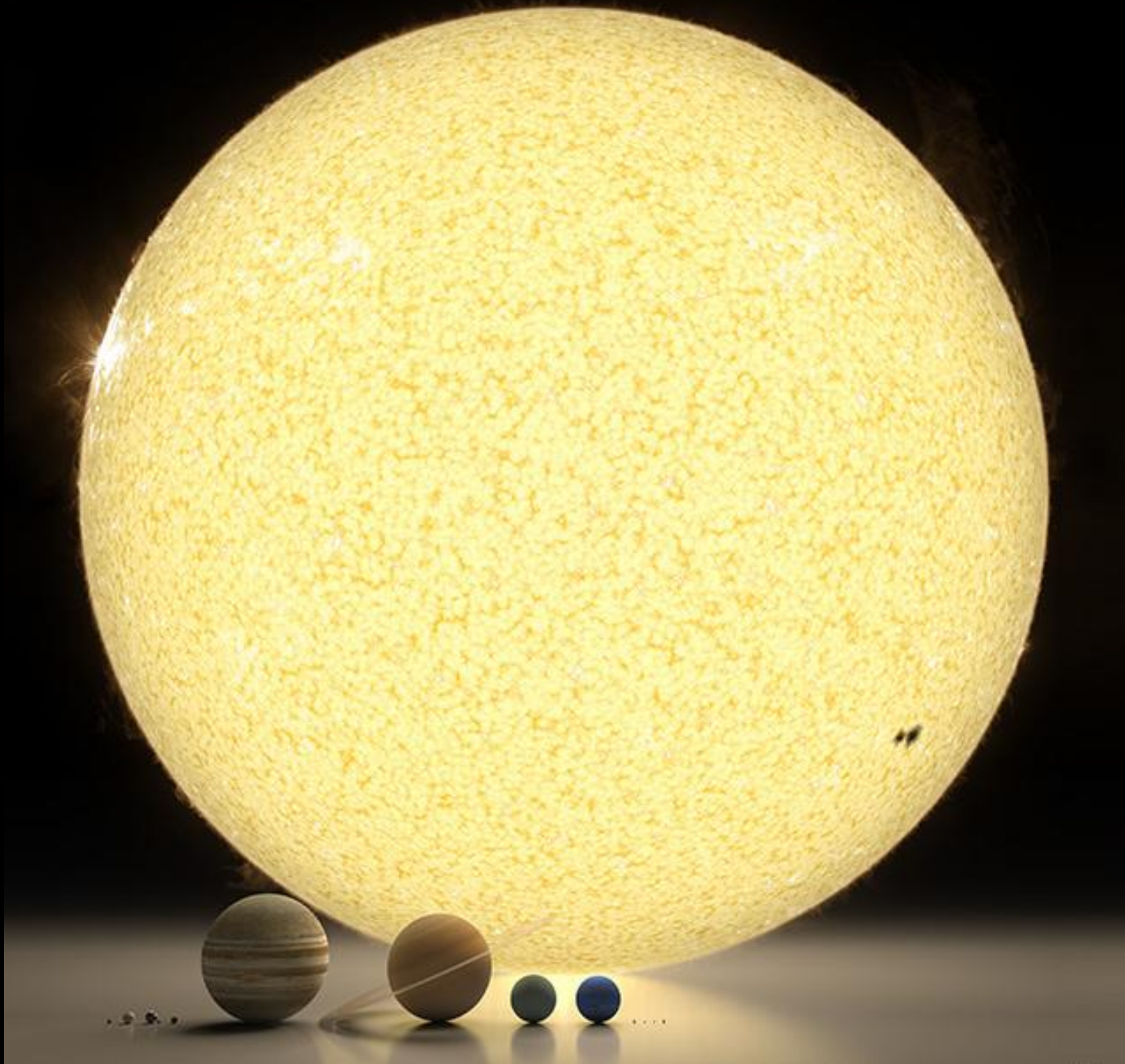


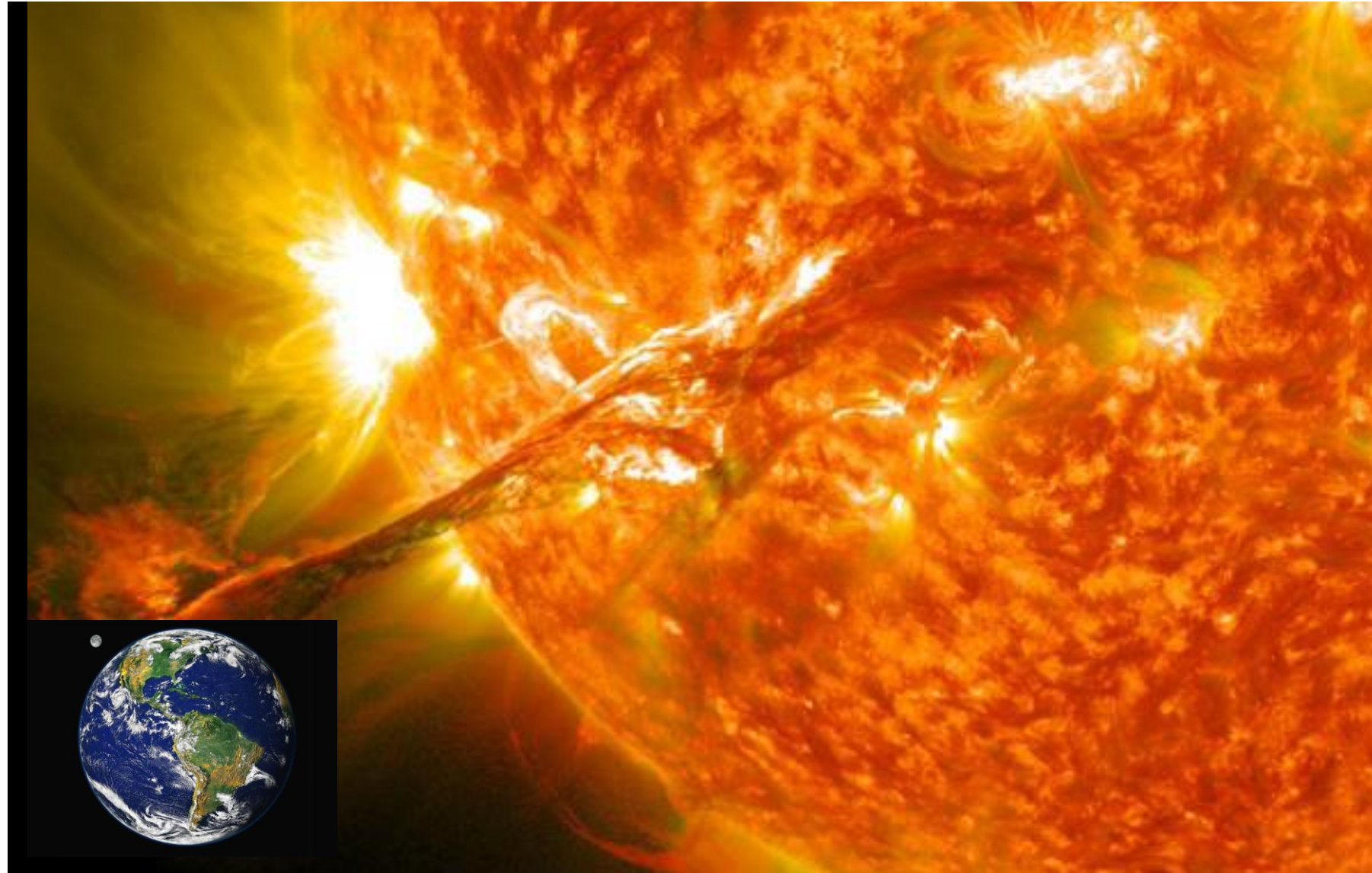
“Cidades e Territórios: Oportunidades e Benefícios da Economia Circular”

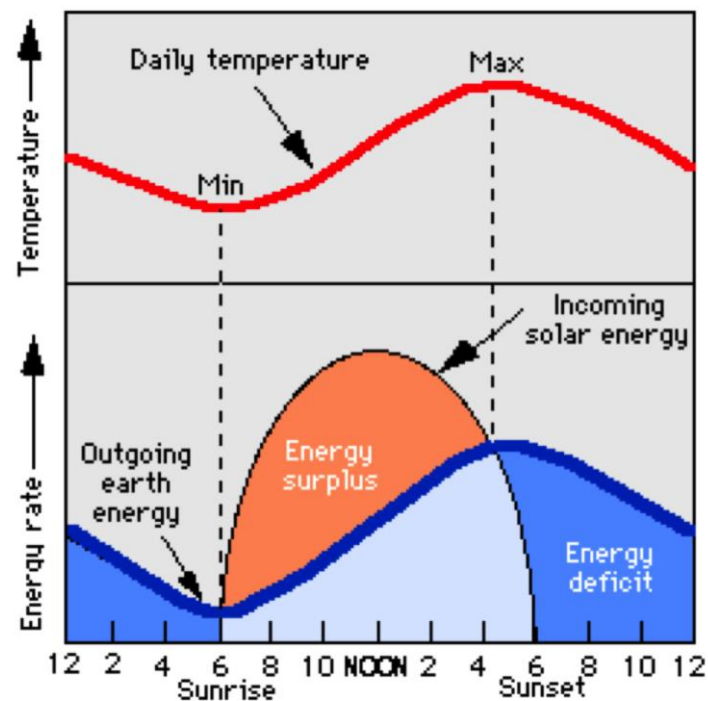
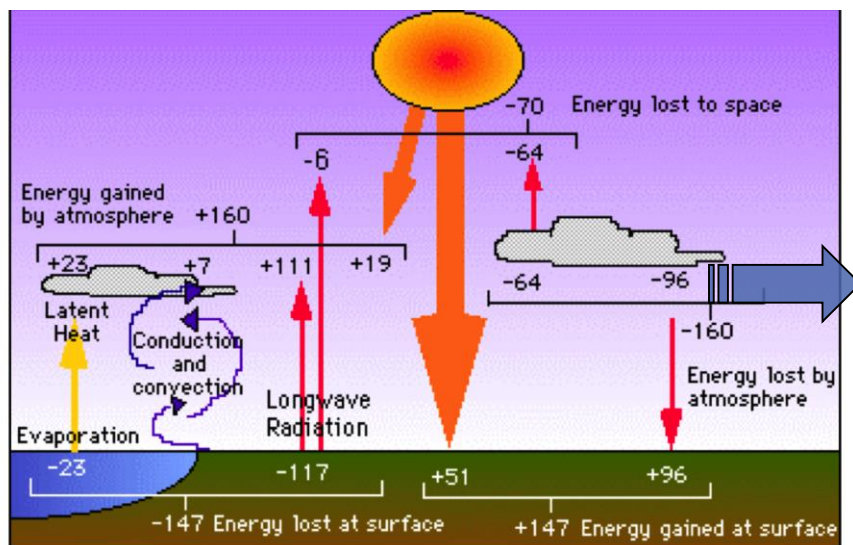
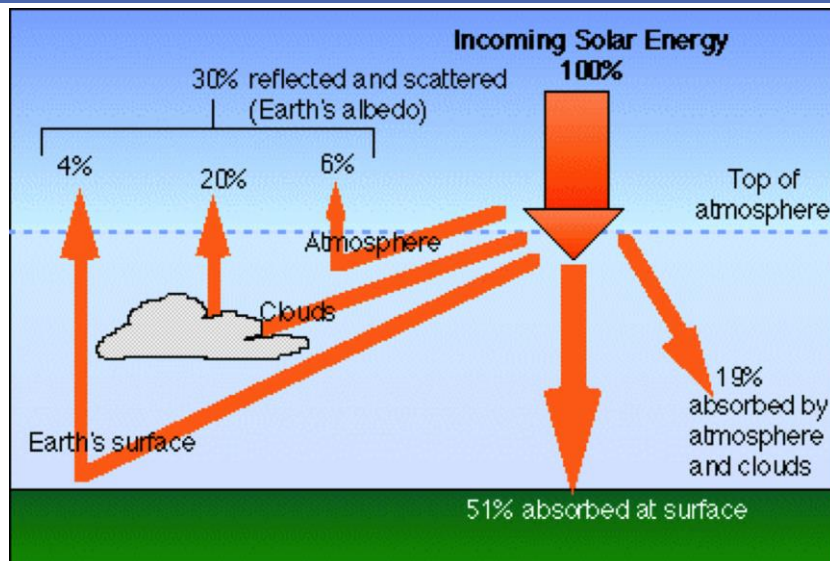
A Água e a Cidade

Paulo J. Ramísio

THE EARTH



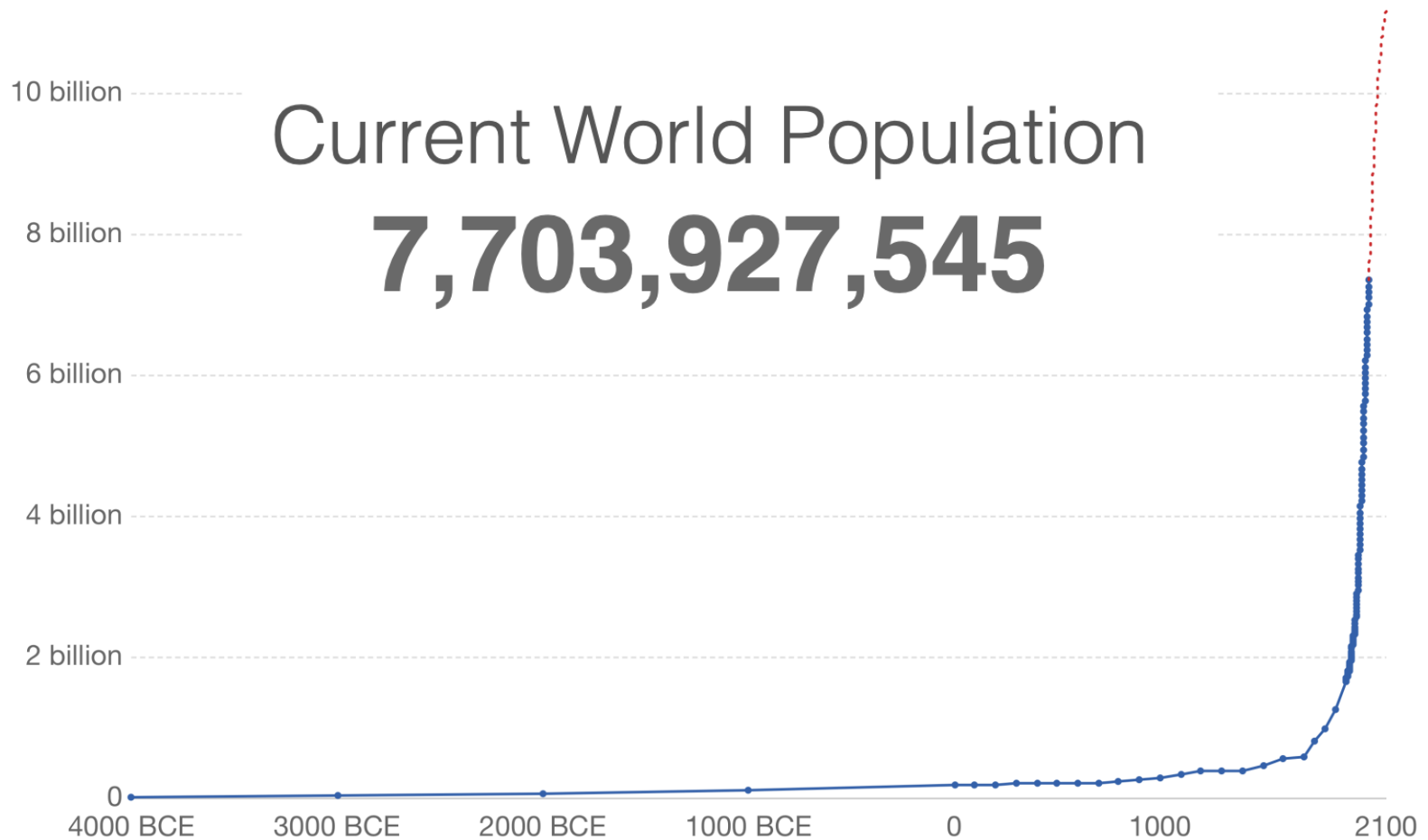




WORLD POPULATION

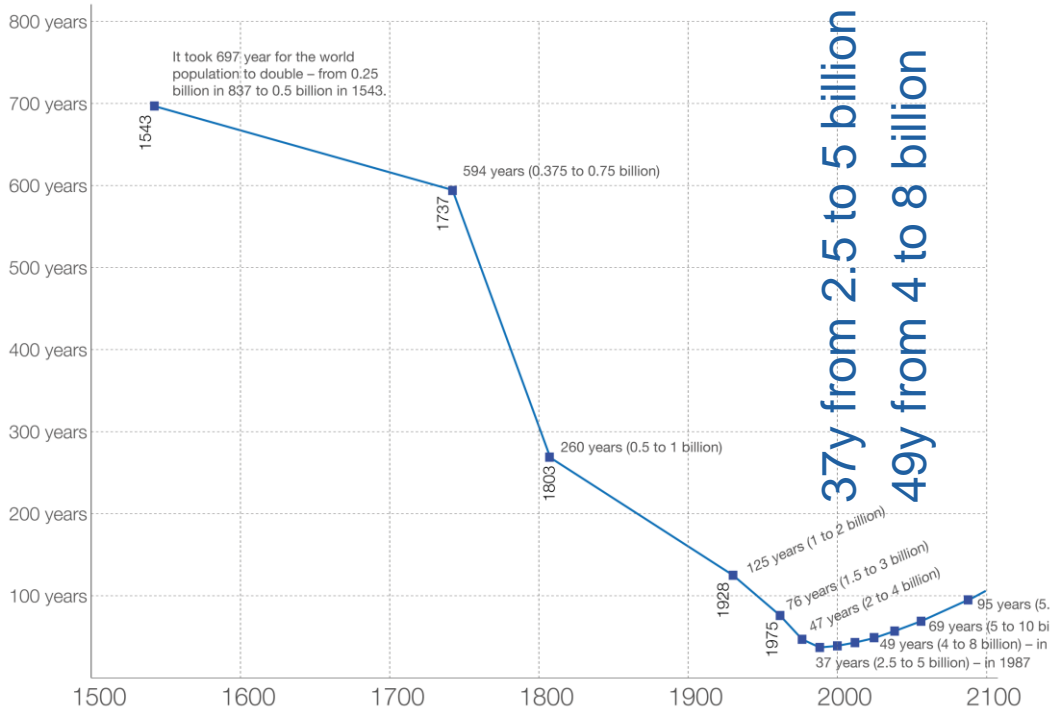
World Population over the last 12,000 years and UN projection until 2100

Our World
in Data

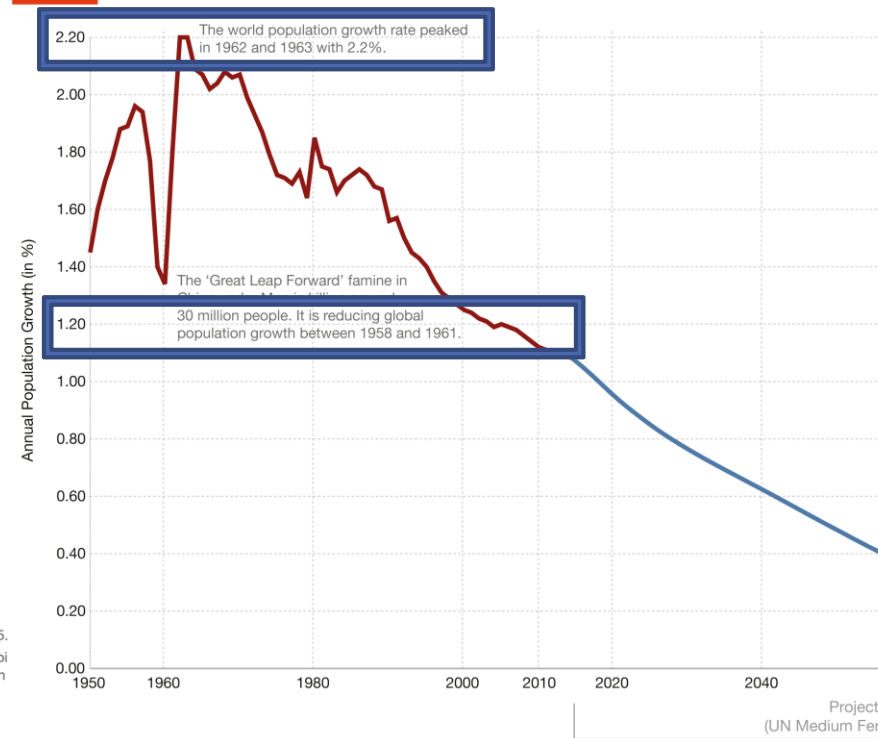


Time it took for the world population to double

Historical estimates of the world population until 2015 – and UN projections until 2100



Annual world population growth rate



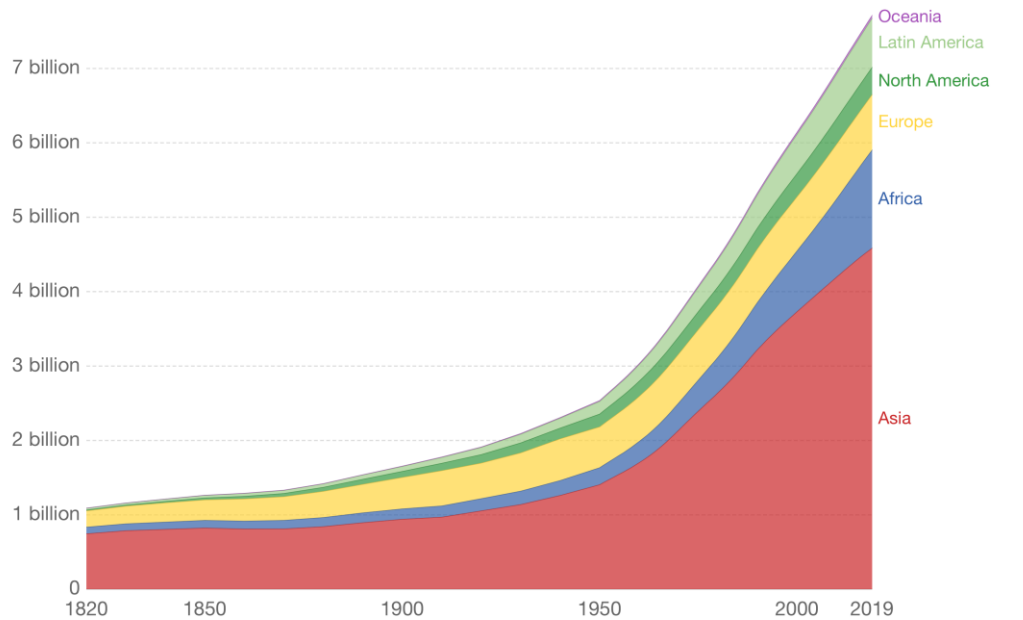
Data source: OurWorldInData annual world population series (Based on HYDE and UN until 2015. And projections from the UN after 2015 ("Medium Variant" 2015 Revision). The data visualization is available at OurWorldInData.org. There you find the raw data, more visualizations, and research on this topic.

