designed and feasibility evaluated



2021-2025

Automated flood control

Real time monitoring

Information send to authorities, control system, citizens

Rainwater in global focus

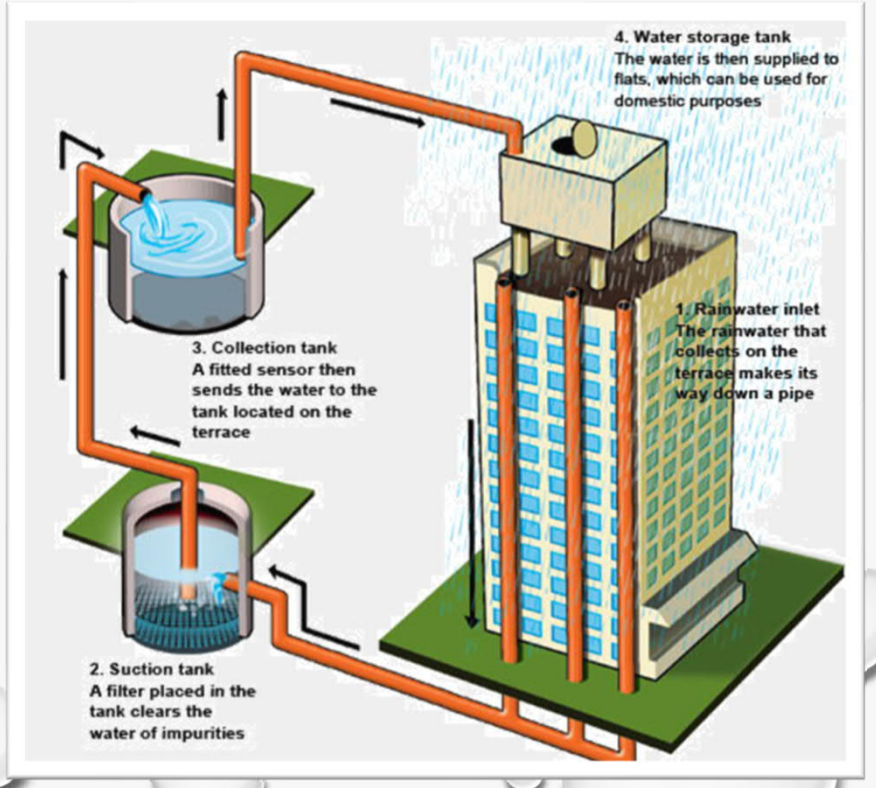
Rain and runoff water recycling can reduce need of tap water by 40 % (EC (2009)).

Purification will decrease health problems

Global focus on harvesting, utilization, and purification

- Harvesting Integrated into spatial city planning
- Solutions for individual households
- municipal treatment systems

