Val di Cornia
Osservatorio UNESCO per l'Ecoidrologia

Nature-based solutions and Managed Aquifer Recharge

IAH MAR Commission
15 April 2025 online MAR seminar

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ADAPTATION to CLIMATE CHANGE

How to anticipate the adverse effects of climate change and acting to prevent or to minimise damages?

How to move from generalised adaptation strategies to adaptation plans at local and regional levels?

Mitigation is the option… but…

Adaptation and resilience - UNFCCC

Adaptation refers to adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects.

It refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change.

Adaptation actions can take on many forms, depending on the unique context of a community, business, organization, country or region.
There is no 'one-size-fits-all-solution'—adaptation can range from building flood defences, setting up early warning systems for cyclones, switching to drought-resistant crops, to redesigning communication systems, business operations and government policies.
Many nations and communities are already taking steps to build resilient societies and economies.

https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction#:~:text=Adaptation%20refers%20to%20adjustments%20in,opportunities%20associated%20with%20climate%20change.

10 June 2021 11:30
EU Council endorses new EU strategy on adaptation to climate change

https://www.consilium.europa.eu/en/press/press-releases/2021/06/10/council-endorses-new-eu-strategy-on-adaptation-to-climate-change/

How to adapt to climate change?

We need solutions that are

robust

reliable

improve environmental quality

low-energy

shared/co-agreed

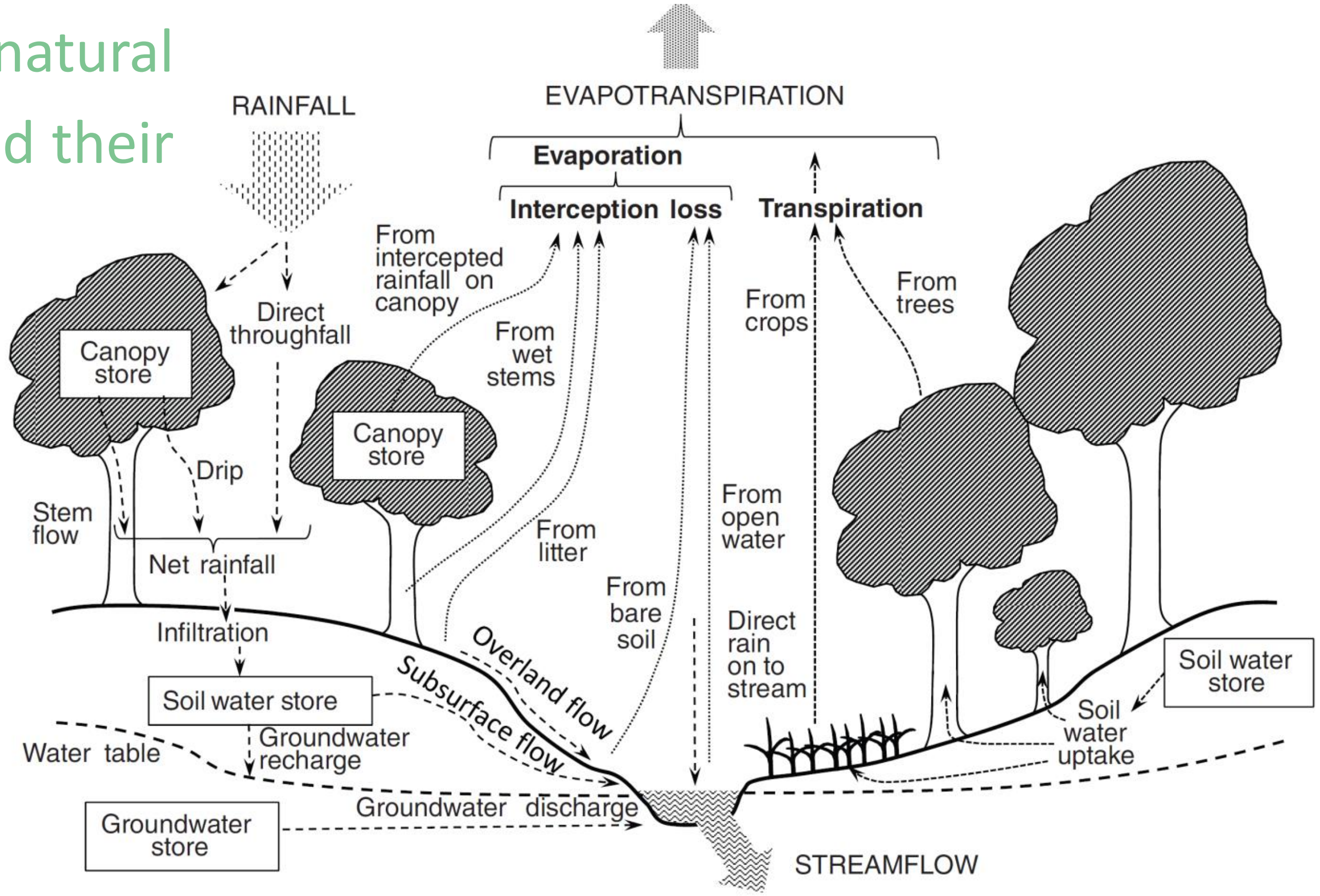
Nature-based solutions may constitute such kind to adapt our societies …