Data sources: Observations: US Census Bureau & Projections: United Nations Population Division (Medium Variant (2015 revision)). The interactive data visualization is available at OurWorldInData.org. There you find the raw data and more visualizations on this topic.


Current World Population

7,703,927,545

World population by region



OurWorldInData.org/world-population-growth/ • CC BY

1		<u>China</u>	1,419,407,621	18,4%
2		<u>India</u>	1,366,815,573	36,2%
3		<u>U.S.A.</u>	328,789,141	40,4%
4		<u>Indonesia</u>	269,177,783	43,9%
5		<u>Brazil</u>	212,193,478	46,7%
6		<u>Pakistan</u>	204,099,709	49,3%
7		<u>Nigeria</u>	200,292,347	51,9%
8		<u>Bangladesh</u>	167,843,790	54,1%
9		<u>Russia</u>	143,904,558	56,0%
10		<u>Mexico</u>	132,122,600	57,7%



Country Overshoot Days 2018

When would Earth Overshoot Day land if the world's population lived like...



WATER AVAILABILITY AND QUALITY

WATER WITHDRAW AND USES GROWTH

Figure 31. Water withdrawal and global population over time in agriculture, industry and municipalities, 1900–2010

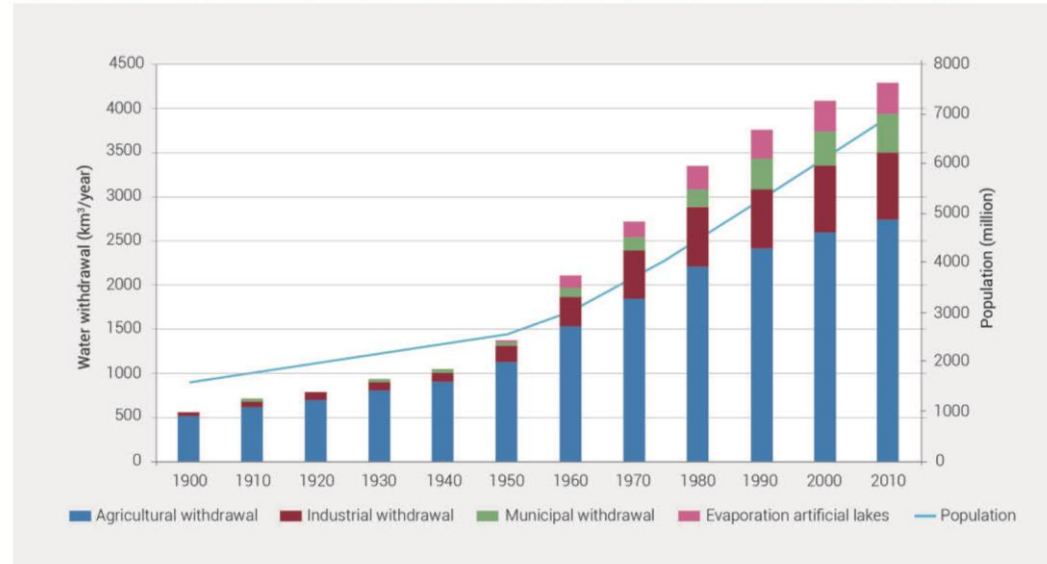
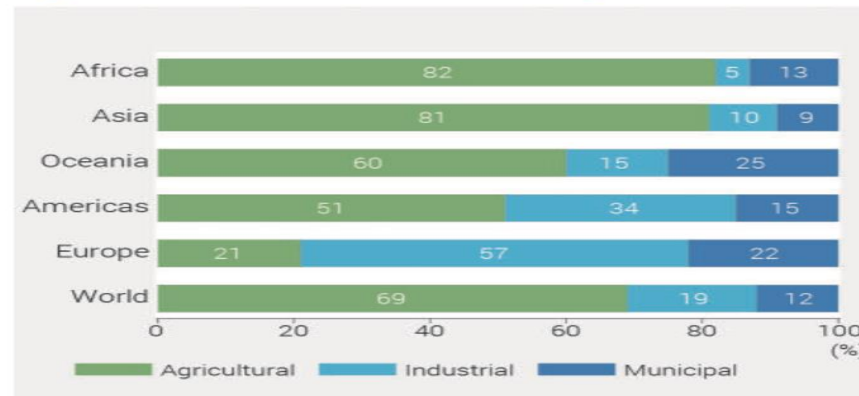


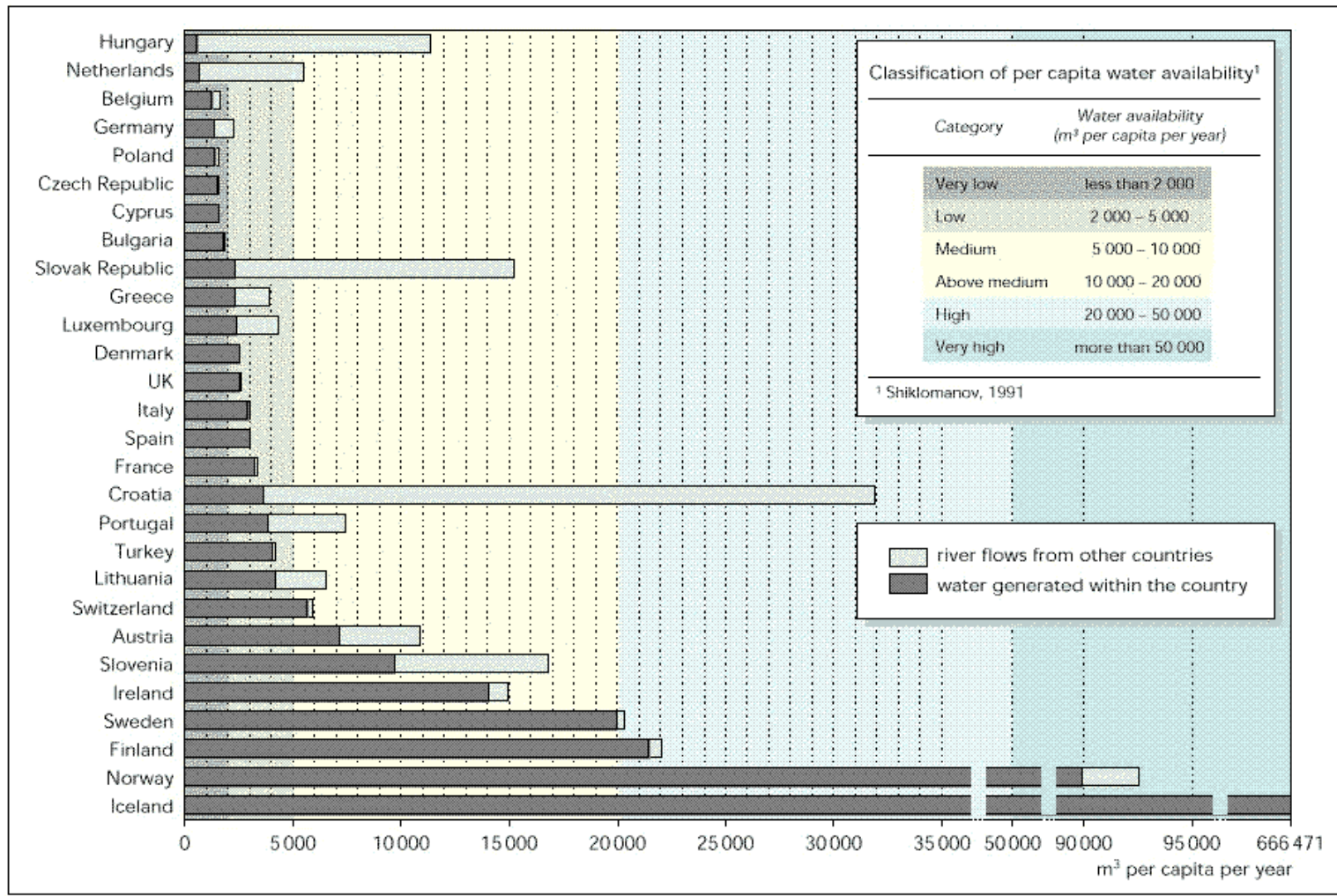
Figure 34. Water withdrawal ratios by continent

Source: FAO (2)



Source: FAO (2016a).

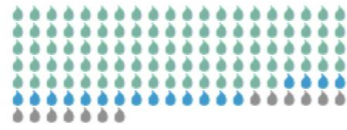
WATER AVAILABILITY IN EUROPE (m³/capita/year)



Global Average Water Footprint

1259 litre per pizza

76% green, 14% blue, 10% grey



132 litre per cup of 125 ml

86% green, 1% blue, 3% grey



109 litre for a 125ml glass of wine

70% green, 16% blue, 14% grey



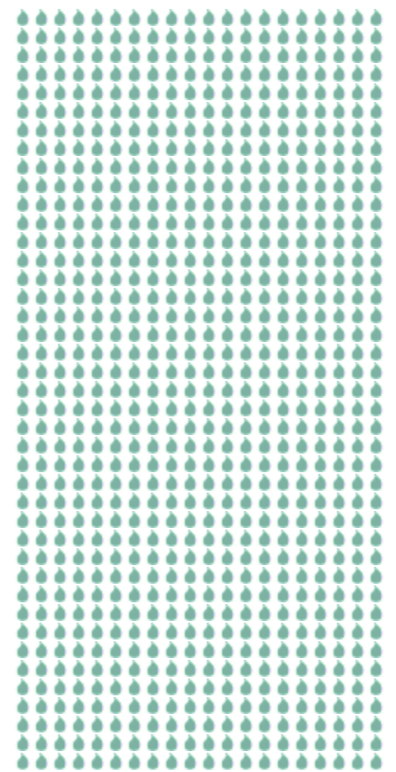
74 litre for a glass of 250 ml

85% green, 6% blue, 9% grey



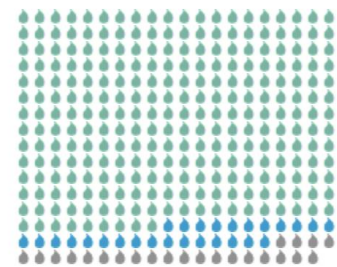
17196 litre/kg

98% green, 1% blue, 1% grey



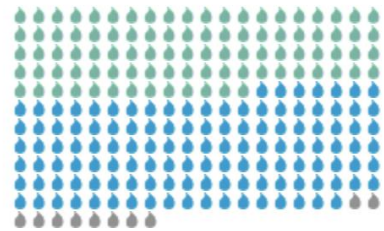
3178 litre/kg

85% green, 8% blue, 7% grey



2277 litre/kg

41% green, 55% blue, 4% grey



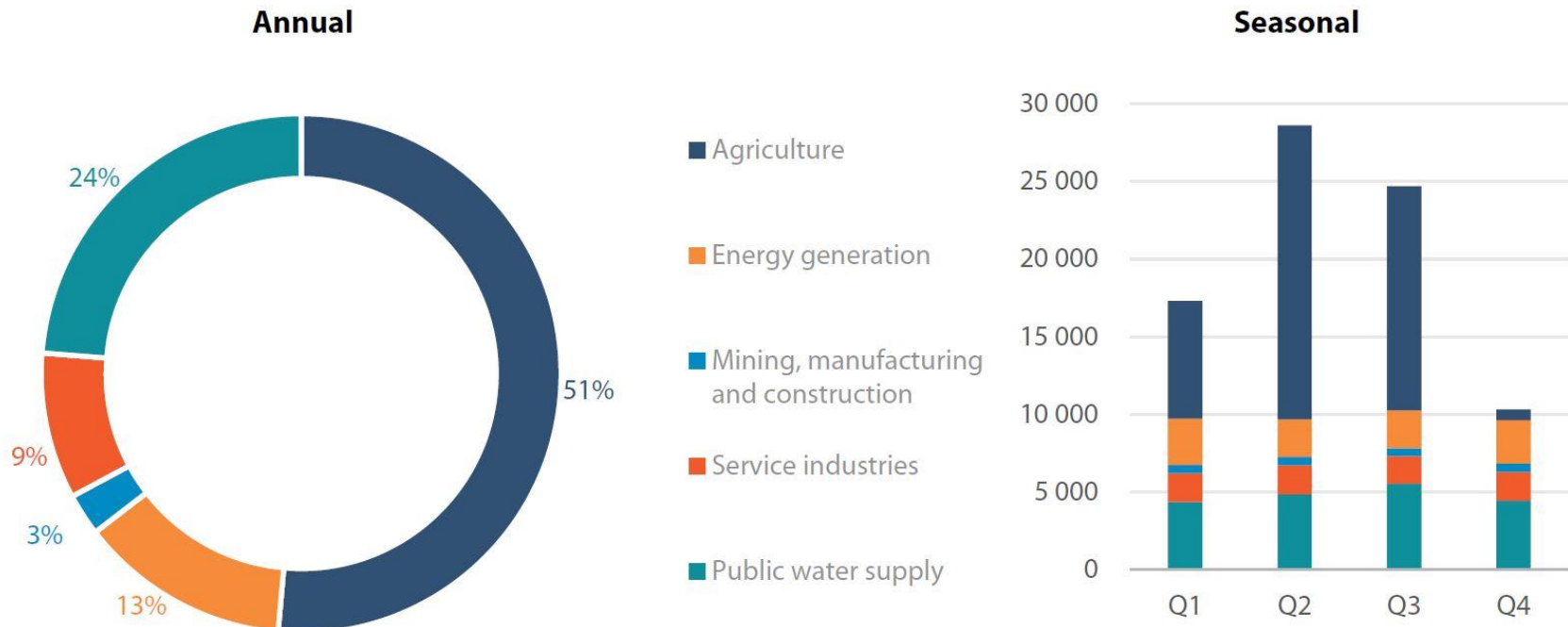
255 litre for a glass of 250 ml

85% green, 8% blue, 7% grey



Water use by economic sectors in Europe

Water use by sector in the EU (2014, hm³)



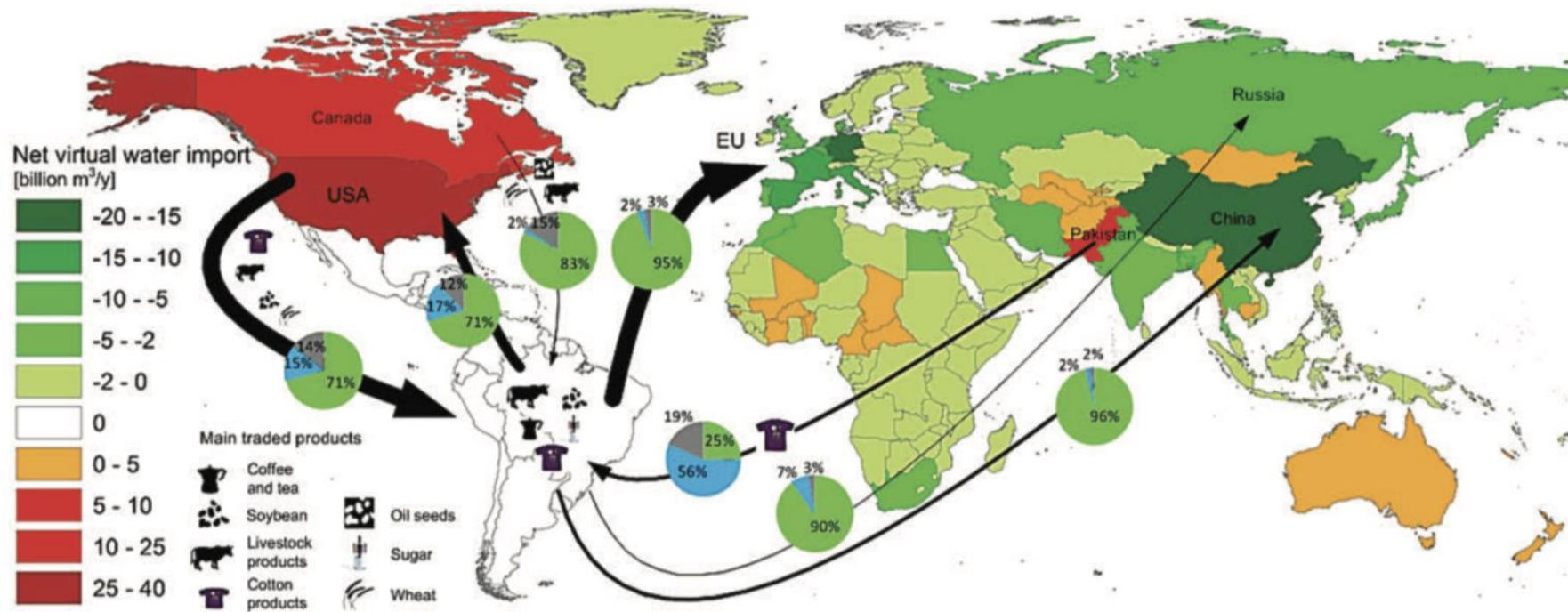
Data source: [European Environment Agency](#).