New EU and national level regulations

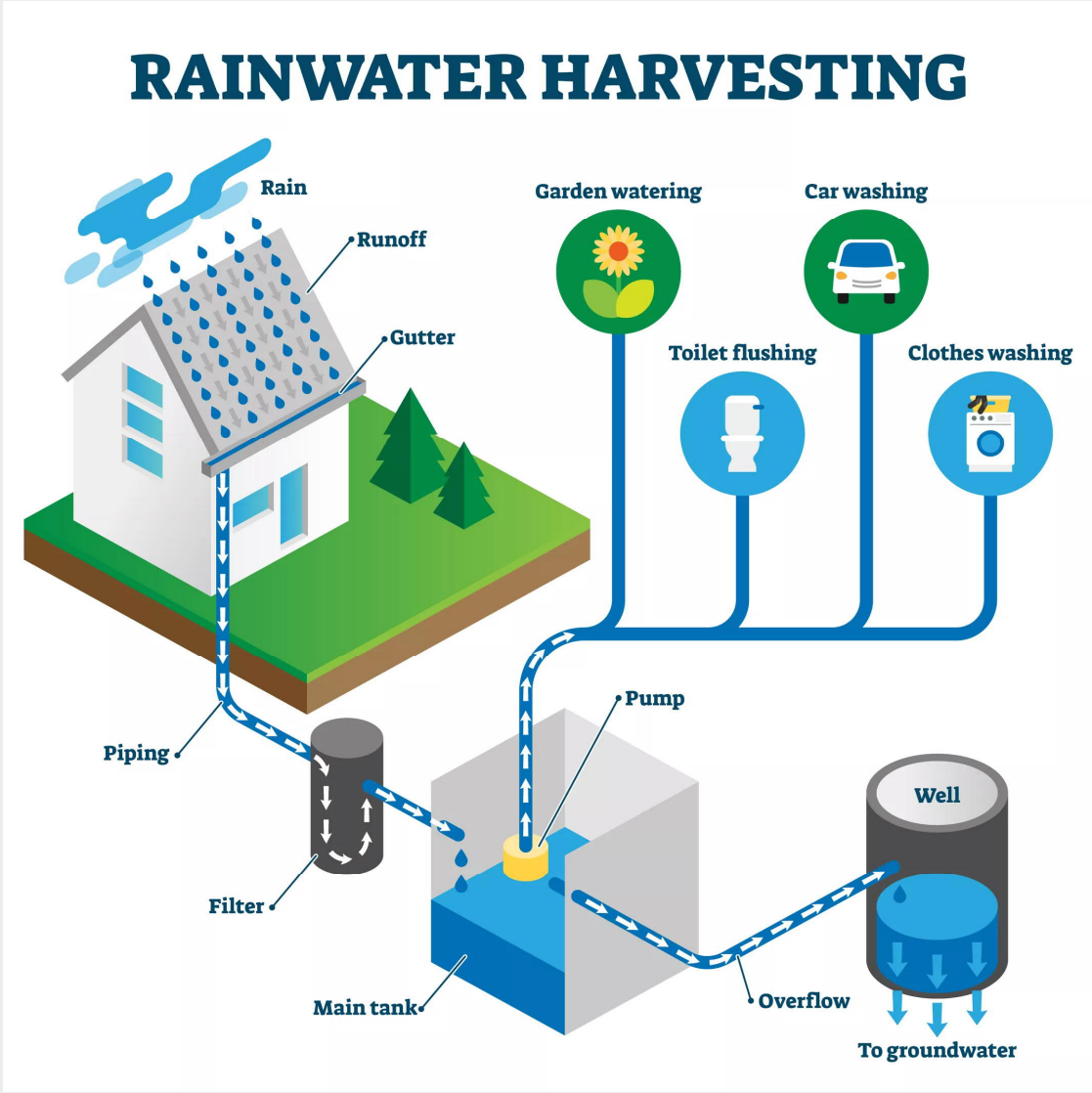


https://www.scribd.com/document/393780361/Rain-Water-Harvesting

Water quality?

Rain is clean

- Rooftop harvesting provides relatively clean water
- Flood water contains small particles, oil compounds, and other contaminants from various surfaces



https://www.treehugger.com/beginners-guide-to-rainwater-harvesting-5089884

https://www.semanticscholar.org/paper/Consideration-of-rainwater-quality-parameters-for-A-Lee-Kim/875f67d48eea4c79187e44b6b9ff3fc542c7a603

Rainwater quality

	Standards[a]		Untreated Rainwater	
	Vietnam	WHO	Median	Range
pH	6.5–8.5	8.2–8.8	7.6	7.0–8.1
TDS (mg l^{-1})	1000	–	48.6	26–404.2
Odor	No odor	None	No odor	No odor
Turbidity	2 NTU	1.5 NTU	1	0.1–1.3
NO2-N (mg l^{-1})	3	3	0.23	0–1.398
NO3-N (mg l^{-1})	50	50	0.96	0.1–8.6
NH3-N (mg l^{-1})	3	–	0.33	0.03–0.86
Hardness (mg l^{-1}CaCO3)	300	–	20	5–22
As (mg l^{-1})	0.01	0.01	0.0001	0.0001–0.005
Fe (mg l^{-1})	0.3	0.1	0.05	0.03–0.084
Cd (mg l^{-1})	0.003	0.003	0.0002	0.0002
Ni (mg l^{-1})	0.02	0.07	0.001	0.001
Cr (mg l^{-1})	0.05	0.05	0.001	0.001
Mn (mg l^{-1})	0.3	0.05	0.001	0.001–0.021
Hg (mg l^{-1})	0.001	0.006	0.0002	0.0001–0.0002
Se (mg l^{-1})	0.01	0.01	0.001	0.001
Pb (mg l^{-1})	0.01	0.01	0.001	0.001–0.003
Zn (mg l^{-1})	3	–	0.05	0.03–1.46
S^{2-} (mg l^{-1})	0.05	–	0.03	0.02–0.035
SO_4^{2-} (mg l^{-1})	250	–	0	0
Coliform (CFU/100 ml)	0	0	270	10–12000
E. Coli (CFU/100 ml)	0	0	8	0–3200