… as they offer **ecosystem services**.

WATER-RELATED ECOSYSTEM-SERVICES

Ecosystem services are the many and varied benefits provided to humans by the natural environment, and healthy ecosystems, and their biodiversity.

Water underpins all ESs provided by the ecosystems, including all agricultural production.



Coates et al., 2013. Water-related Ecosystem Services and Food Security ©CAB International 2013. Managing Water and Agroecosystems for Food Security (ed. E. Boelee)

WATER-related Agro -Ecosystem Services	Processes	BENEFITS
Water purification	Remove heavy metals Remove/reuse nutrients Remove pharmaceuticals	Improved water quality Drinking water supply Irrigation water supply Disaster reduction Freshwater ecosystem conservation Economic saving in treatment Aesthetic values
Flood mitigation Drought mitigation	Regulations of water flows	
Increased water storage	Water retention	

WHY NATURE-BASED SOLUTIONS

The latest IPCC report demonstrated that nature-based solutions such as reducing the destruction of forests and other ecosystems, restoring them, and improving the management of working lands, such as farms — are among the top five most effective strategies for mitigating carbon emissions by 2030.

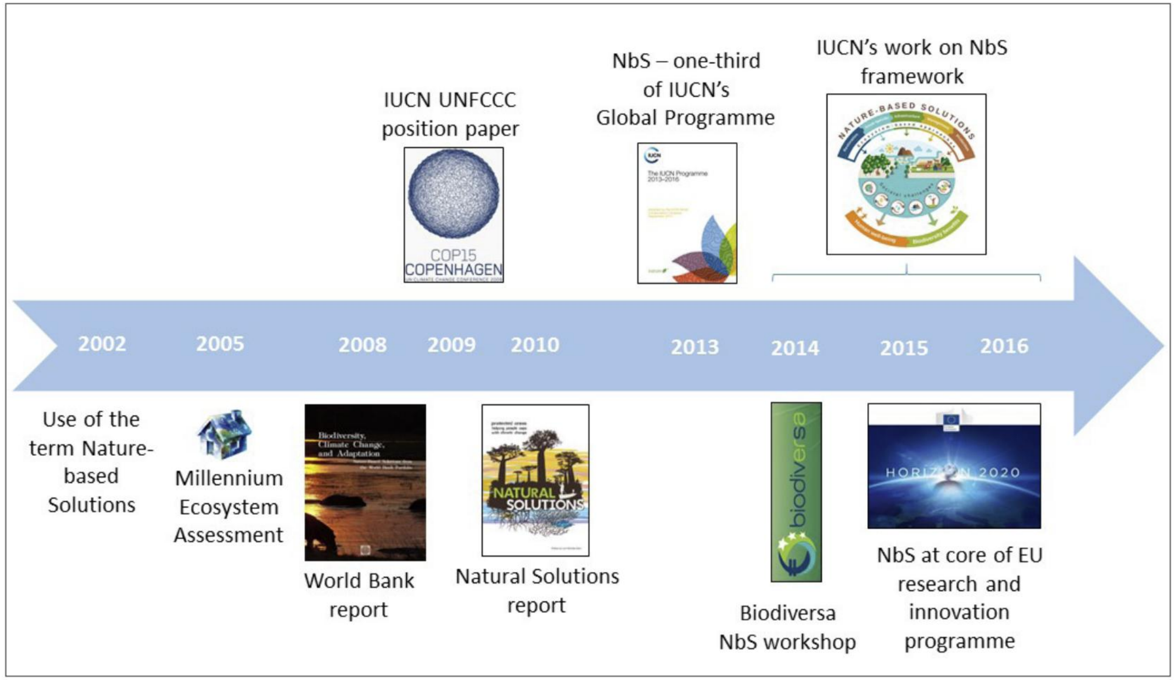
Nature-based Solutions for both mitigation and adaptation serve as an integral piece of the required global response for climate action.