Source: European Environmental Agency

Data coverage: EEA Member countries: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom

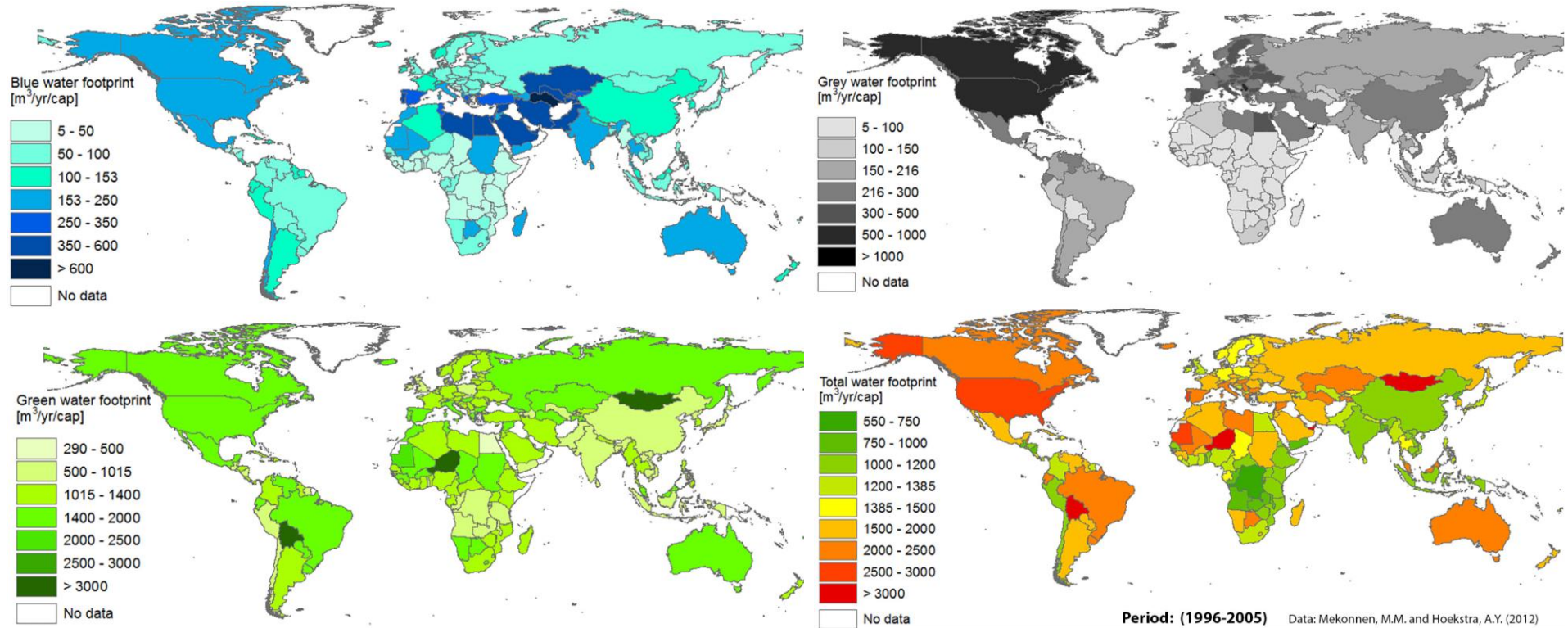
Cooperating countries: Albania, Montenegro, Serbia, the Former Yugoslav Republic of Macedonia

Net virtual water import and export related to imports of agricultural and industrial products from (green) and to (red) Latin America and the Caribbean



Period of 1996-2005 (only the largest gross virtual water flows (> 10 billion m³/y)
 Source: Mekonnen et al. (2015)

Blue, Green, Grey and Total Water Footprint (m³/year/capita)



Source: Mekonnen, M.M. and Hoekstra, A.Y. (2012)

blue water footprint - volume of surface and groundwater consumed (evaporated) as a result of the production of a good;

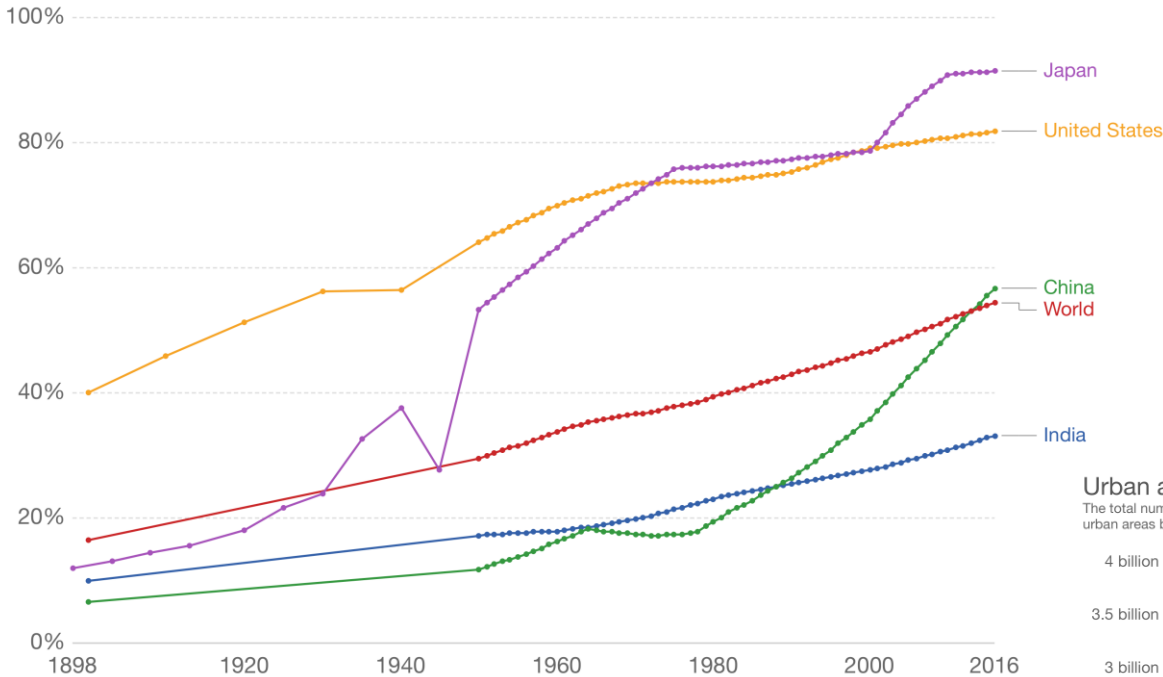
green water footprint - rainwater consumed.

grey water footprint - volume of freshwater required to assimilate the load of pollutants based on existing ambient water quality standards.

NATURAL AND URBAN ENVIRONMENT

Urbanization over the past 500 years

Share of the total population living in urban areas. Urban areas are based on national definitions and may vary by country.

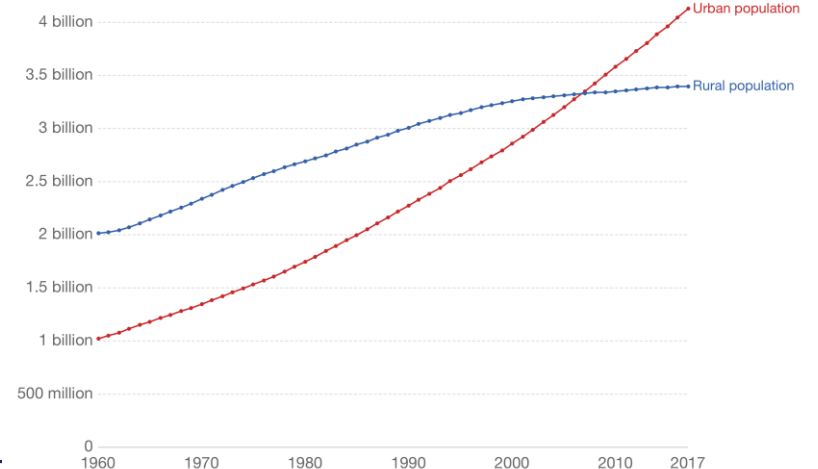


Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)

Our World in Data

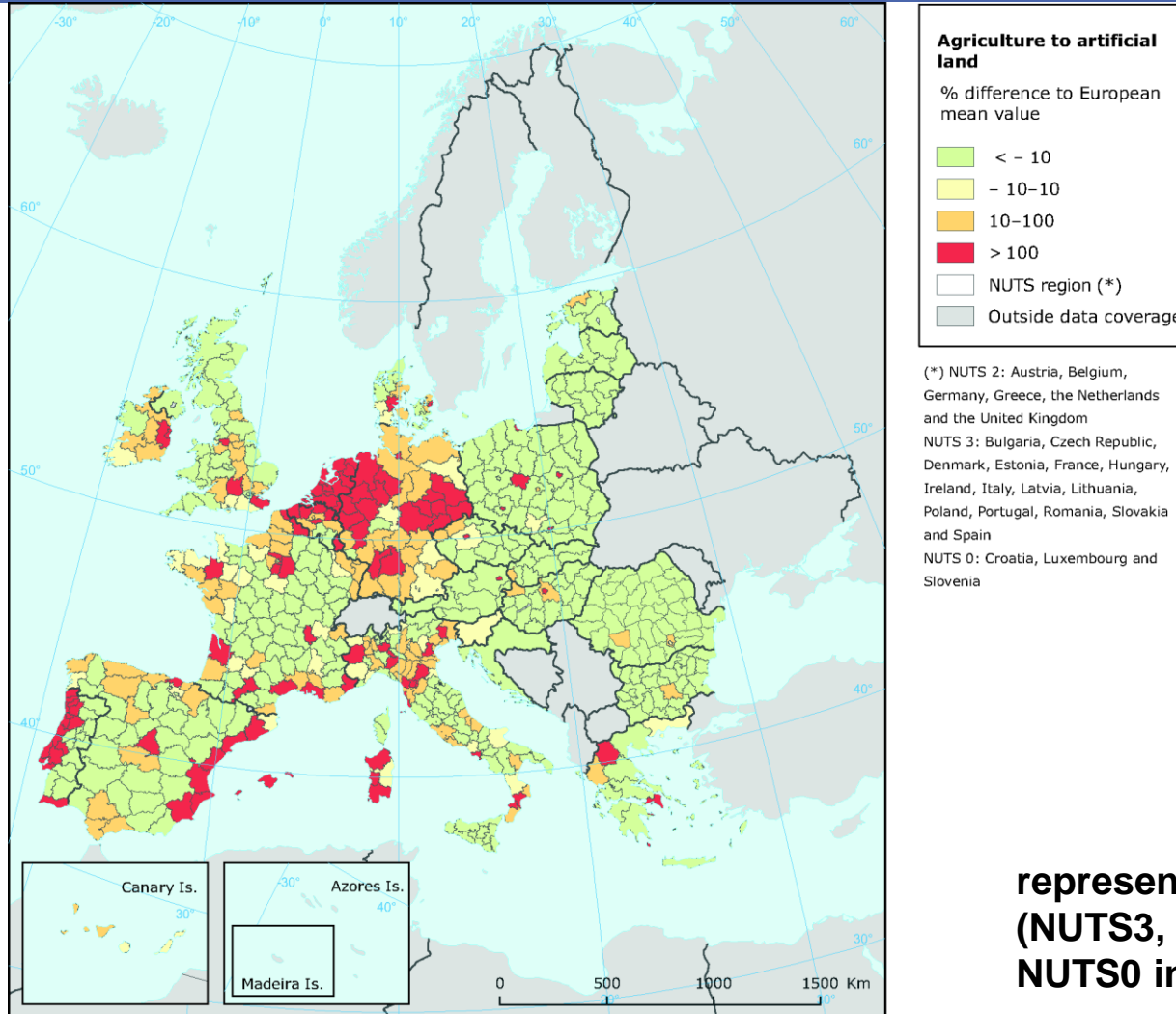
Urban and rural population, World

The total number of people living in urban or rural areas. Urban populations are defined based on the definition of urban areas by national statistical offices.



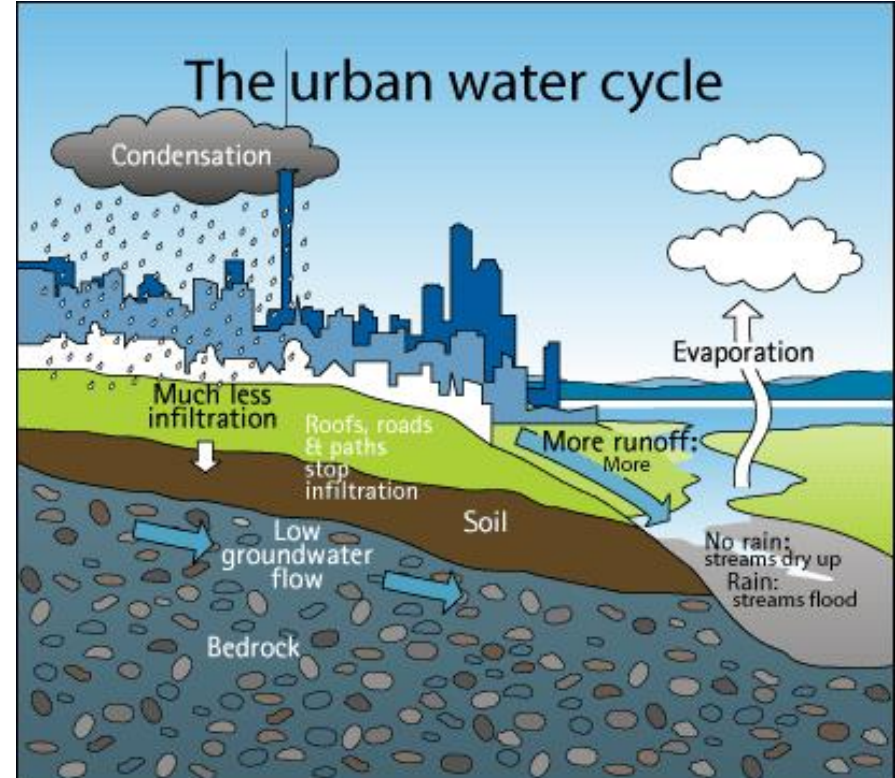
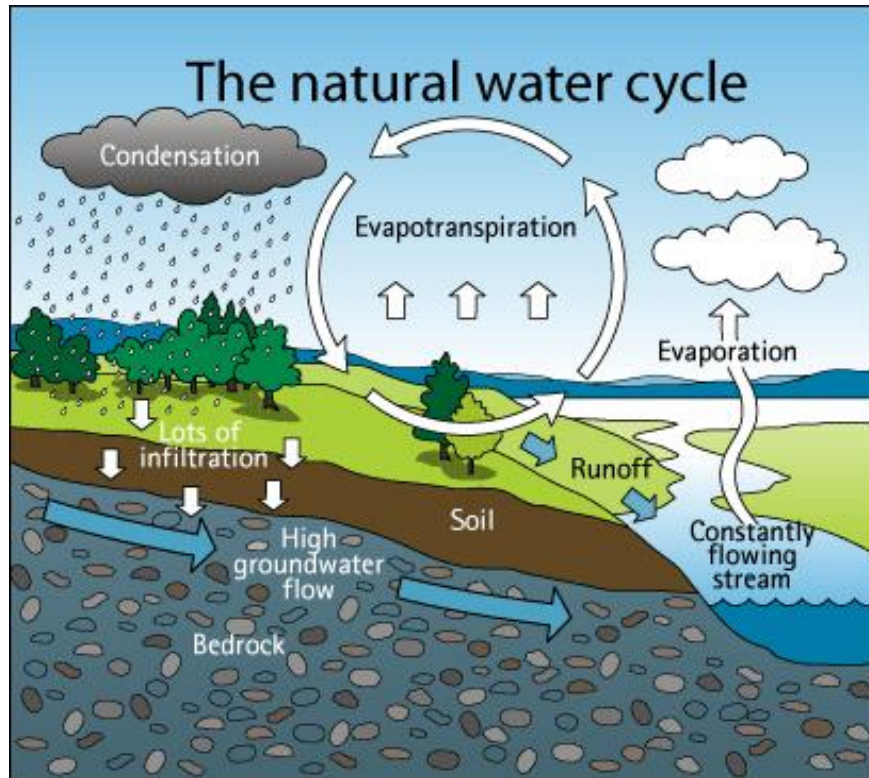
Source: World Bank, based on UN estimates

Deviation from average of the Urban sprawl (1990-2000)

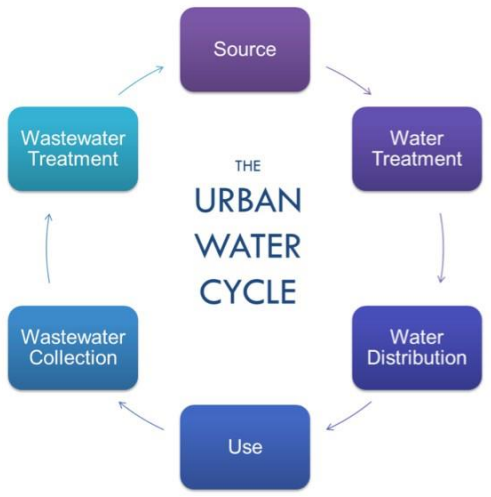


**represented by NUTSX
 (NUTS3, NUTS2 mainly,
 NUTS0 in a few cases)**

Source: European Environment Agency



(Source: Auckland Council)



Water Distribution: “Closed system”
Controlled by downstream

Wastewater Drainage: “Open System”
Controlled by upstream

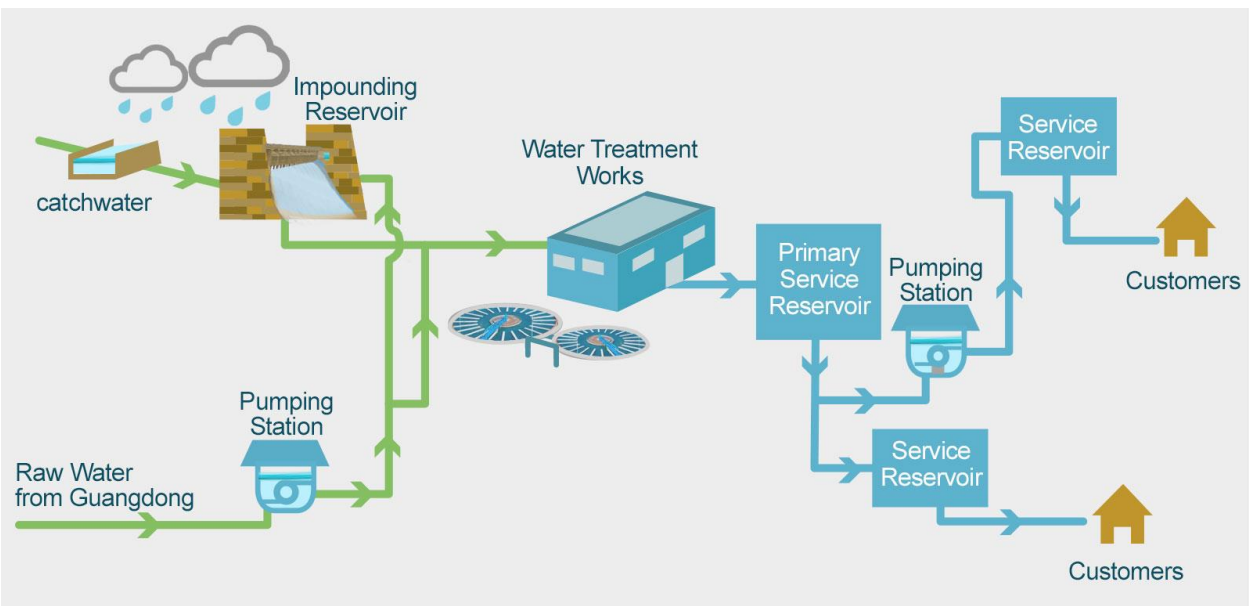


Figure 4.12 Current and projected levels of wastewater treatment in Europe

Population connected to urban wastewater treatment
(% of total population)

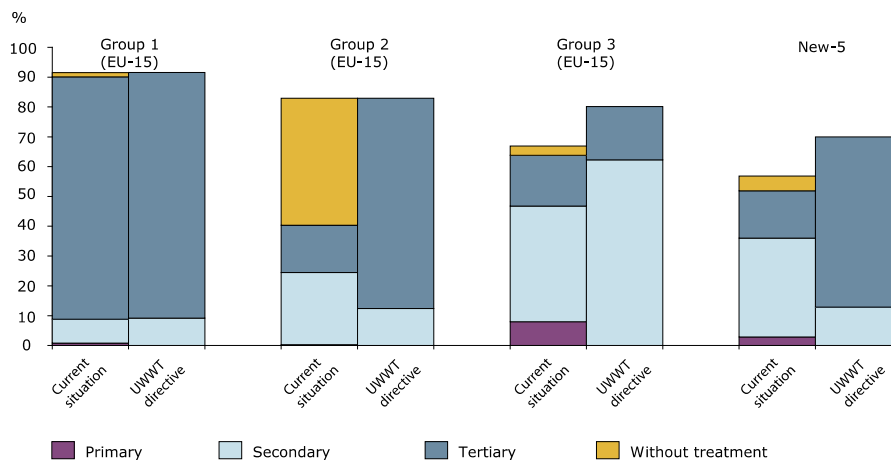
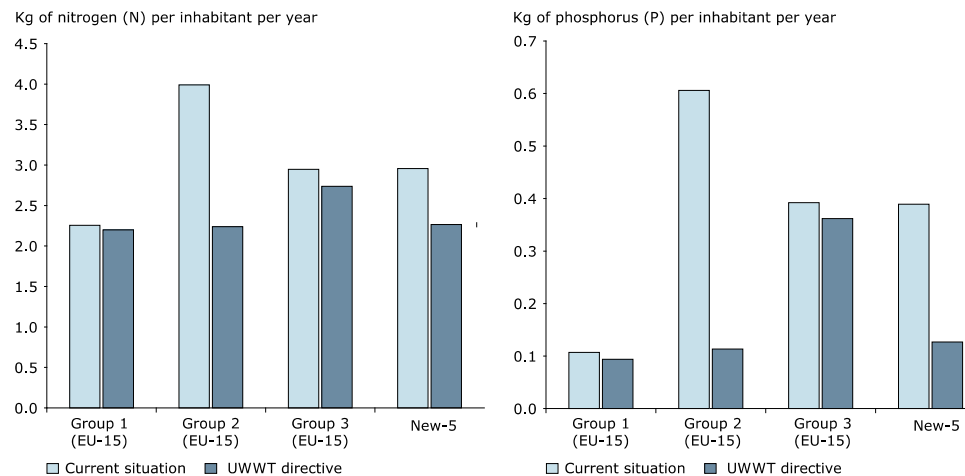


Figure 4.13 Discharges of nitrogen and phosphorus from wastewater treatment plants



Group 1 (EU-15) countries: the Netherlands, Germany, Austria, Denmark, Sweden, Finland.

Group 2 (EU-15) countries: Belgium and Luxembourg.