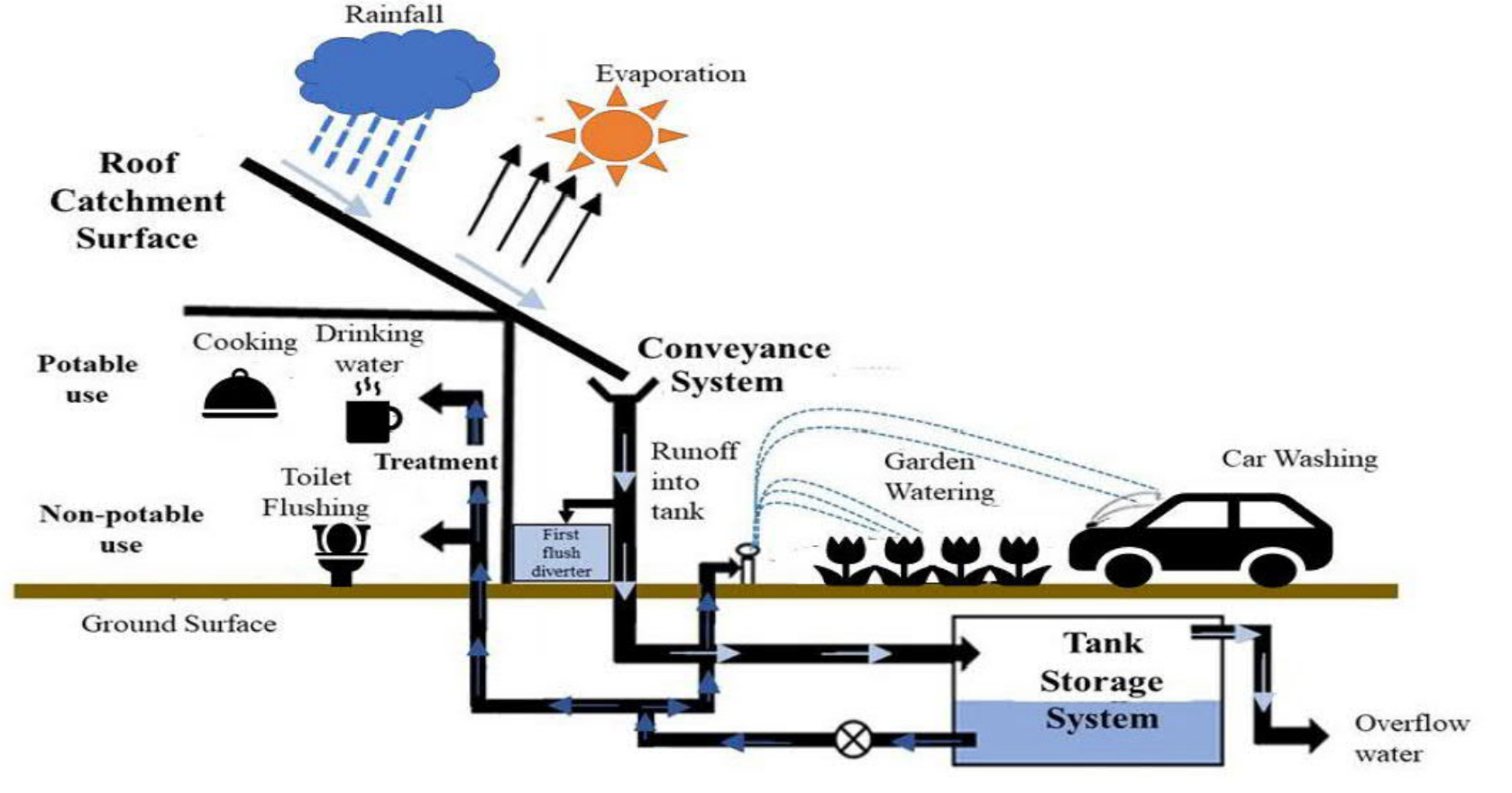
[a] Vietnam Standard: National Technical regulation on Drinking Water Quality (2009), World Health Organization (WHO) Standard