Nature-based solutions can address climate change in three ways:

- Decrease greenhouse gas emissions related to deforestation and land use
- Capture and store carbon dioxide from the atmosphere
- Enhance resilience of ecosystems, and as such support societies to adapt to climate hazards such as flooding, sea-level rise, and more frequent and intense droughts, floods, heatwaves, and wildfires.

From: https://www.iucn.org/our-work/topic/nature-based-solutions-climate

WHY NATURE-BASED SOLUTIONS/2



The concept of Nature-based Solutions (NbS) emerged in 2008 World Bank report.

The first research programme on NbS was launched in 2013.

The concept emerged from the search for innovative solutions to manage natural systems in a way that can balance the benefits for both nature and society.

Barbara Sowińska-Świerkosz, Joan García, What are Nature-based solutions (NBS)? Setting core ideas for concept clarification. Nature-Based Solutions, Volume 2, 2022, 100009, ISSN 2772-4115, https://doi.org/10.1016/j.nbsj.2022.100009

Nature-based Solutions to address global societal challenges. Editors: E Cohen-Shacham, G Walters, C Janzen, S Maginnis https://portals.iucn.org/library/node/46191

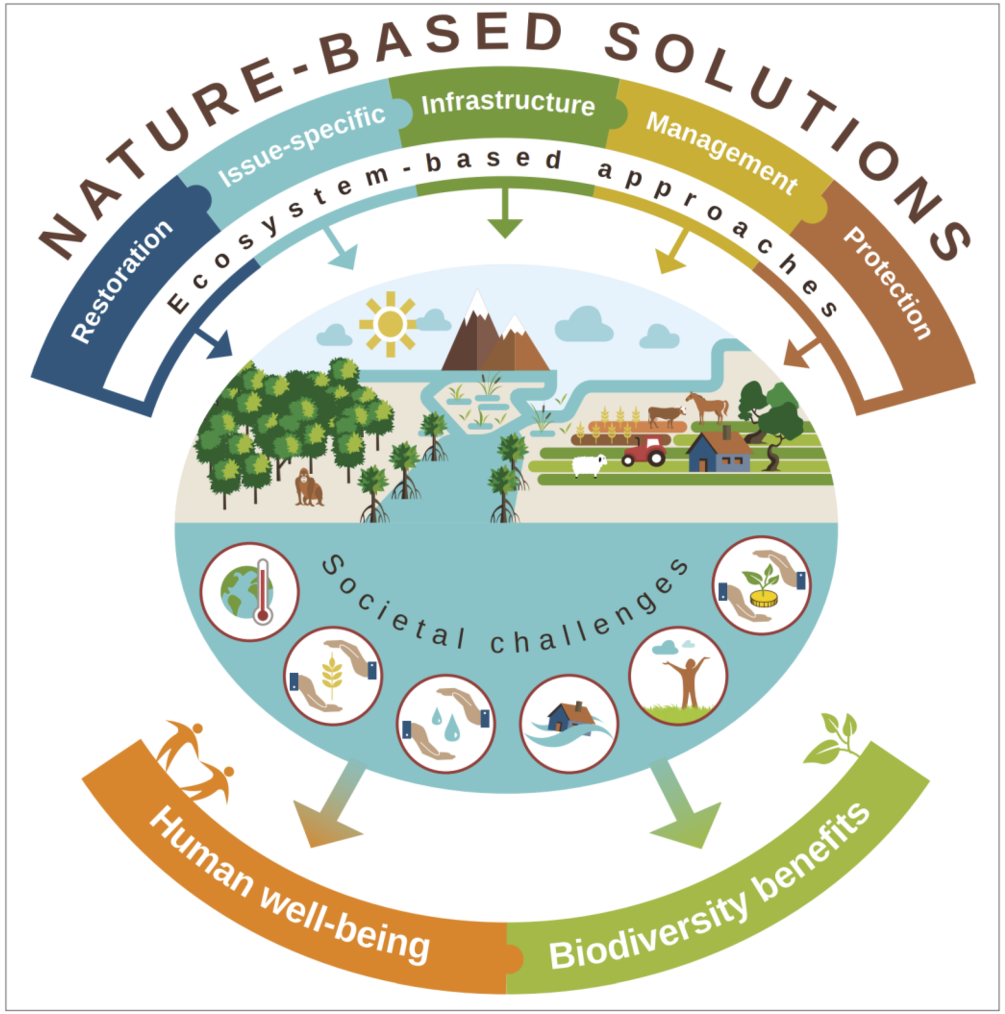


Figure 6. NbS as an umbrella term for ecosystem-related approaches

WHAT NATURE-BASED SOLUTIONS (NbS)ARE

NbS are solutions mimicking natural processes to provide ecosystem services.

Several definition on the shelf:

The EU Commission defines nature-based solutions as:

Solutions that are **inspired** and **supported** by **nature**,

- cost-effective,
- simultaneously provide

environmental,

social and economic benefits, and help build resilience.

VIDEO RESOURCE
https://www.youtube.com/watch?v=TGuyMakgeVw

Such solutions bring more, and more diverse, nature and natural features and processes into **cities**, **landscapes** and **seascapes**, through locally adapted, resource-efficient and systemic interventions.

Nature-based solutions must therefore **benefit biodiversity** and support the delivery of a range of ecosystem services.

https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en