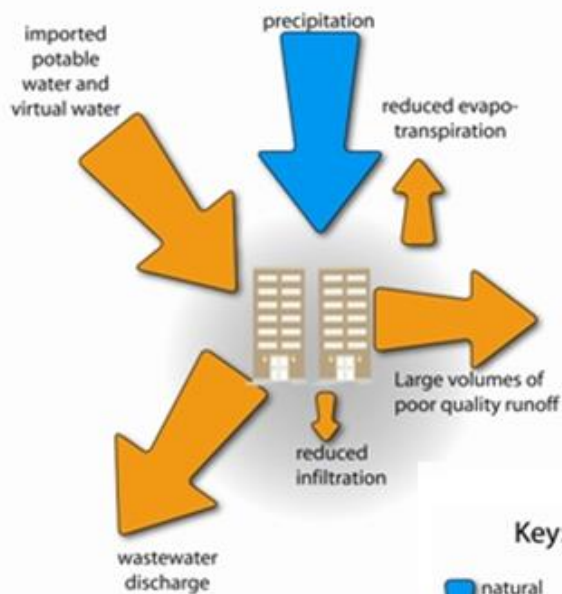
Group 3 (EU-15) countries: France, Ireland, Italy, Greece, Portugal, Spain.

New-5 countries: Estonia, Czech Republic, Poland, Hungary and Slovenia.

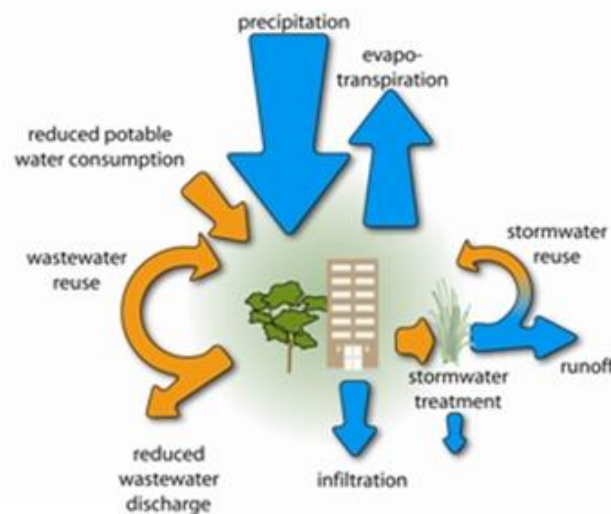
The natural water cycle



The conventional urban water cycle



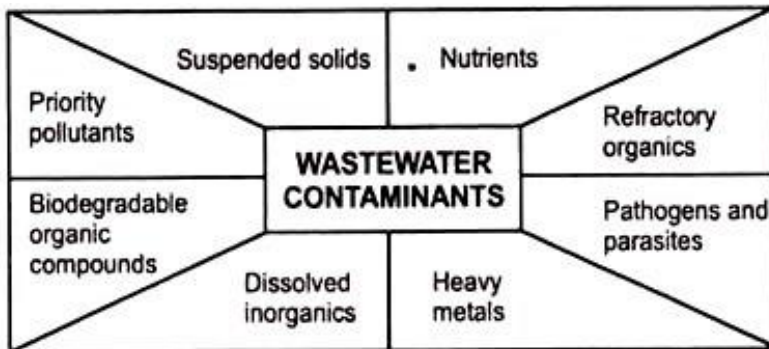
Sustainable urban water cycle



Key:



Urban Wastewater



Urban runoff

Pollutant	Urban runoff (1)	Highway runoff (2)	Roof runoff (3)	Atm. deposition, % (3)	Attached to SS, % (3, 4)	Drinking water std. (5)
SS	30-100	30-60	5-50			
COD	40-60	25-60	less	19	75	
Tot.N	2	1-2	less	70		11.3*
Tot.P	0.5	0.2-0.5	less	23	50	0.15
Pb	50-150	50-125	10-100	40	70-80	50
Zn	300-500	125-400	100-1000	30	30-40	100
Cd	0.5-3				70	5
Cu	5-40	5-25	10-100	7	30-40	100

(1) PH-Consult, 1990 (2) Hvitved-Jacobsen et al., 1992 (3) Malmquist, 1982 (4) Johansen, 1985
(5) DME, 1988

* Limit value specified as NO₃-N

Wastewater (continuous)

Microorganisms

Nutrients (N,P)

Metals

Inorganic substances

Biodegradable organic substances

Odor

Heat

Wastewater (intermittent)

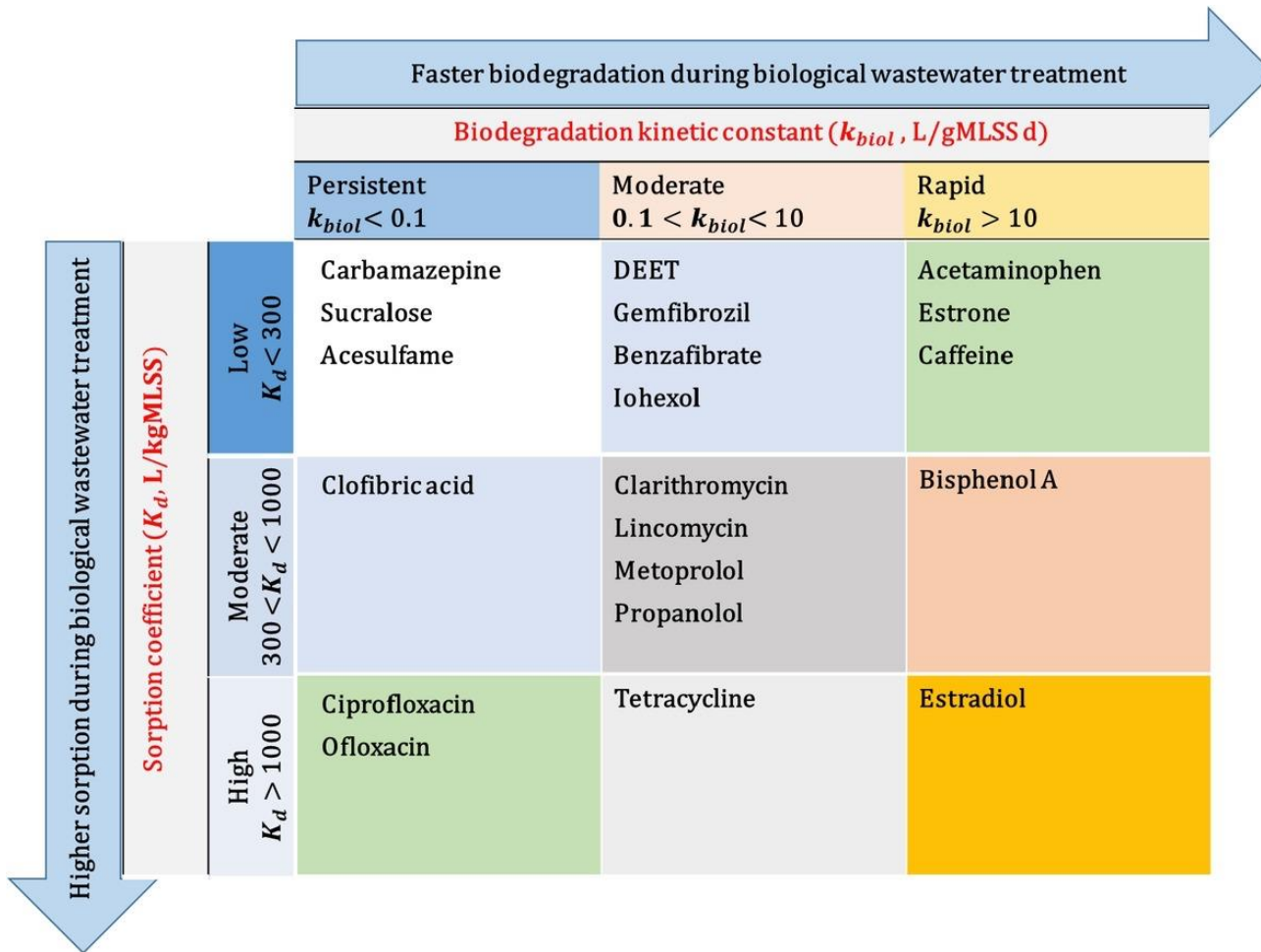
Nutrients (N,P)

Metals (Zn, Cu, Cr, Cd, Pb)

Inorganic substances

Heat

Occurrence and fate of emerging contaminants in municipal wastewater treatment plants



		Faster biodegradation during biological wastewater treatment		
		Biodegradation kinetic constant (k_{biol} , L/gMLSS d)		
		Persistent $k_{biol} < 0.1$	Moderate $0.1 < k_{biol} < 10$	Rapid $k_{biol} > 10$
Higher sorption during biological wastewater treatment	Low $K_d < 300$	Carbamazepine Sucralose Acesulfame	DEET Gemfibrozil Benzafibrate Iohexol	Acetaminophen Estrone Caffeine
	Moderate $300 < K_d < 1000$	Clofibric acid	Clarithromycin Lincomycin Metoprolol Propranolol	Bisphenol A
	High $K_d > 1000$	Ciprofloxacin Ofloxacin	Tetracycline	Estradiol

Ngoc Han Tran, Martin Reinhard, Karina Yew-Hoong Gin (2018) Occurrence and fate of emerging contaminants in municipal wastewater treatment plants from different geographical regions-a review, Water Research, Volume 133, Pages 182-207, ISSN 0043-1354, <https://doi.org/10.1016/j.watres.2017.12.029>.

Contaminants fate in environment

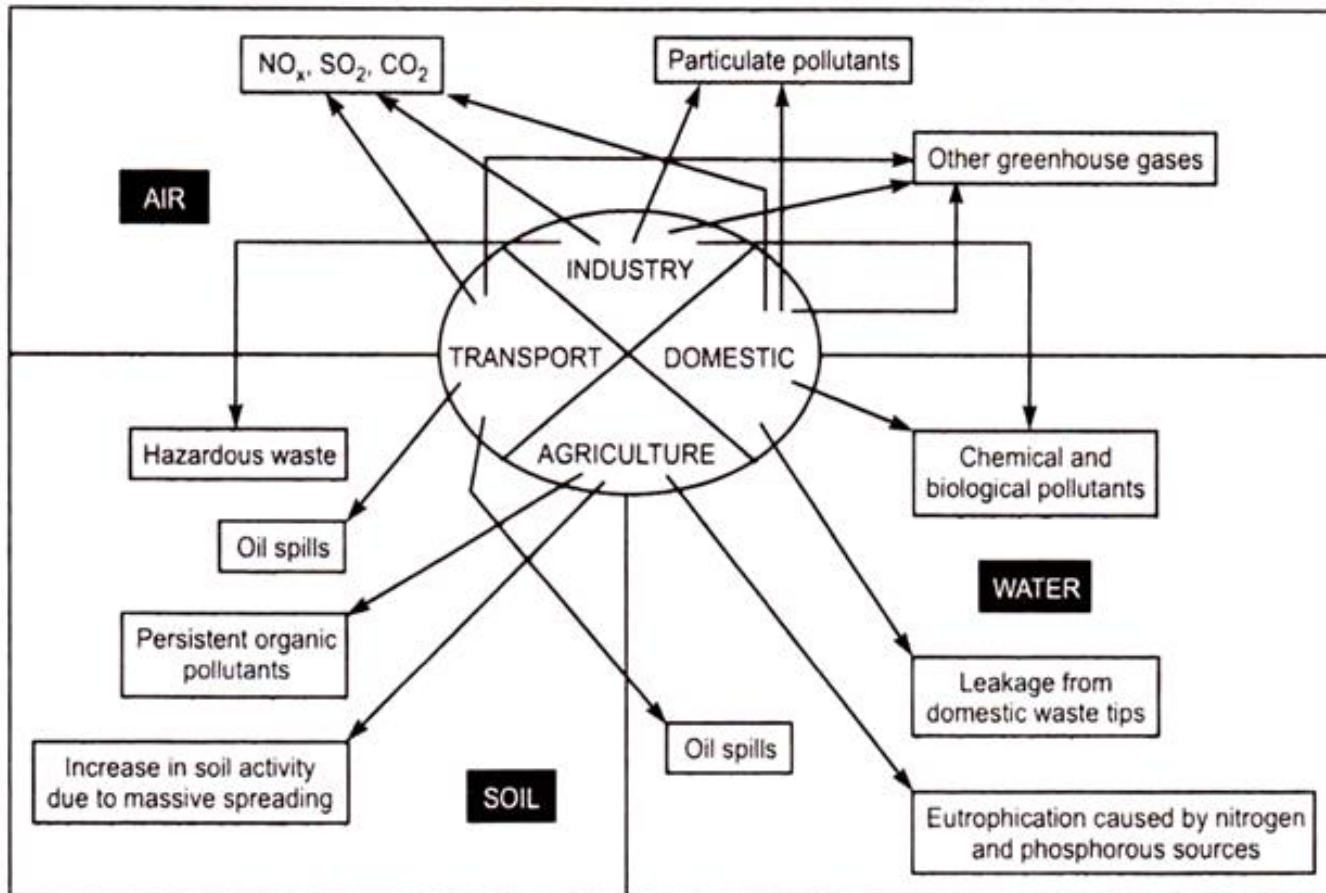
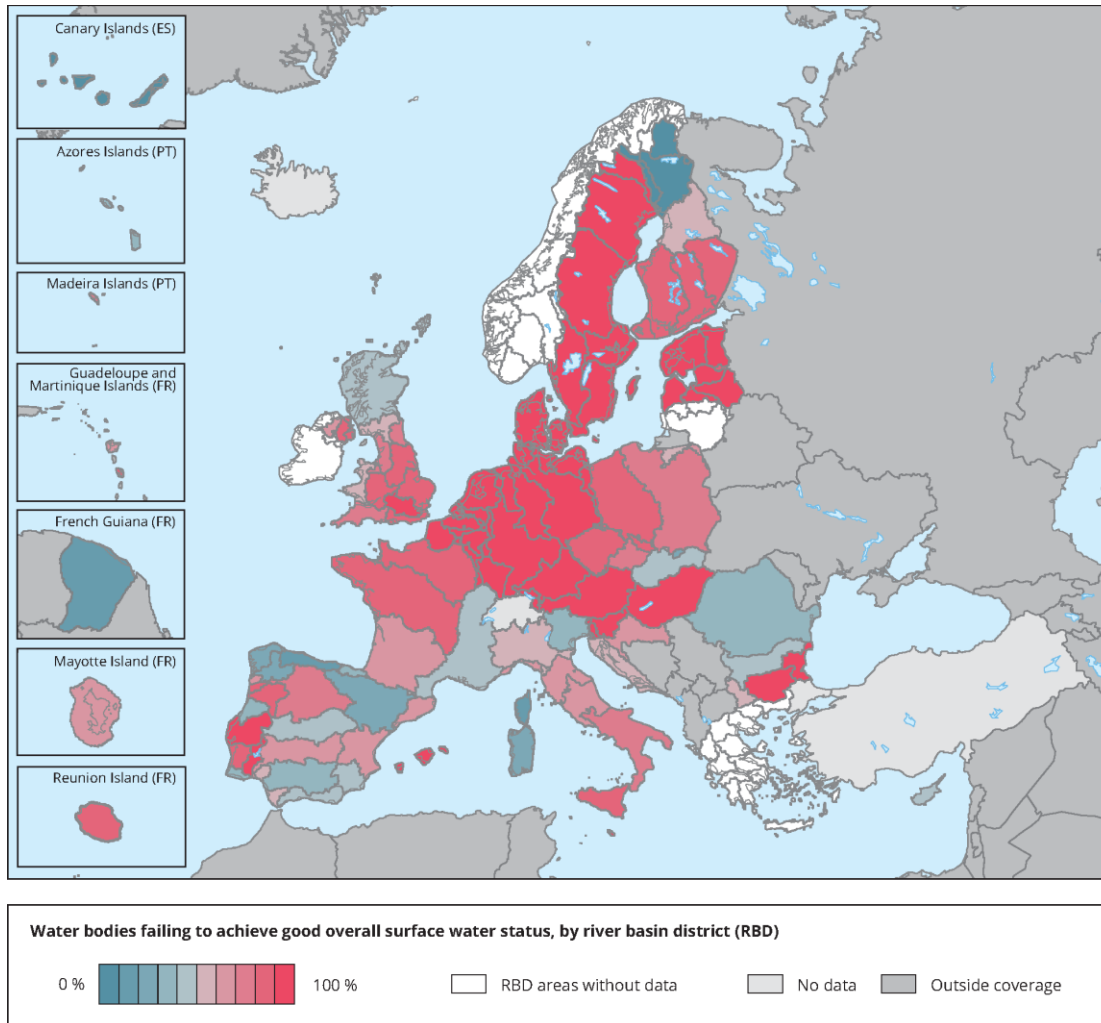


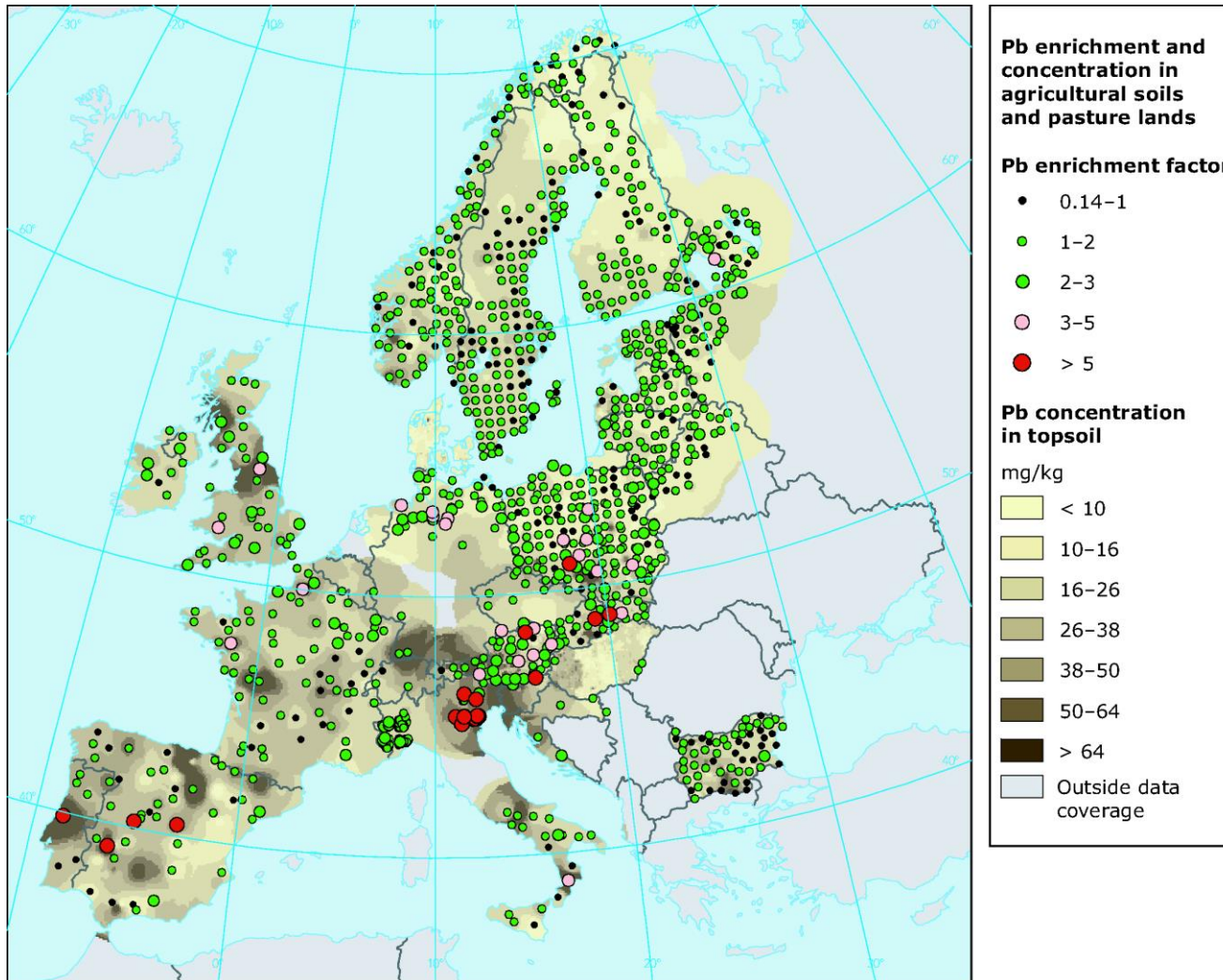
Fig. 16.1: The spider of environmental pollution due to anthropogenic activities. (Adapted from EIBE 2000)

Water bodies failing to achieve good status (%)