WHO and national regulations set limits for drinking and household water.

Example shows a case study from Vietnam. According to it, which one is the most likely the reason the rainwater is not drinkable?

S) Bacteria growth
P) Metal content
R) Odor

Rooftop harvesting



Gaining drinkable water requires sanitation. For example, ozone treatment

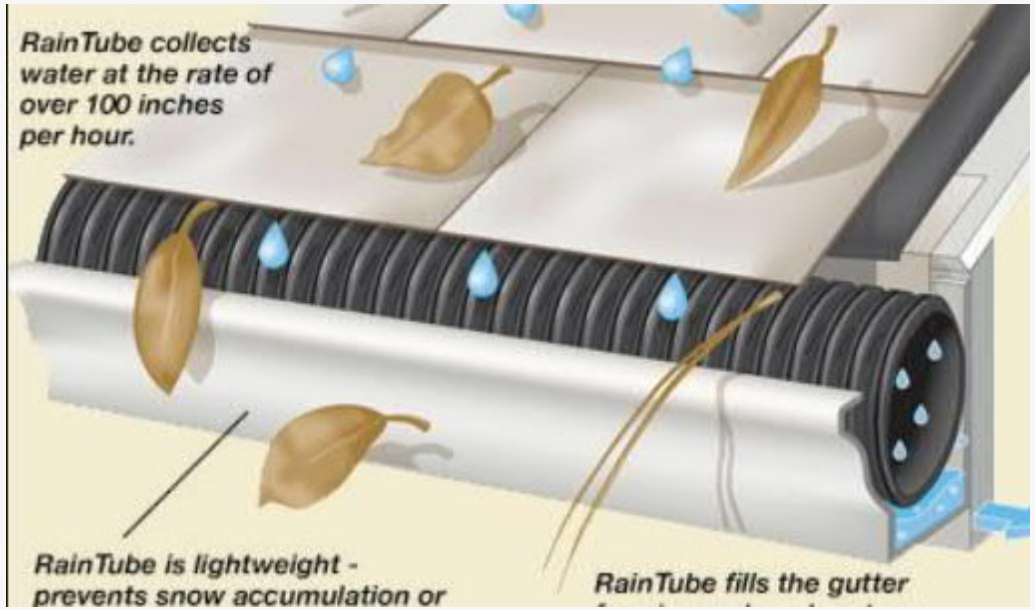
After filtering non-potable use.

Without filtering: irrigation, gardening

Overflow can be led to ground only, if is clean enough. The quality and volume might be regulated, and leading run-off or overflow to streets is illegal?

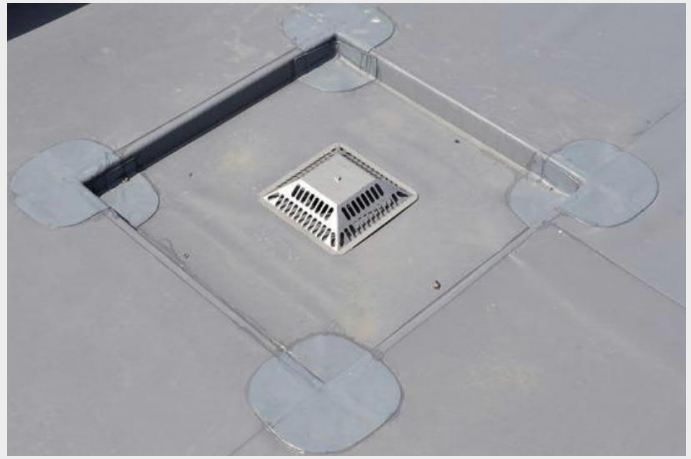
Examples

Sophisticated details starting from the gutters, filters, tanks, ...
Design might not be that easy?



https://www.building.co.uk/cpd/cpd-7-2016-rainwater-outlet-design-and-specification/5080978.article

UK



Compute an example case from your region:
How much rainwater you get on roof, if the size of roof is

Case 1

100 m^2

Case 2

1500 m^2

If consumption of one person is 150 L/d:
Would the roof provide enough water for one year for one person?