WHAT NATURE-BASED SOLUTIONS ARE/2

The **Food and Agriculture Organization of the United Nations (FAO)** describes NbS for agricultural water management in the following terms:

NbS can **mimic natural processes** and build on fully operational water-land management concepts that aim to simultaneously improve

- water availability and quality, and
- raise agricultural productivity.

As such, NbS comprise closely related concepts such as

improved water use efficiency and **integrated watershed management**,

source-to-sea initiatives,

ecosystem approaches,

eco-hydrology and agroecology, and

green and blue infrastructure development (Sonneveld et al, 2015)

https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_ws_nature-based-solutions-water-management_final-report_2022_en.pdf.pdf

WHAT NATURE-BASED SOLUTIONS ARE/3

NbS are defined by the International Union for Conservation of Nature (IUCN) as

actions to protect, **sustainably manage** and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et al., 2016).

This definition includes:

protection, management,

and restoration of both natural and modified ecosystems.

It does not mention costs or economic benefits.

VIDEO RESOURCE
https://www.youtube.com/watch?v=UWKsln6bU24

https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_ws_nature-based-solutions-water-management_final-report_2022_en.pdf.pdf

3 types of NATURE-BASED SOLUTIONS

To reflect the intensity of engineering intervention of the NbS in the ecosystem, Eggermont et al. (2015)

proposed to divide NbS in three typologies:

– T1. **None or minimal intervention in ecosystems**.

This type maintains/improves delivery of ecosystem services of preserved ecosystems. This NbS incorporates areas where people live and work in a sustainable way including nature conservation and national parks.

– T2. **Partial interventions in ecosystems**.

This type develops sustainable and multi-functional ecosystems and landscapes that improve delivery of selected ecosystem services. This type of NbS is strongly connected to benefitting from natural systems agriculture and conserving agroecology.