Source: European Environment Agency

CCDRN – Economia Circular – S. Tirso, 14 maio 2019



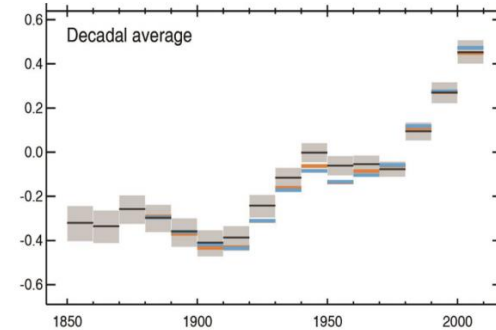
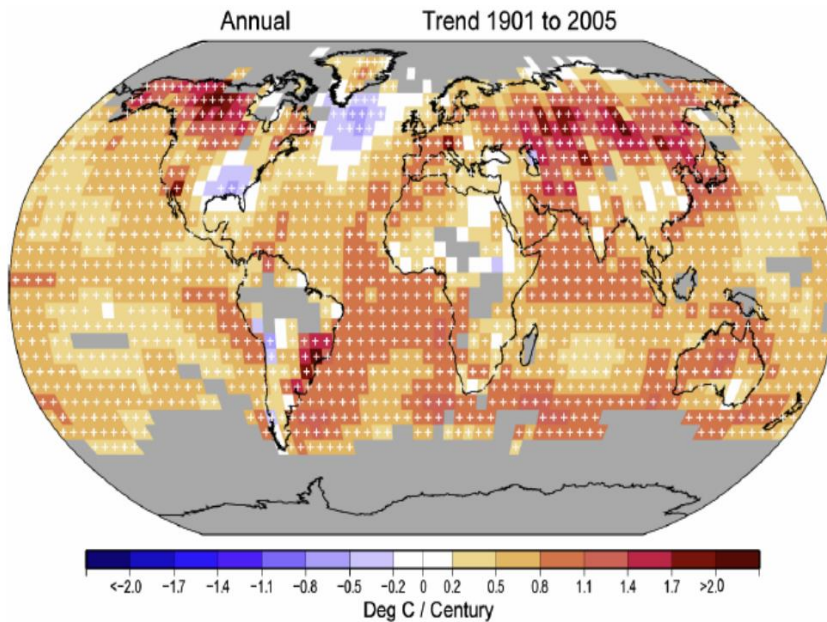
Source: European Environment Agency
 CCDRN – Economia Circular – S. Tirso, 14 maio 2019

FUTURE CHALLENGES



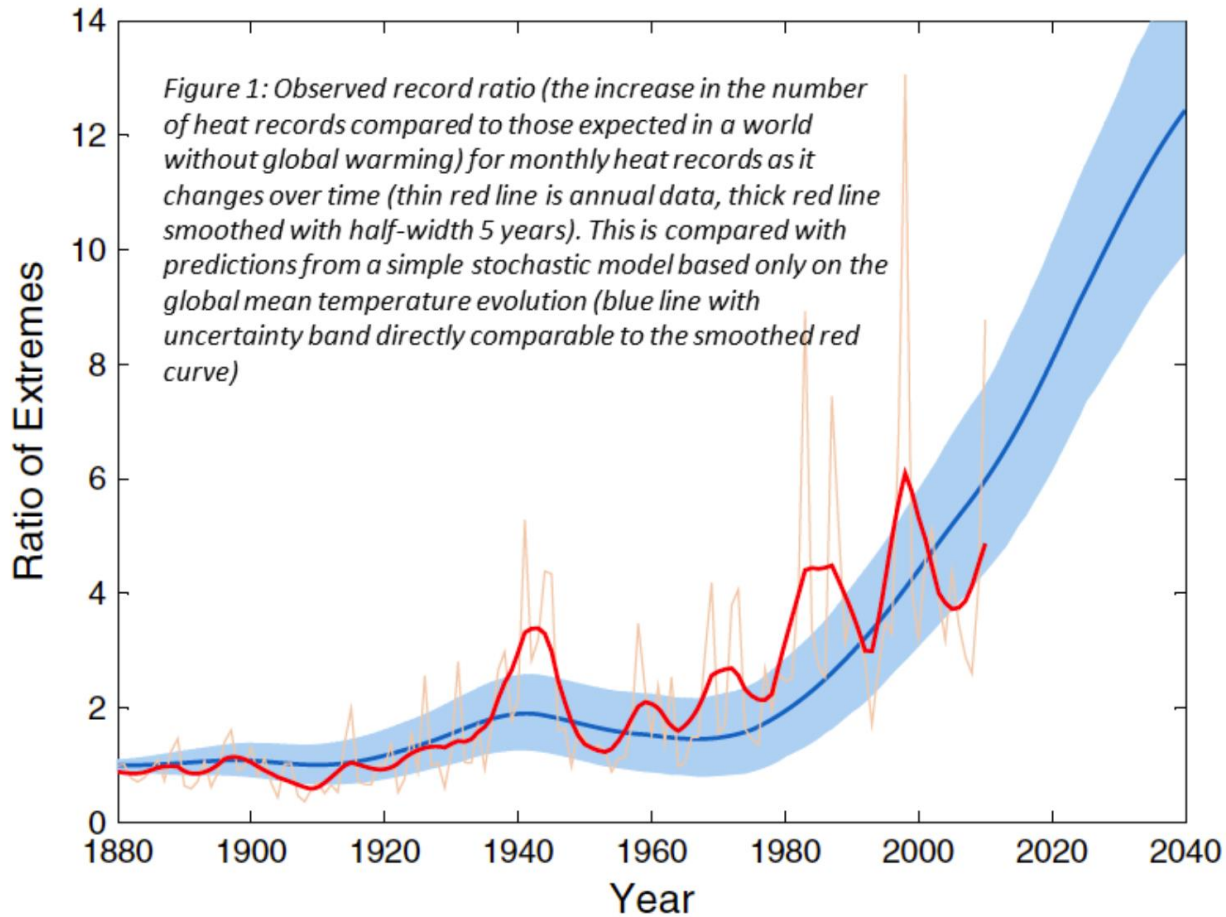
GREEN
CLIMATE
FUND

Observed change in the climate system: Recent warming of the planet is unequivocal and unprecedented

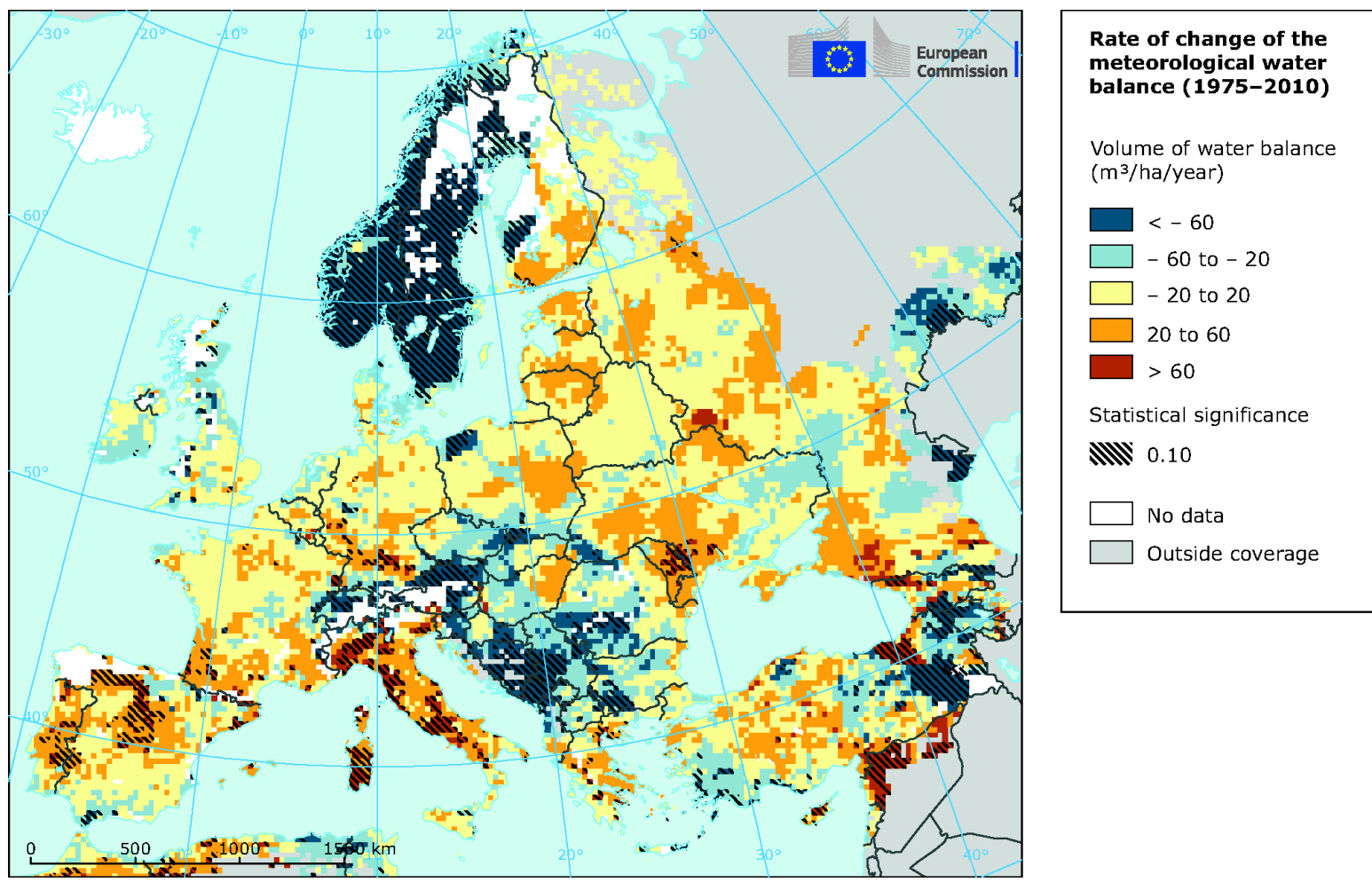


The Earth surface
temperature has been
successively warmer
in the last three
decades than in any
previous decade since
1850

The planet is over 1°C warmer than it was in 1860, but there are substantial geographic differences in the rate of warming



Climatic Change January 2013 Global increase in record-breaking monthly-mean temperatures Dim Coumou, et al



Source: European Environment Agency



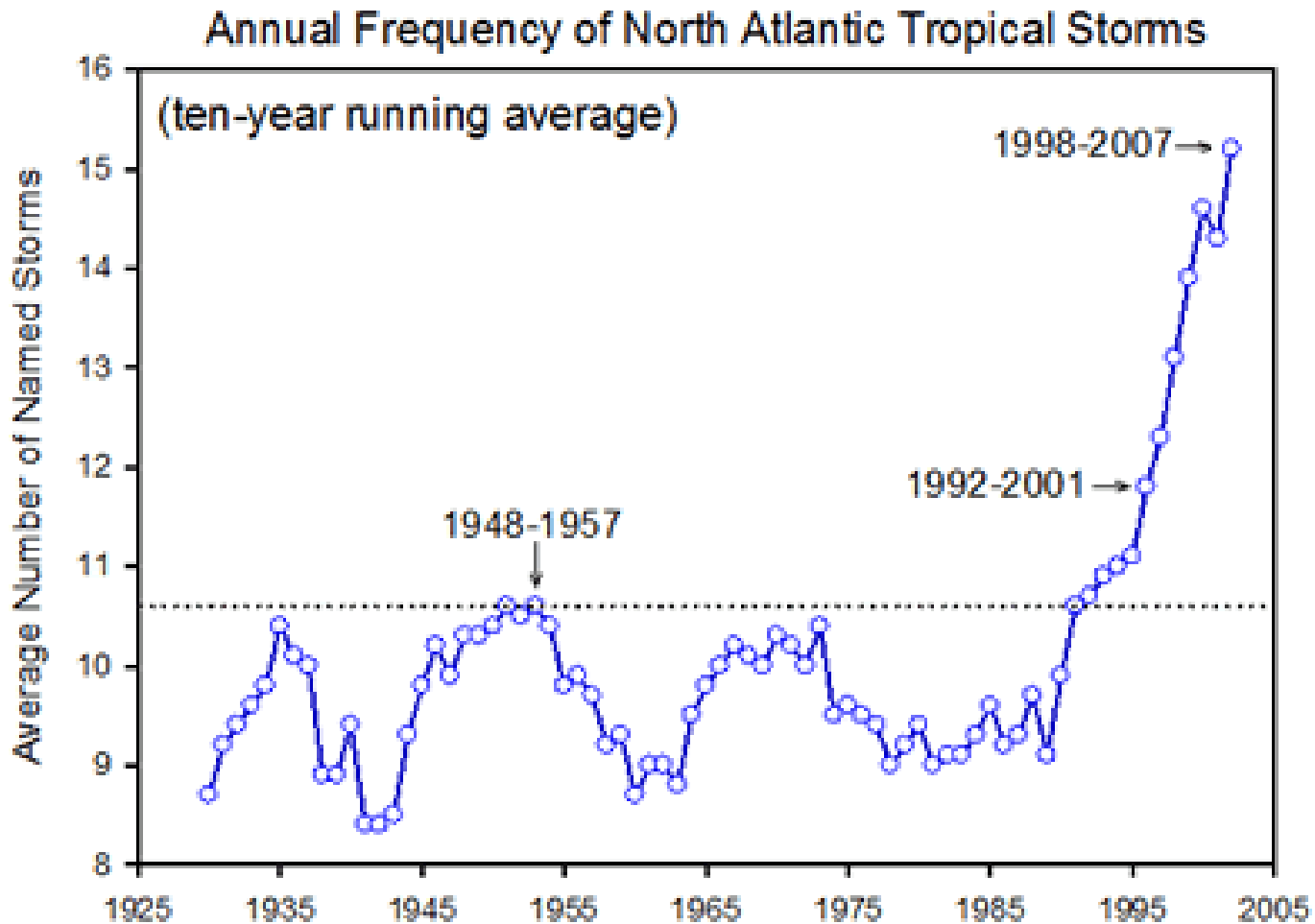






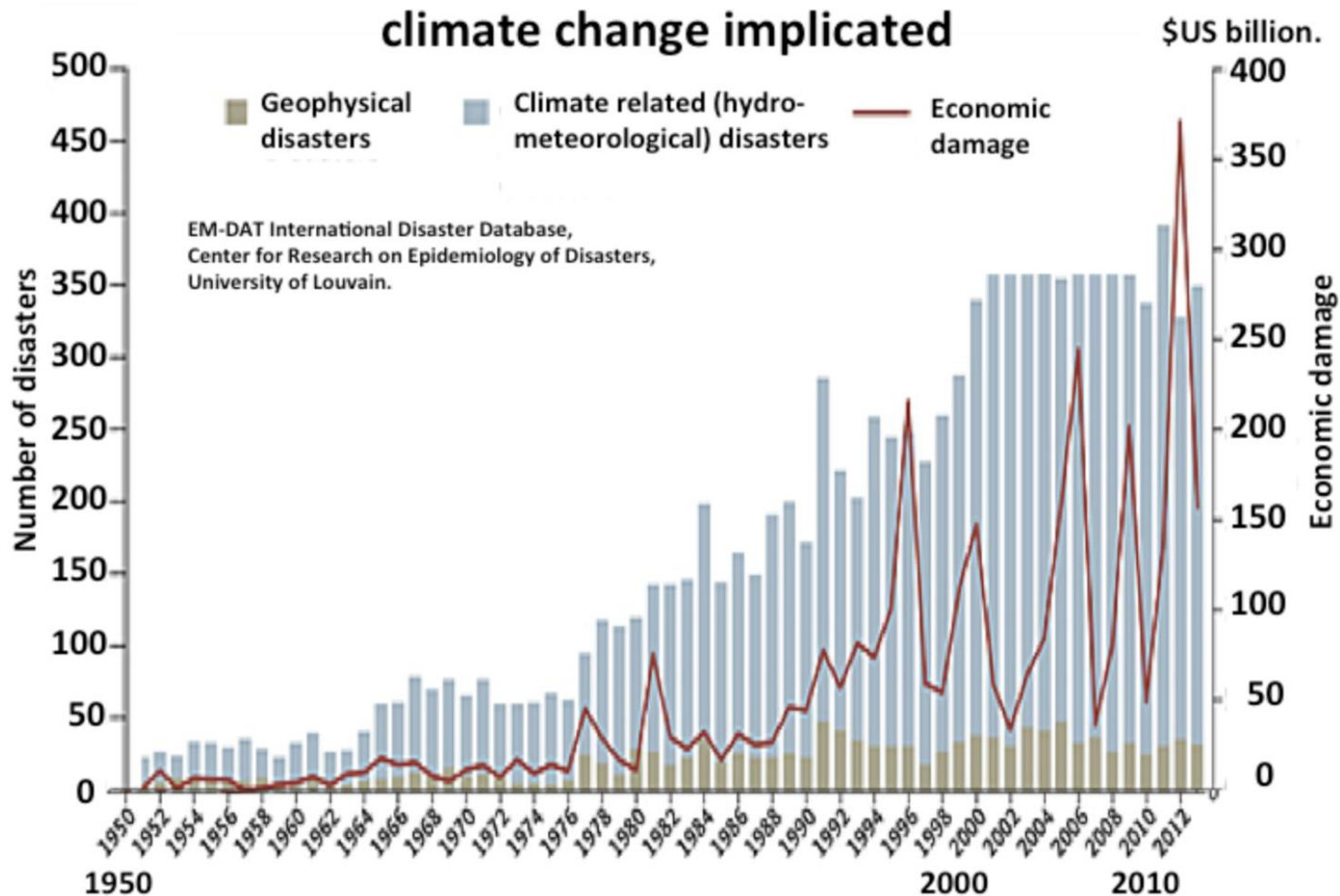
CLIMATE CHANGE

Annual Frequency of Storm events



CLIMATE CHANGE

Disasters and Economic damage



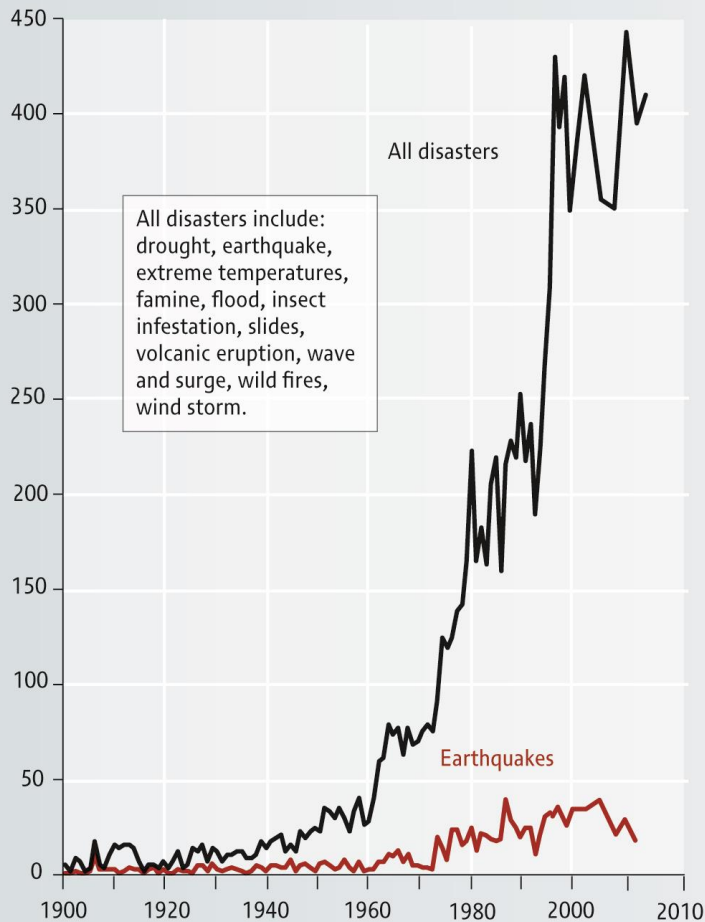
Fonte: Climate emergency institute

CLIMATE CHANGE

Number of reported disasters

Number of disasters

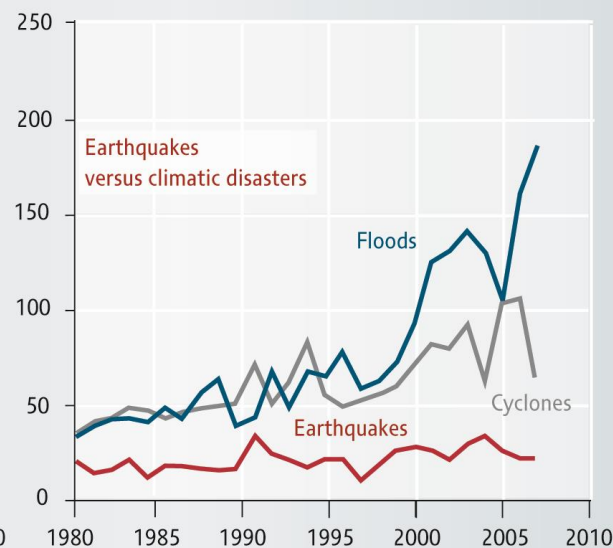
per year



Source: CRED Annual Disaster Statistical Review 2006, 2007.

Trends in number of reported disasters

Much of the increase in the number of hazardous events reported is probably due to significant improvements in information access and also to population growth, but the number of floods and cyclones reported is still rising compared to earthquakes. Is global warming affecting the frequency of natural hazards?