Compute an example case from your region:
How much rainwater you get on roof, if the size of roof is

Case 1

100 m^2

If consumption of one person is 150 L/d:
Would the roof provide enough water for one year for one person?

Example solution Case 1

Precipitation 600 mm/a = 0.6 m/a

Roof area: 100 m^2

Volume of rain: 60 m^3 = 60 000 L

Consumption 150 L/d

Water would cover 60 000 L/(150 L/d) = 400 d consumption.

Answer: theoretically, yes

It is estimated that only 40 % tap water consumption can be replaced with rainwater harvested in various ways

Choose one that is NOT correct

A. Water quality of runoff water is not as good as original rainwater, and making it potable water will require extensive treatment.

O. Storage tanks and pipelines have to be designed large enough to handle heavy rains.

U. Harvesting rainwater and run-off water is increasing globally.

E. Communities are not really investing to run-off water and flood water handling.

Copenhagen: field serves as flood water storage

http://www.urbanecodesignlab.org/18dff

Actions in sustainable urban development

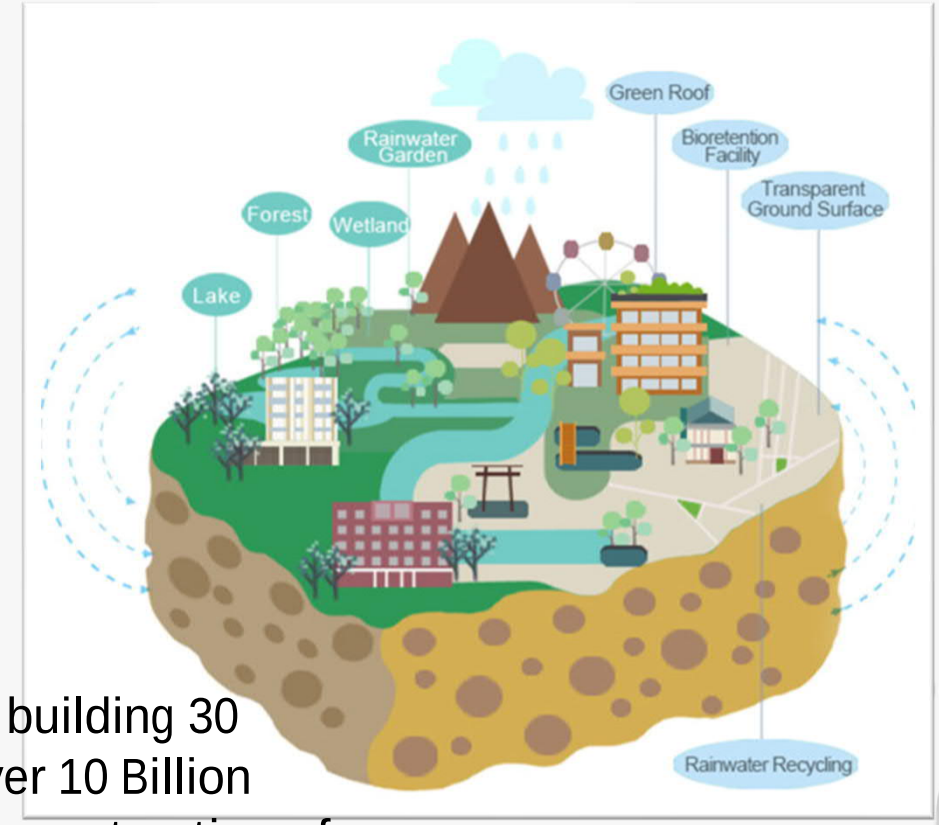
Spatial city planning

- Green roofs, constructed wetlands, flood tanks integrated to infrastructure, increased tree cover, permeable pavements, utilization of rainwater in watering plants