– T3. **Intrusive intervention in ecosystems**.

This type manages ecosystems in intrusive ways and includes full restoration of degraded or polluted areas using grey infrastructures.

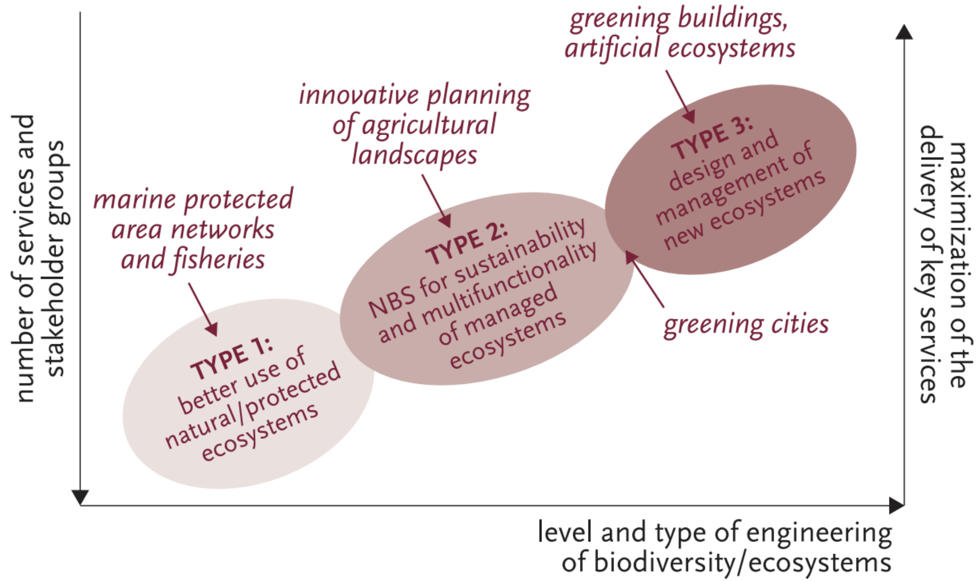


FIGURE 1: Schematic representation of the range of nature-based solutions (NBS) approaches. Three main types of NBS are defined, differing in the level of engineering or management applied to biodiversity and ecosystems (x-axis), and in the number of services to be delivered, the number of stakeholder groups targeted, and the likely level of maximization of the delivery of targeted services (y-axis). Some examples of NBS are located in this schematic representation. Note that the y-axes could be shifted, and that type 3 cannot be viewed as "better" than type 1, the three types being complementary.

Eggermont et al. 2015. https://www.biodiversa.org/898/download

https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_ws_nature-based-solutions-water-management_final-report_2022_en.pdf.pdf

SPATIAL SCALE of NbS

There exist a number of NbSs for water resource management (or water-related NbSs).

They may be divided by the spatial scale of the Nbs.