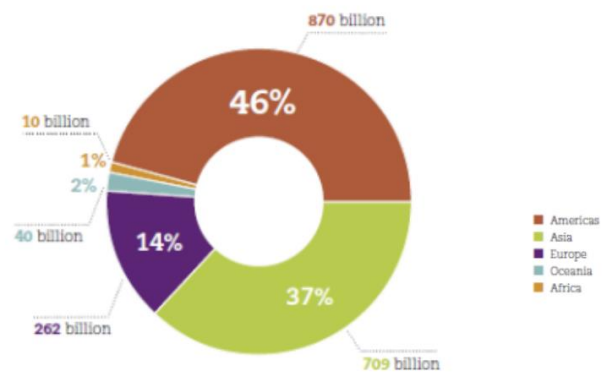


Climate-related Disasters (GAR, 2015)

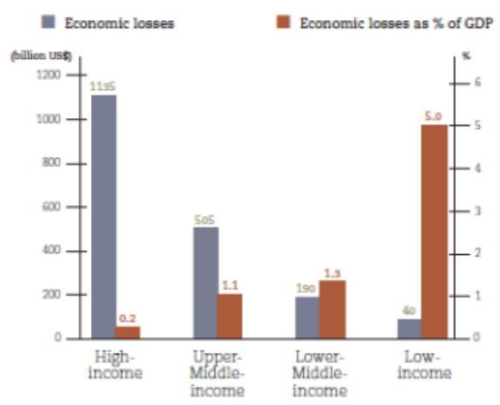
Climate related disasters are on the rise:

- About 90% of natural disasters
- About 90% of casualties
- About 70% of economic losses

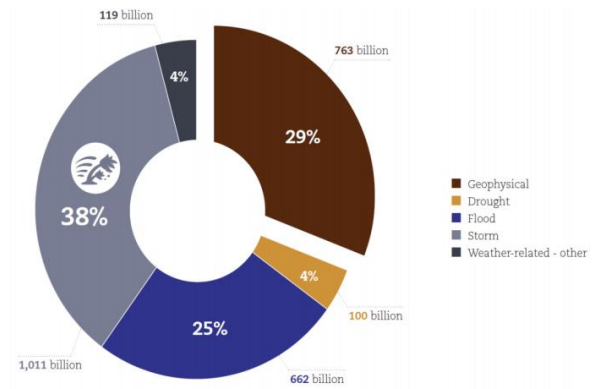
Climate related-disasters will continue to rise as climate change gathers pace



Economic damage (US\$) per region (1995-2015)



Economic losses (absolute and as % of GDP, 1995-2015)

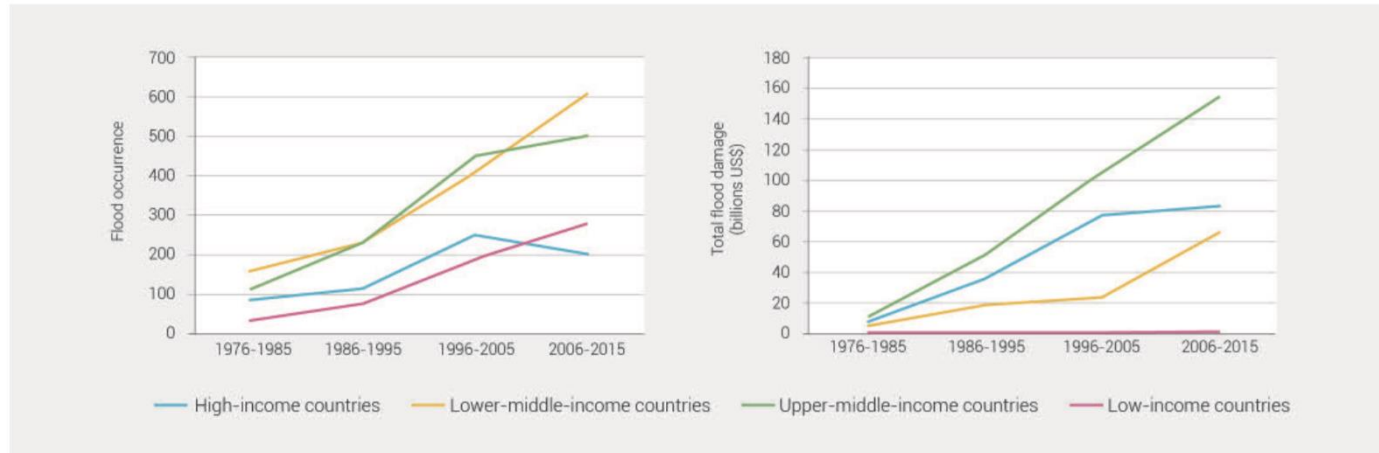


Economic damage (US\$) per disaster (1995-2015)

CLIMATE CHANGE

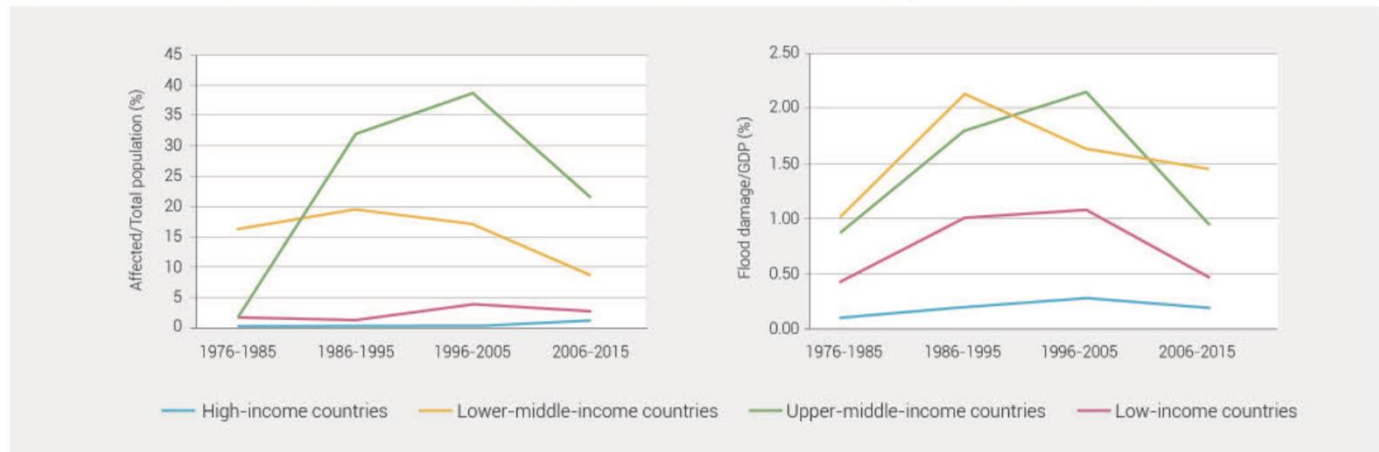
Flood occurrence and economic damage over time

Figure 37. Flood occurrence (left) and economic damage (right) increase over time



Data sources: CRED (n.d.); United Nations, Department of Economic and Social Affairs, Population Division (2017a); United Nations, Statistics Division (n.d.).

Figure 38. Percentage change in flood-affected population (left) and flood damage percentage of GDP (right) over time

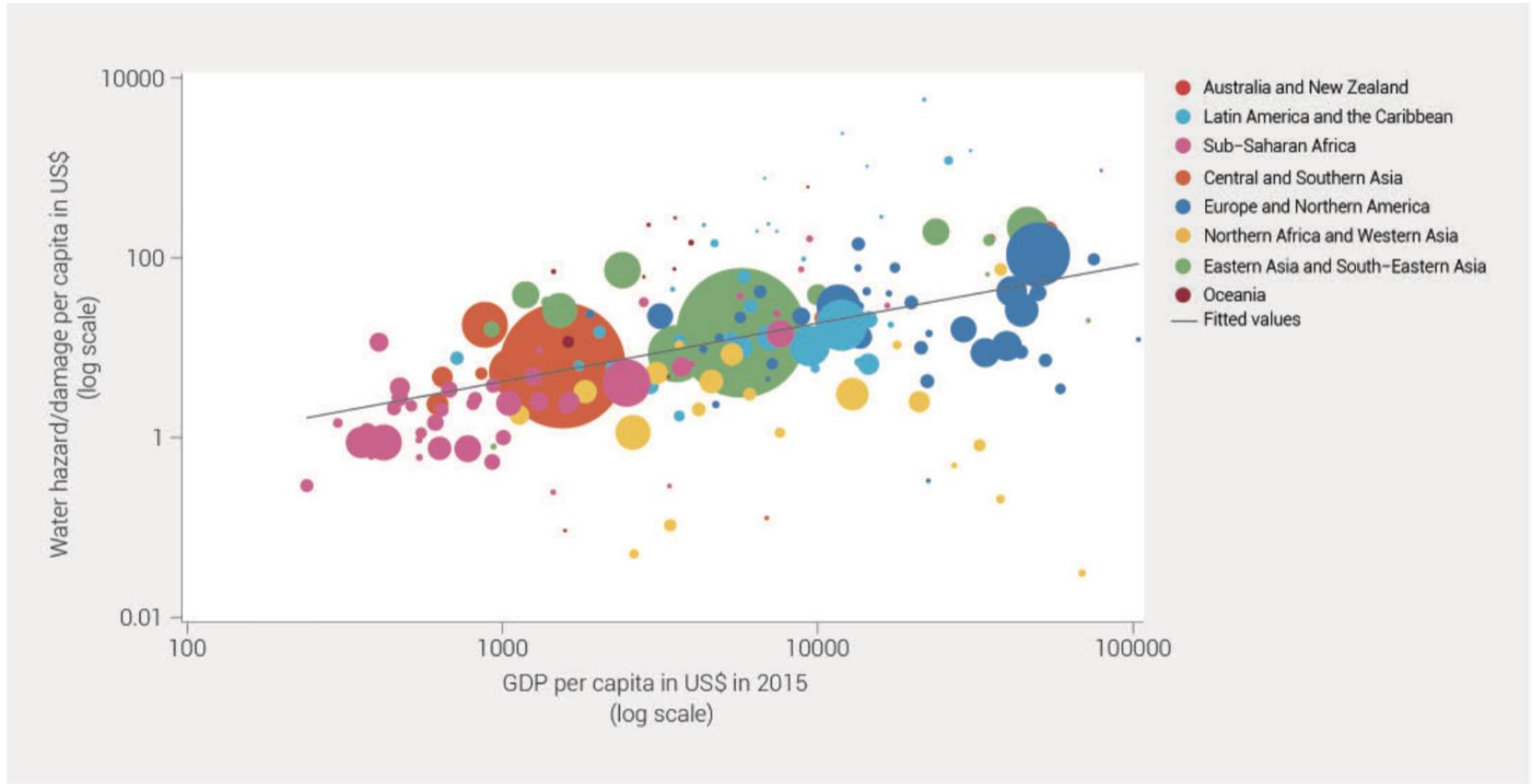


Data sources: CRED (n.d.); United Nations, Department of Economic and Social Affairs, Population Division (2017a); United Nations, Statistics Division (n.d.).

CLIMATE CHANGE

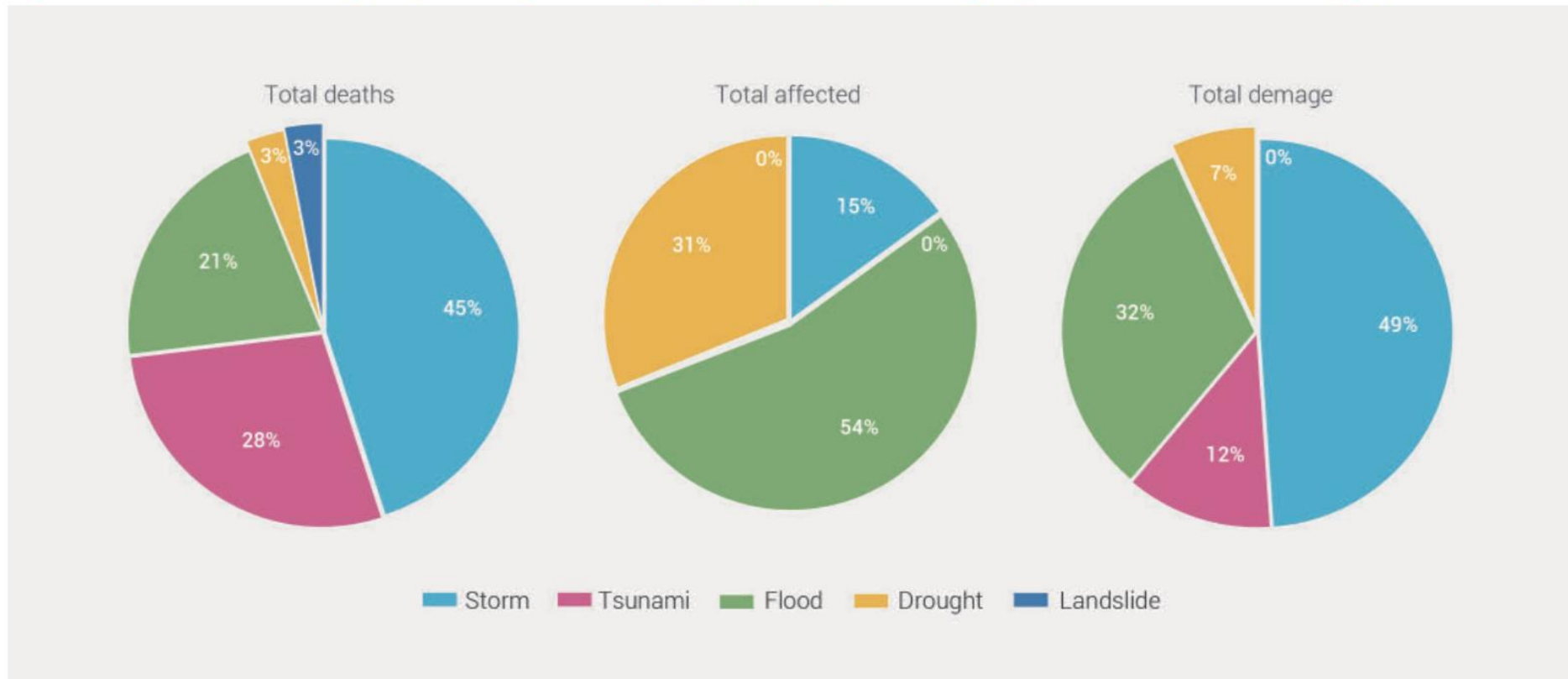
Water Hazard damages

Figure 39. Relationship between water hazard damage per capita and GDP, 2015



Data source: World Bank (2018).

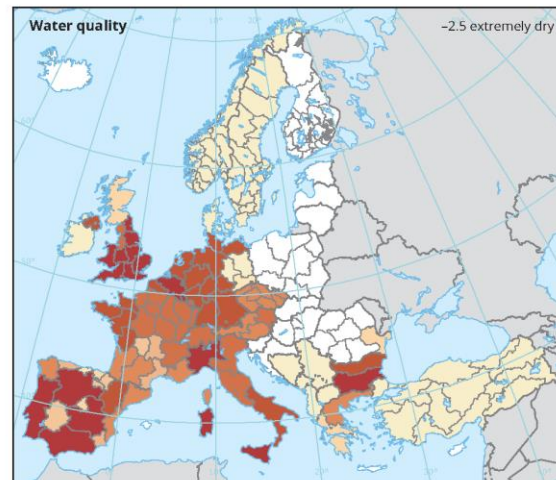
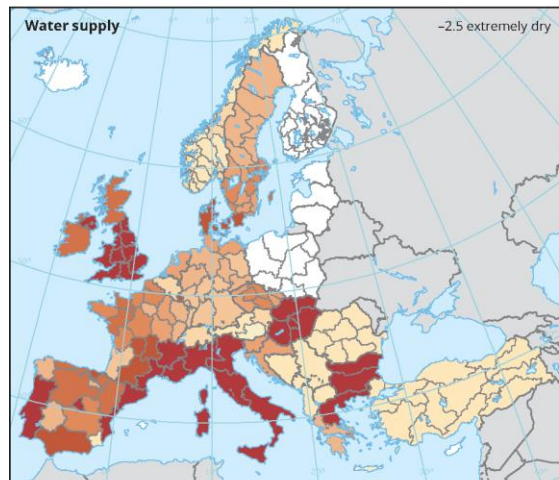
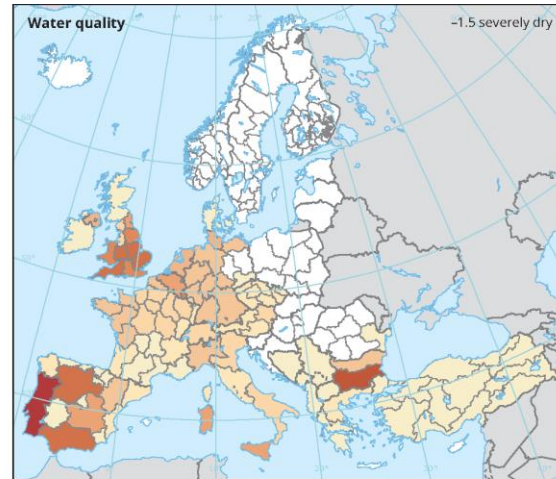
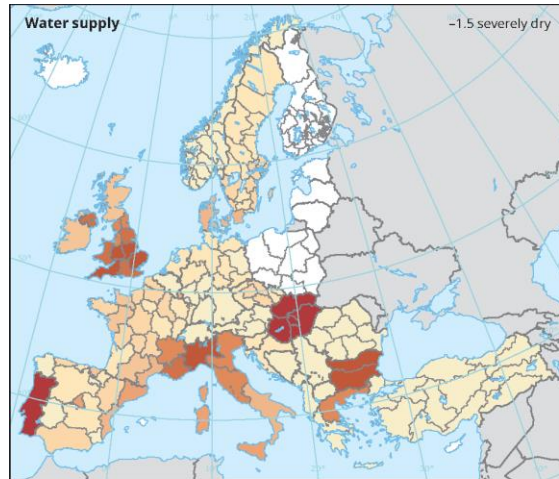
Figure 36. Disaster mortality (left), directly affected people (middle) and damage by water-related hazards (right), 1990–2015



Data source: CRED (n.d.).