Green and bio based innovations and technologies

- Chemical free technologies, water harvesting and distributed purification, innovative solutions for sustainable utilization and recycling

Huge investments



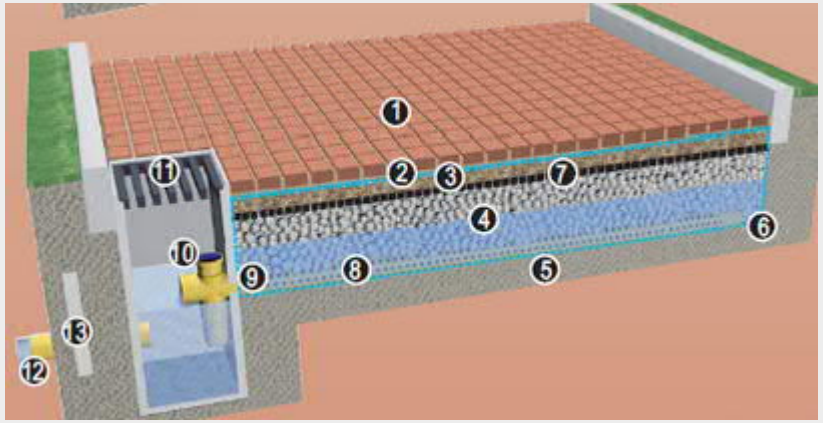
Example: China is building 30 ‘sponge cities’ (over 10 Billion euros allocated in construction of infrastructure)

Global examples Paving should let water infiltrate

http://www.urbanecodesignlab.org/18dff

https://wiki.sustainabletechnologies.ca/wiki/Permeable_pavements

Permeabel pavements let the water in



Permeable pavers in Hoboken, NJ used around trees which allow air and water to reach the roots (Source: Bruce Ferguson)