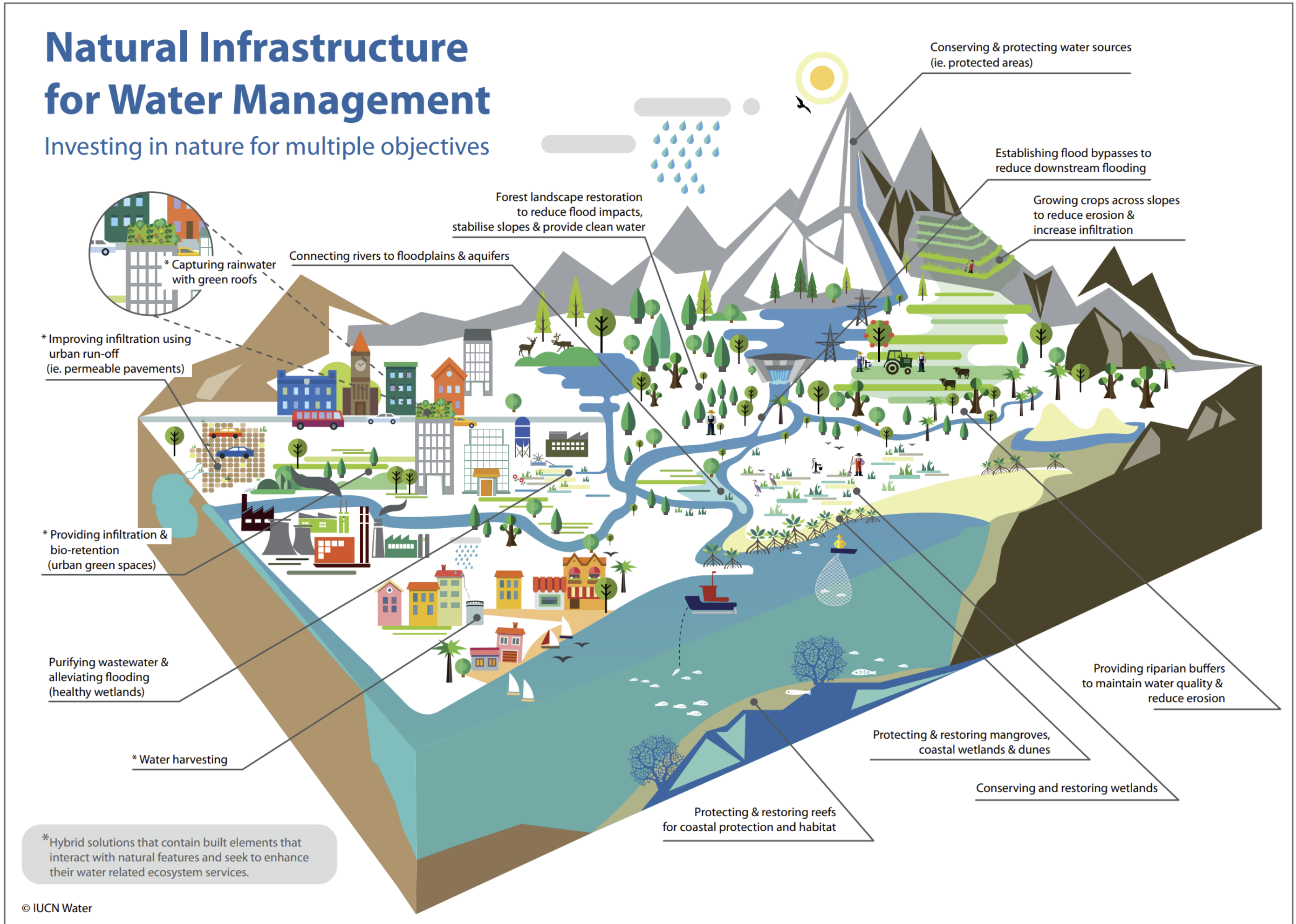
– Field/building scale NbS (*small scale*)

- Urban area/Rural area scale

- Watershed scale (*large scale*)

NO MENTION TO MAR

Nature-based Solutions to address global societal challenges.
Editors: E Cohen-Shacham, G Walters, C Janzen, S Maginnis
https://portals.iucn.org/library/node/46191



Source: IUCN (as part of 'WISE-UP to Climate' project). See http://www.iucn.org/theme/water/our-work/wise-climate

Managed Aquifer Recharge

Intentional recharge of an aquifer

A process to intentionally increase the volume ordinarily stored underground soil surface

Techniques mimicking/enhancing natural processes

(or, Bower (2002): *the main objective of artificial recharge techniques are to increase the available groundwater resources and to improve groundwater quality*)

This recharge is intentional (managed) in order to assure an adequate protection of human health and the environment.

This management makes this recharge different from non intentional recharge (i.e. excess irrigation), which may pose threath to the above.

Managed Aquifer Recharge

Geoengineering schemes

Potential use and objectives:

- Increase groundwater uses;
- Compensate diminishing recharge due to human activities;
- Replenishment against overdrafting;
- Control of subsidence phenomena;
- Combat seawater intrusion;
- Sustain groundwater-dependant ecosystems;
- Improving groundwater quality.