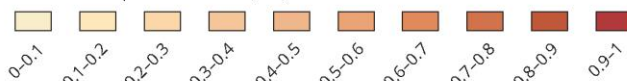
CLIMATE CHANGE

Drought risk maps with the likelihood of impact occurrence



Drought impacts on public water supply (left) and water quality (right) for two drought severity levels

Likelihood of impact occurrence (LIO)



No data Outside coverage

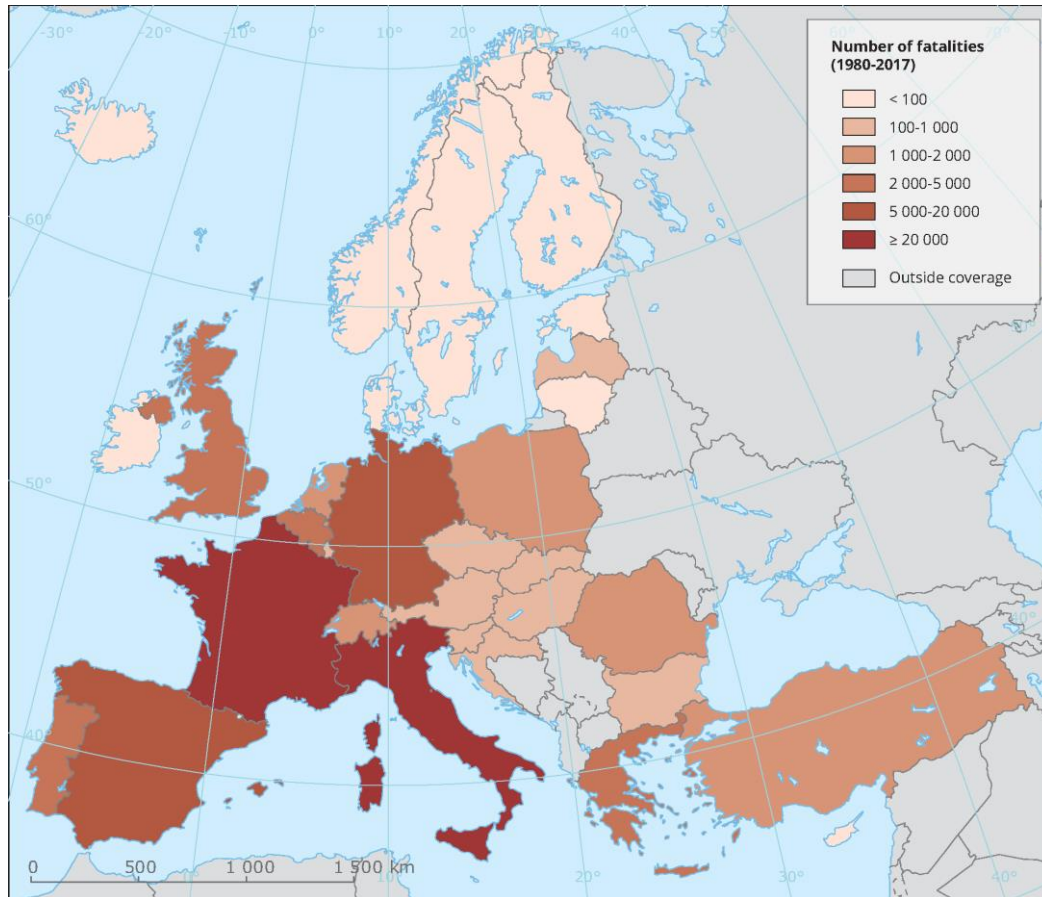
0 500 1000 1500 km

Source:

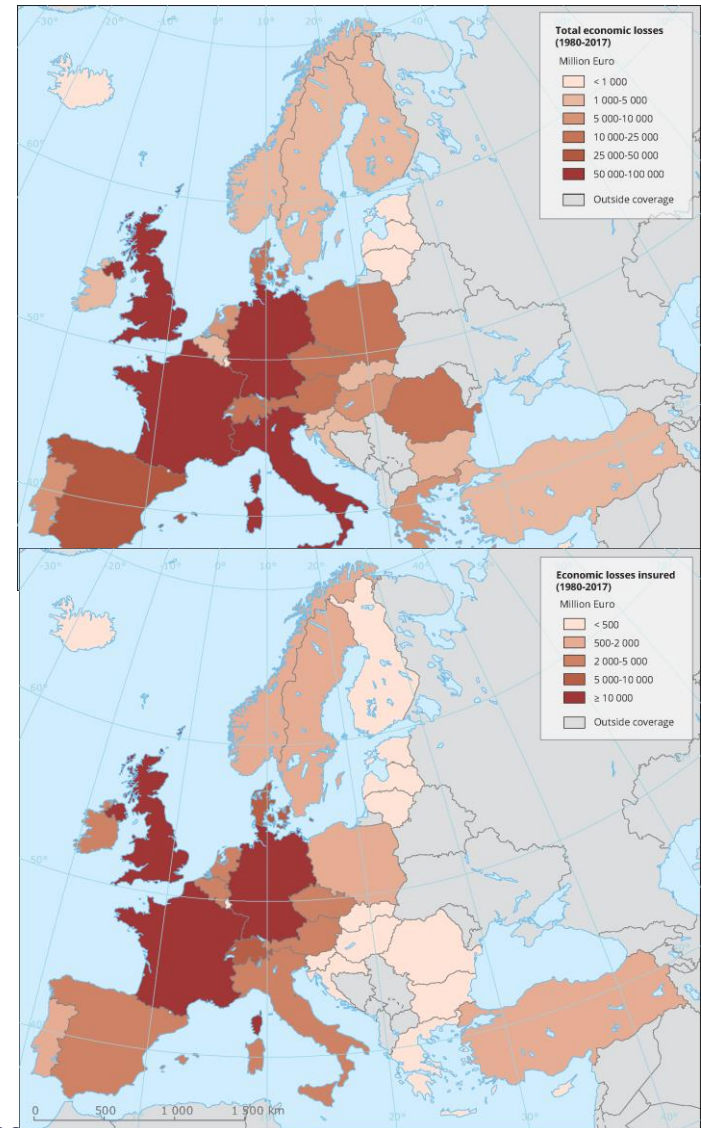
European Environment Agency

CLIMATE CHANGE

Impacts of extreme weather and climate related events in EU

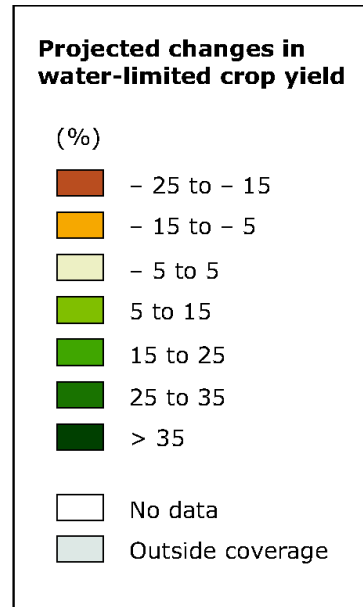
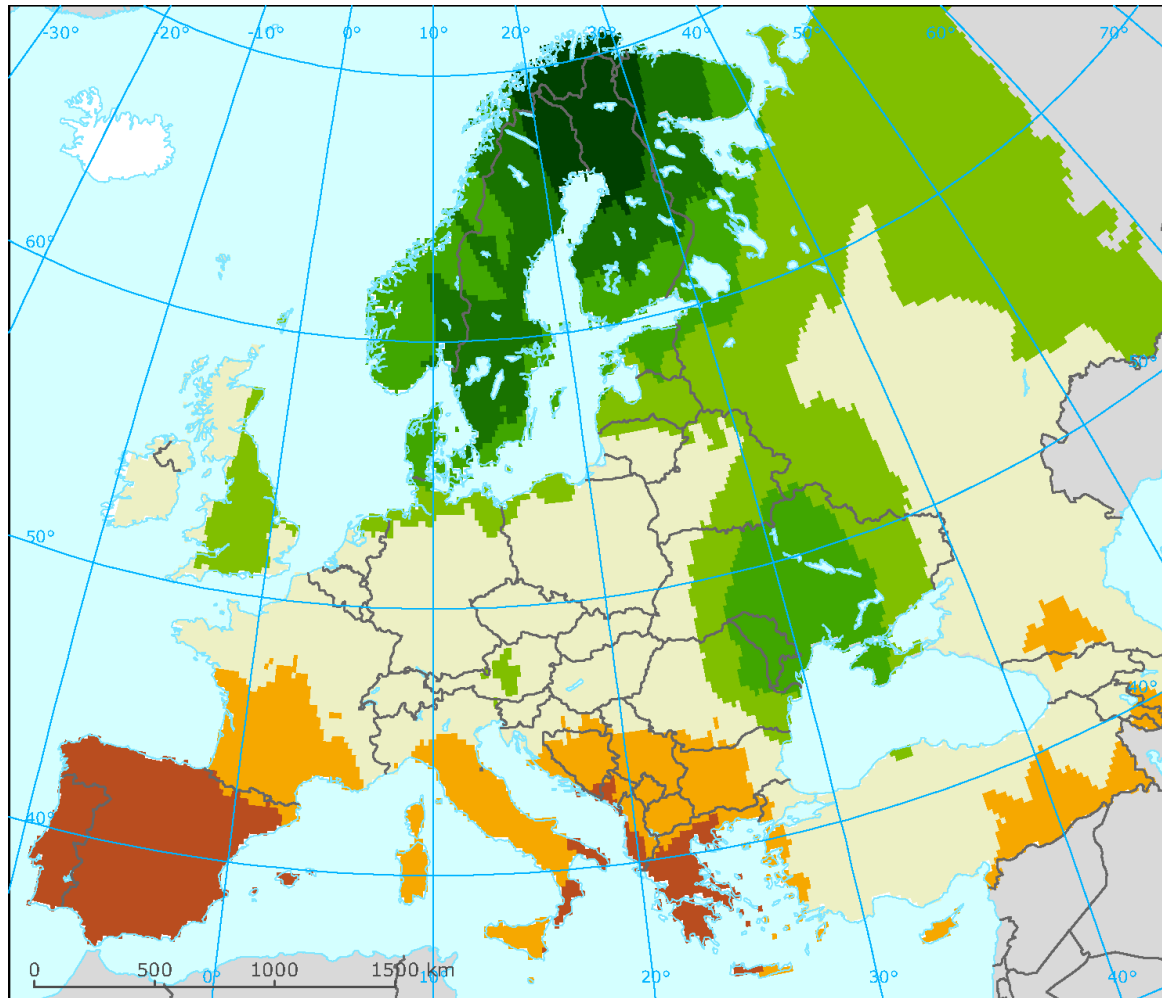


Source: European Environment Agency



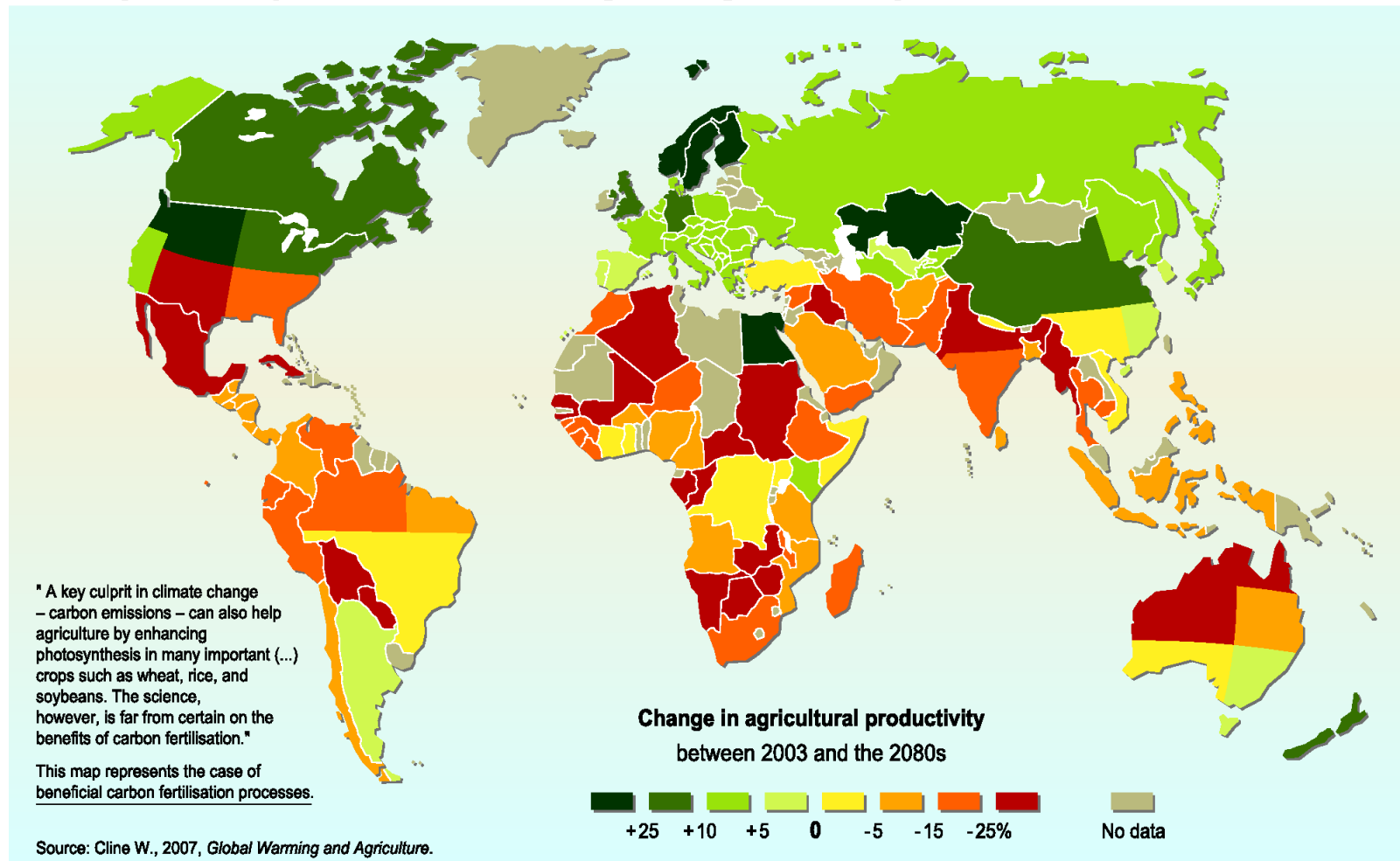
CLIMATE CHANGE

Projected changes in water-limited crop yield in Europe (%)



Source:
European Environment Agency

Projected impact of climate change on agricultural yields



CLIMATE CHANGE

Global risks in terms of likelihood and impact (2008-2018)

50

Figure IV: The Evolving Risks Landscapes, 2008–2018

Top 5 Global Risks in Terms of Likelihood

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1st	Asset price collapse	Asset price collapse	Asset price collapse	Storms and cyclones	Severe income disparity	Severe income disparity	Income disparity	Interstate conflict with regional consequences	Large-scale involuntary migration	Extreme weather events	Extreme weather events
2nd	Middle East instability	Slowing Chinese economy (<6%)	Slowing Chinese economy (<6%)	Flooding	Chronic fiscal imbalances	Chronic fiscal imbalances	Extreme weather events	Extreme weather events	Extreme weather events	Large-scale involuntary migration	Natural disasters
3rd	Failed and failing states	Chronic disease	Chronic disease	Corruption	Rising greenhouse gas emissions	Rising greenhouse gas emissions	Unemployment and underemployment	Failure of national governance	Failure of climate-change mitigation and adaptation	Major natural disasters	Cyberattacks
4th	Oil and gas price spike	Global governance gaps	Fiscal crises	Biodiversity loss	Cyber attacks	Water supply crises	Climate change	State collapse or crisis	Interstate conflict with regional consequences	Large-scale terrorist attacks	Data fraud or theft
5th	Chronic disease, developed world	Retrenchment from globalization (emerging)	Global governance gaps	Climate change	Water supply crises	Mismanagement of population ageing	Cyber attacks	High structural unemployment or underemployment	Major natural catastrophes	Massive incident of data fraud/theft	Failure of climate-change mitigation and adaptation

Top 5 Global Risks in Terms of Impact

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1st	Asset price collapse	Asset price collapse	Asset price collapse	Fiscal crises	Major systemic financial failure	Major systemic financial failure	Fiscal crises	Water crises	Failure of climate-change mitigation and adaptation	Weapons of mass destruction	Weapons of mass destruction
2nd	Retrenchment from globalization (developed)	Retrenchment from globalization (developed)	Retrenchment from globalization (developed)	Climate change	Water supply crises	Water supply crises	Climate change	Rapid and massive spread of infectious diseases	Weapons of mass destruction	Extreme weather events	Extreme weather events
3rd	Slowing Chinese economy (<6%)	Oil and gas price spike	Oil price spikes	Geopolitical conflict	Food shortage crises	Chronic fiscal imbalances	Water crises	Weapons of mass destruction	Water crises	Water crises	Natural disasters
4th	Oil and gas price spike	Chronic disease	Chronic disease	Asset price collapse	Chronic fiscal imbalances	Diffusion of weapons of mass destruction	Unemployment and underemployment	Interstate conflict with regional consequences	Large-scale involuntary migration	Major natural disasters	Failure of climate-change mitigation and adaptation
5th	Pandemics	Fiscal crises	Fiscal crises	Extreme energy price volatility	Extreme volatility in energy and agriculture prices	Failure of climate-change mitigation and adaptation	Critical information infrastructure breakdown	Failure of climate-change mitigation and adaptation	Severe energy price shock	Failure of climate-change mitigation and adaptation	Water crises

■ Economic
 ■ Environmental
 ■ Geopolitical
 ■ Societal
 ■ Technological

Source: World Economic Forum 2008–2018, Global Risks Reports.

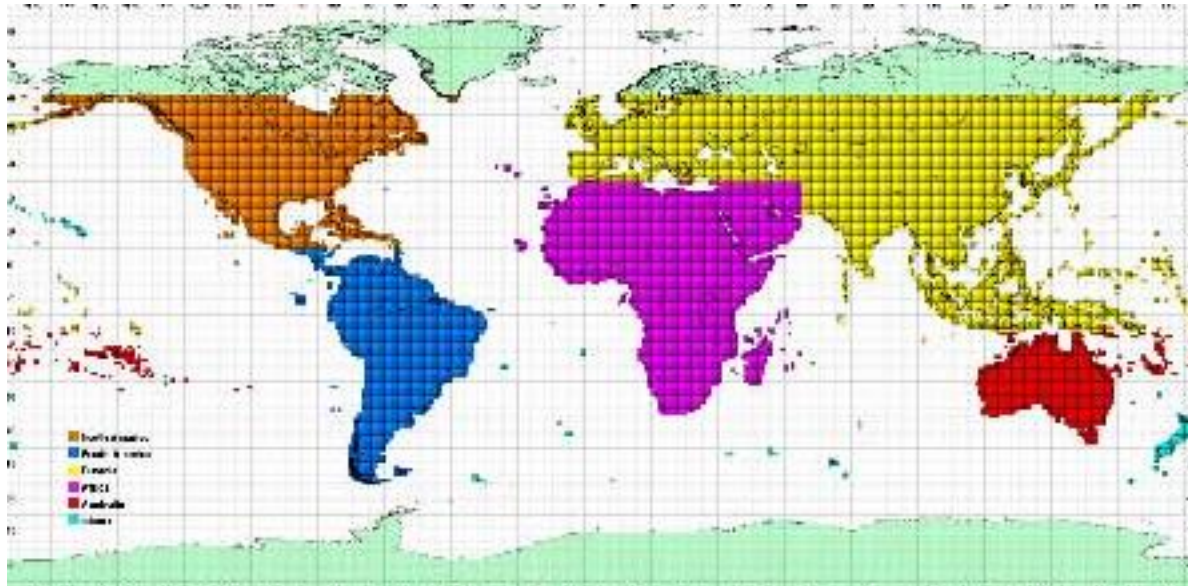
Note: Global risks may not be strictly comparable across years, as definitions and the set of global risks have evolved with new issues emerging on the 10-year horizon. For example, cyberattacks, income disparity and unemployment entered the set of global risks in 2012. Some global risks were reclassified: water crises and rising income disparity were re-categorized first as societal risks and then as a trend in the 2015 and 2016 Global Risks Reports, respectively.

ADDRESSING THE CHALLENGES FOR A (SUSTAINABLE) FUTURE

Terrain Data

**SRTM3 - Shuttle Radar Topography Mission Global Coverage (~90m)
Version 2**

Resolution: ~90 m, 3 arc-sec - **Coverage:** Global **Projection:** Geographic ;




DATA AND TOOLS

CORINE – Land cover



DATA AND TOOLS

AQUAMAPS – Global spatial database on water and agriculture

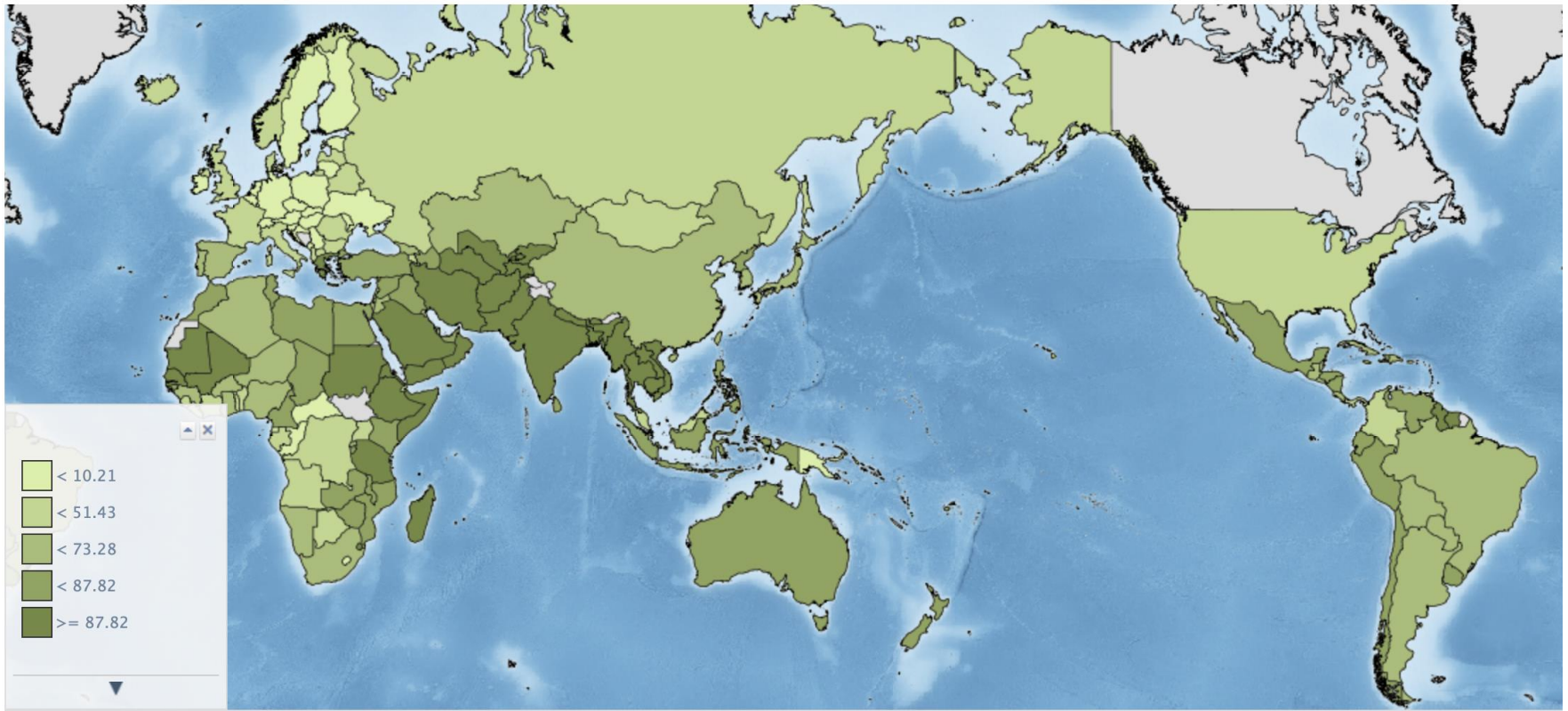


The screenshot displays the AQUAMAPS web interface. At the top, it features the FAO logo and the text 'Food and Agriculture Organization of the United Nations' and 'Global spatial database on water and agriculture'. The main area shows a global map with various data layers overlaid. On the left, there is a 'Available layers' panel with a tree view of categories like 'Rivers / Water bodies', 'Irrigation / Infrastructure', 'Hydrological Basins', 'Climate', 'Analyses', and 'Models: GlobWat'. On the right, there is a 'Layers list' panel with three layers: 'Major agricultural systems', 'Agricultural Systems at Risk: human pressure on land and water', and 'Bluemable'. Below the map is a 'Legend' panel with a list of agricultural systems and their corresponding colors: 101 Water, 104 Other land, 107 Forest, 108 Irrigated, 109 Paddy rice, 110 Dry savanna agriculture, 111 Humid savanna agriculture, 112 Highland agriculture, 113 113 Warm (sub-) humid agriculture, 114 Temperate agriculture, 221 Desert, 222 Dry rangeland, 224 Temperate rangeland, and 225 Boreal.