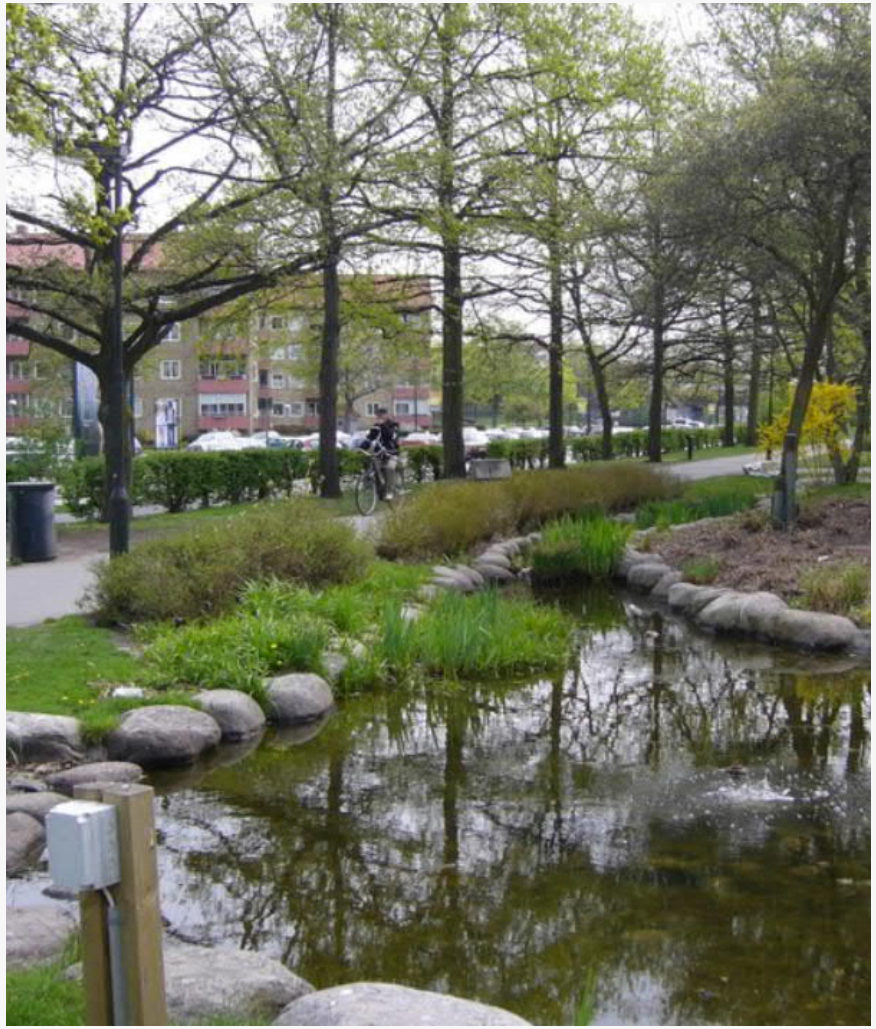


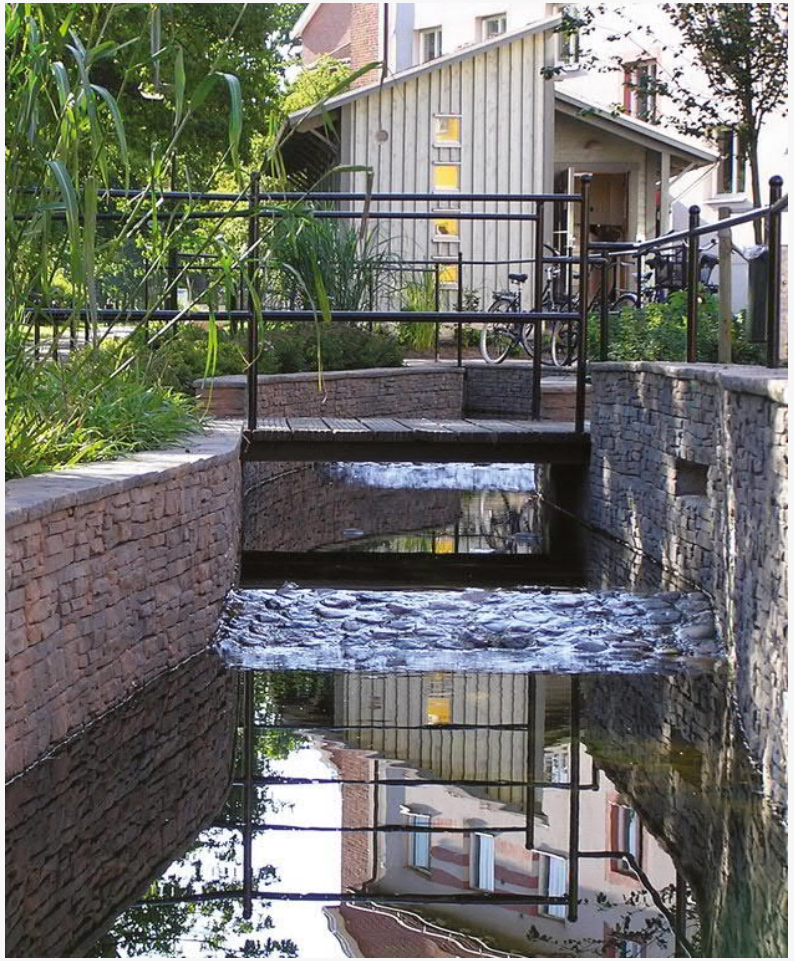

Chinese sponge cities aim 70 % utilization of rainwater
Shanghai announced in early 2016 the construction of 400,000 square meters of rooftop gardens

https://woods.stanford.edu/news/green-infrastructure-helps-manage-water-milwaukees-urban-landscape

Green Infrastructure Helps Manage Water In Milwaukee's Urban Landscape

Malmö, Sweden





https://climate-adapt.eea.europa.eu/metadata/case-studies/urban-storm-water-management-in-augustenborg-malmo

Green roofs
bring environmental, economical and social benefits

https://www.urbanscape-architecture.com/do-you-really-know-all-the-benefits-of-green-roofs/

Catch water where it falls: Urban rainwater harvesting

and re-use it