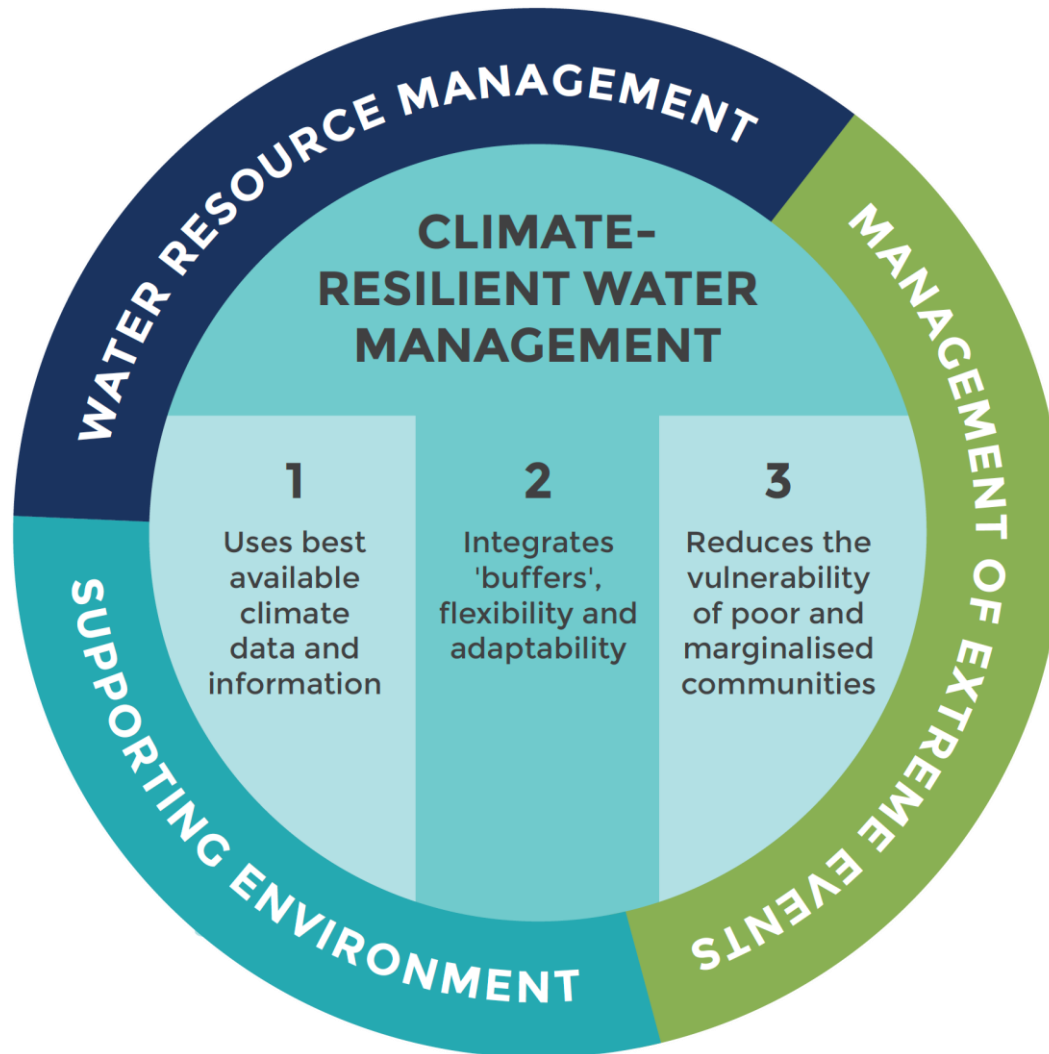
<http://www.fao.org/nr/water/aquamaps/>

DATA AND TOOLS

Proportion of total water withdrawal for agriculture (%)



Source: AQUASTAT, FAO



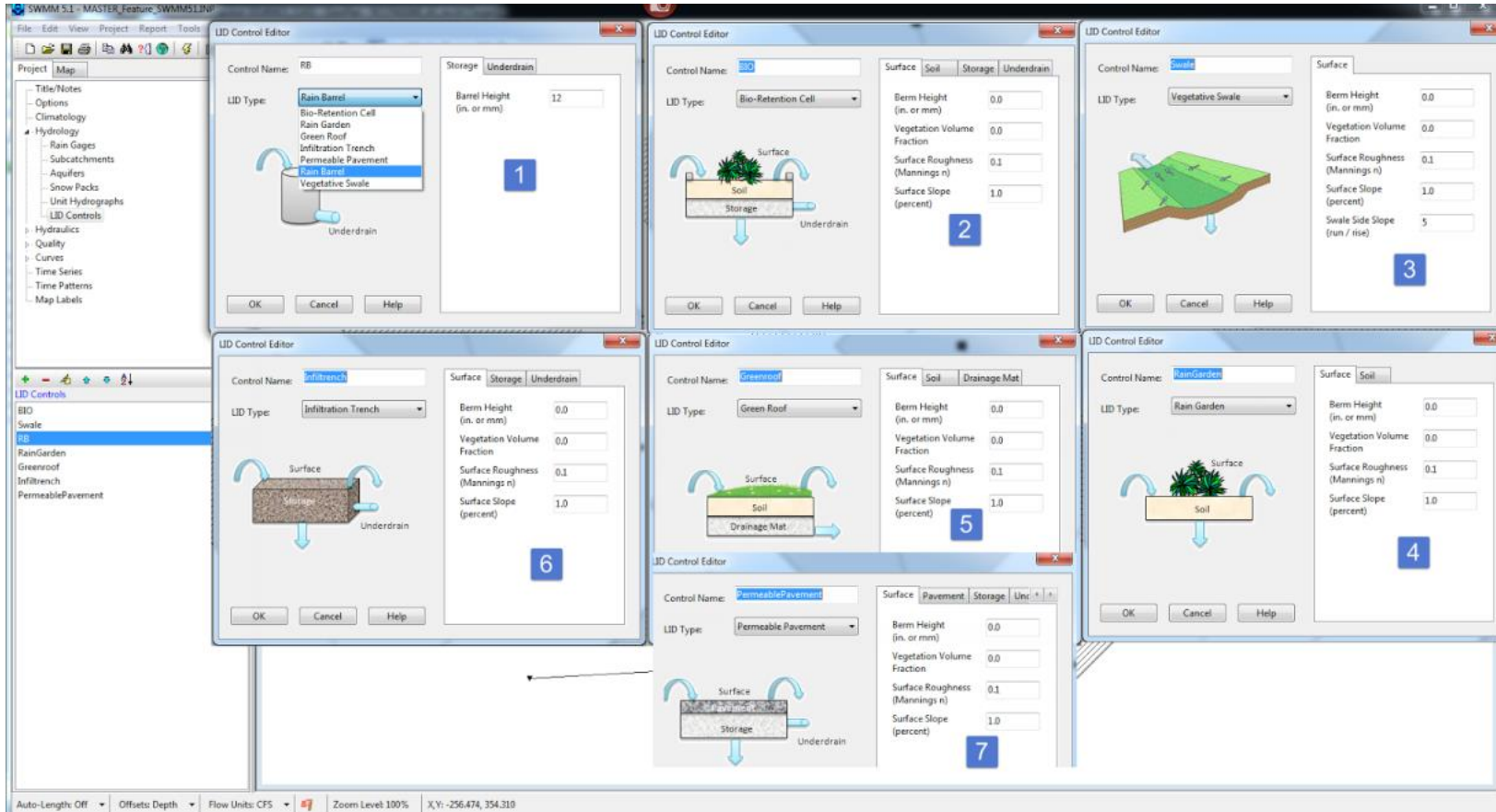


Sustainable Urban Drainage Systems



NATURAL AND URBAN WATER CYCLE SUSTAINABLE URBAN DRAINAGE SYSTEMS

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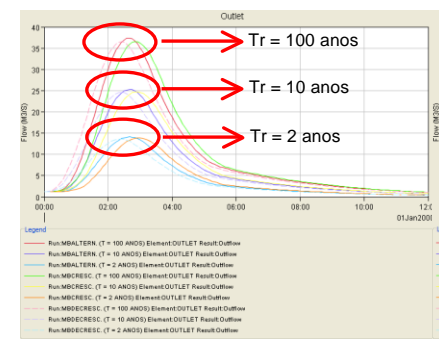
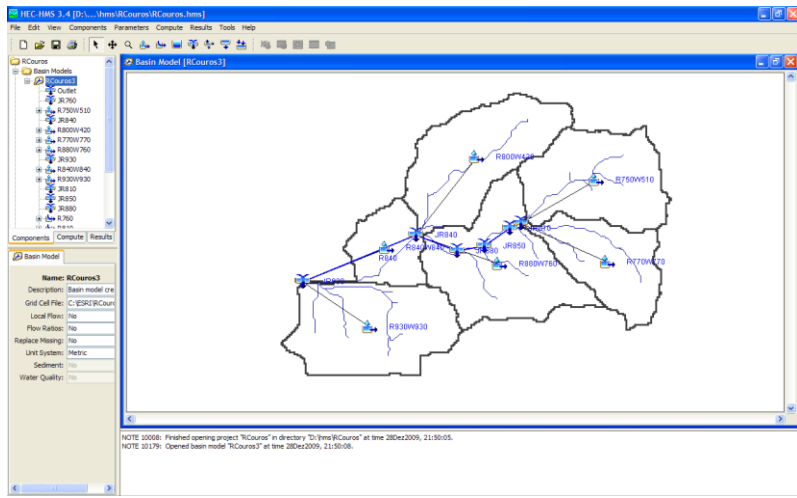
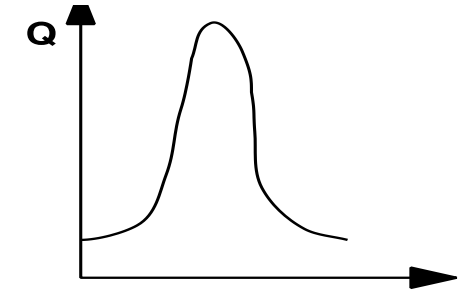
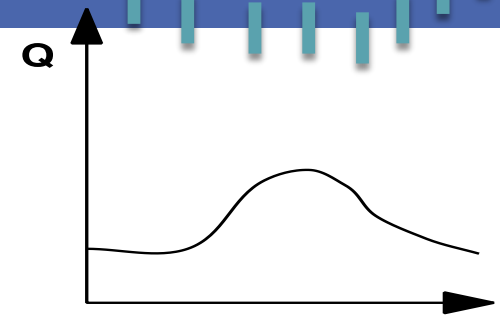
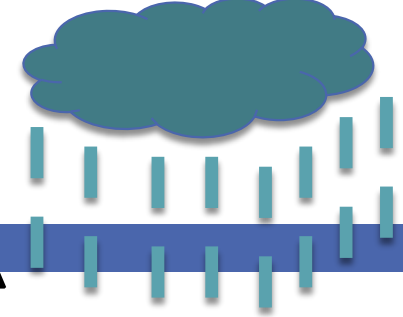
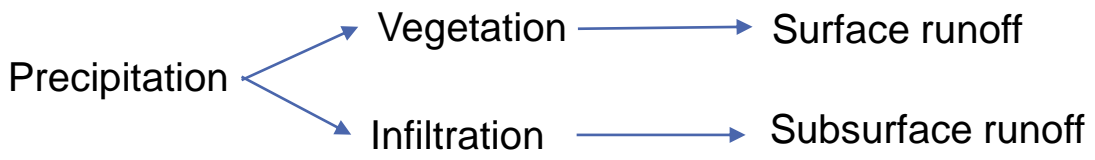
The screenshot displays the SWMM 5.1 software interface with seven LID Control Editor dialog boxes, each showing a different LID type and its configuration parameters. The dialog boxes are numbered 1 through 7:

- 1. Rain Barrel:** Control Name: RB, LID Type: Rain Barrel, Barrel Height: 12 (in. or mm).
- 2. Bio-Retention Cell:** Control Name: BIC, LID Type: Bio-Retention Cell, parameters include Berm Height, Vegetation Volume Fraction, Surface Roughness, and Surface Slope.
- 3. Swale:** Control Name: Swale, LID Type: Vegetative Swale, parameters include Berm Height, Vegetation Volume Fraction, Surface Roughness, Surface Slope, and Swale Side Slope.
- 4. RainGarden:** Control Name: RainGarden, LID Type: Rain Garden, parameters include Berm Height, Vegetation Volume Fraction, Surface Roughness, and Surface Slope.
- 5. Greenroof:** Control Name: Greenroof, LID Type: Green Roof, parameters include Berm Height, Vegetation Volume Fraction, Surface Roughness, and Surface Slope.
- 6. Infiltration Trench:** Control Name: Infiltration Trench, LID Type: Infiltration Trench, parameters include Berm Height, Vegetation Volume Fraction, Surface Roughness, and Surface Slope.
- 7. PermeablePavement:** Control Name: PermeablePavement, LID Type: Permeable Pavement, parameters include Berm Height, Vegetation Volume Fraction, Surface Roughness, and Surface Slope.

<https://swmm5.org/2014/04/20/seven-types-of-lid-controls-in-swmm-5-1/>

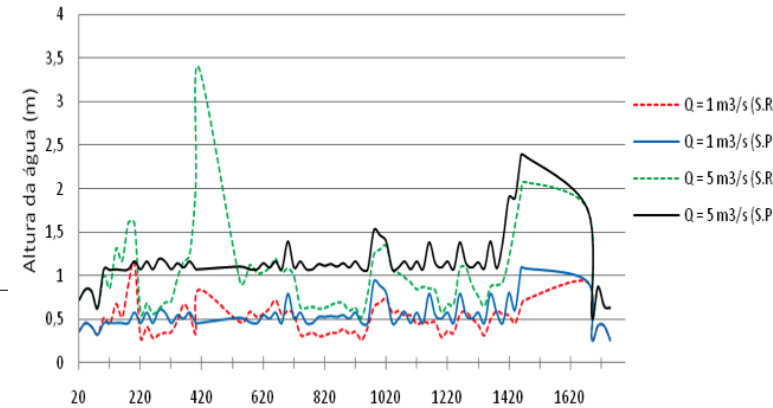
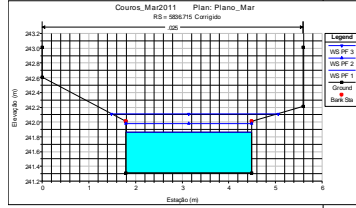
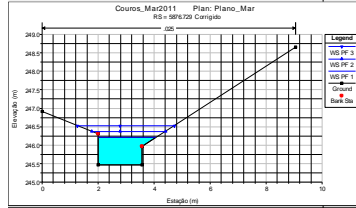
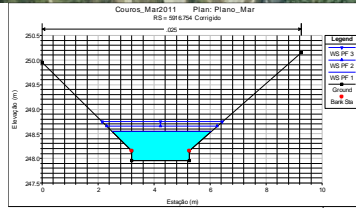
HYDROLOGICAL STUDIES

FLOOD CONTROL



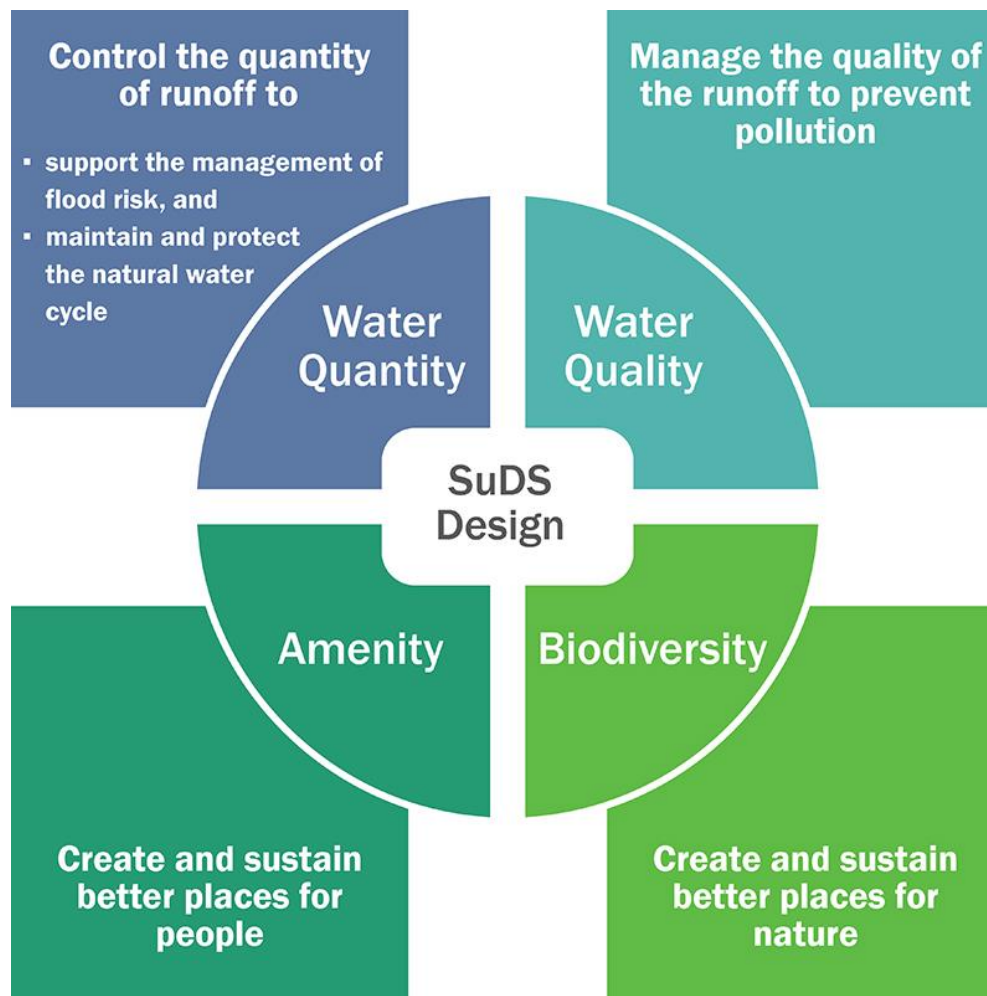
HYDRODYNAMIC MODELS

FLOOD CONTROL



NATURAL AND URBAN WATER CYCLE

SUSTAINABLE URBAN WATER SYSTEMS



INTEGRATED WATER RESOURCES MANAGEMENT

RESILIENT SYSTEMS

CIRCULAR ECONOMY - RESOURCE RECOVERY

CHANGES FOR A SUSTAINABLE DEVELOPMENT SUSTAINABLE DEVELOPMENT GOALS

Figure 21. How SDG 6 can bring immense benefits for sustainable development



SDG 6 Global Indicators

INDICATORS	TIER	CUSTODIANS
6.1.1 Proportion of population using safely managed drinking water services	II	WHO, UNICEF
6.2.1 Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water	II	WHO, UNICEF
6.3.1 Proportion of wastewater safely treated	II	WHO, UN-Habitat, UNSD
6.3.2 Proportion of bodies of water with good ambient water quality	II	UN Environment
6.4.1 Change in water-use efficiency over time	II	FAO
6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	I	FAO
6.5.1 Degree of integrated water resources management implementation (0-100)	I	UN Environment
6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation	I	UNESCO, UNECE
6.6.1 Change in the extent of water-related ecosystems over time	I	UN Environment, Ramsar
6.a.1 Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan	I	WHO, UN Environment, OECD
6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	I	WHO, UN Environment, OECD

“Cidades e Territórios: Oportunidades e Benefícios da Economia Circular”

A Água e a Cidade

Paulo J. Ramísio