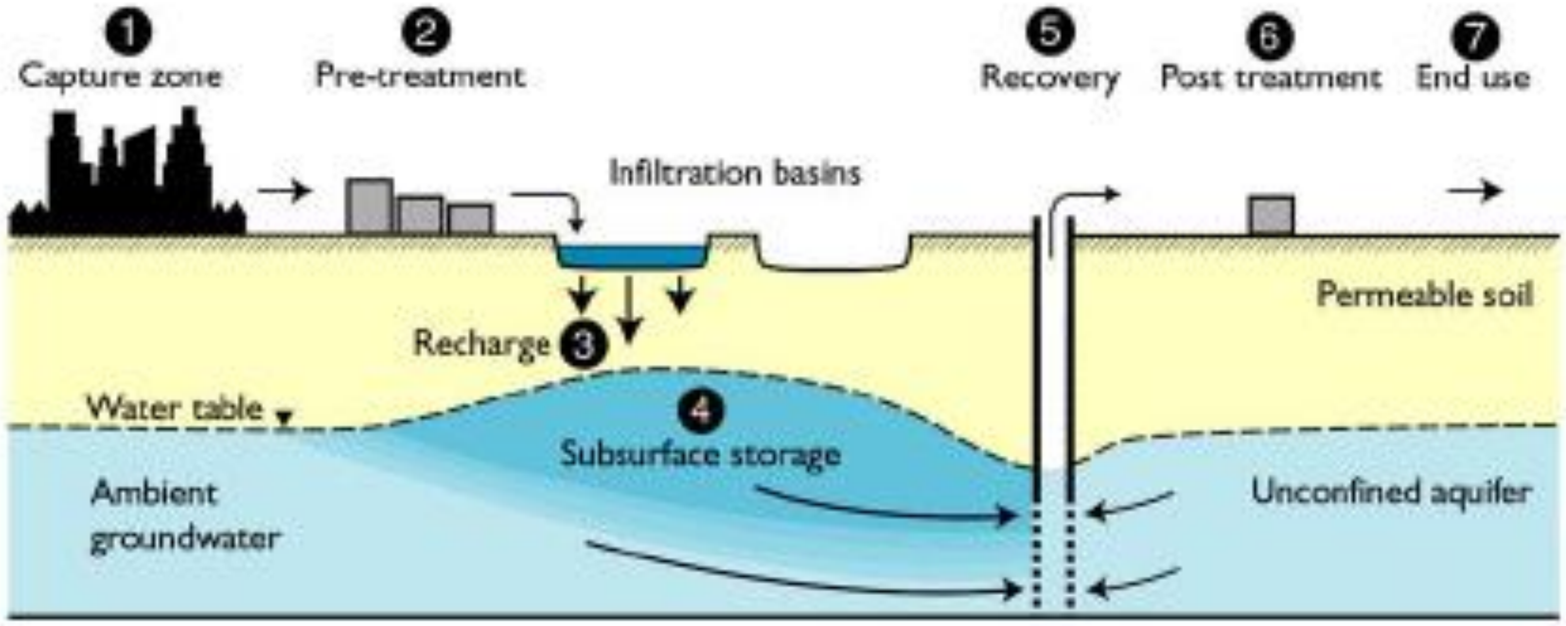
Video resource

Managed Aquifer Recharge (CSIRO – Australia)

https://www.youtube.com/watch?v=9HyeGKYulwo

MAR components

1) Source
2) (if needed) pre-treatment
3) Recharge scheme
4) Aquifer
5) Pumping system
6) Post-treatment
7) Final users



Scientific resource
From: AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGING HEALTH AND ENVIRONMENTAL RISKS (PHASE 2)
Managed Aquifer Recharge
(Natural Resource Management Ministerial Council + Environment Protection and Heritage Council +National Health and Medical Research Council 2009)
https://www.waterquality.gov.au/sites/default/files/documents/water-recycling-guidelines-full-21.pdf

Managed Aquifer Recharge

Sources of water for recharge

Surface water (river, streams, lakes, dams, …)

(partially) treateted wastewater (reclaimed water)

Desalinated water (surplus…)

Groundwater from aquifers other than that to be recharged

Urban runoff

Excess irrigation (incidental)

MAR types

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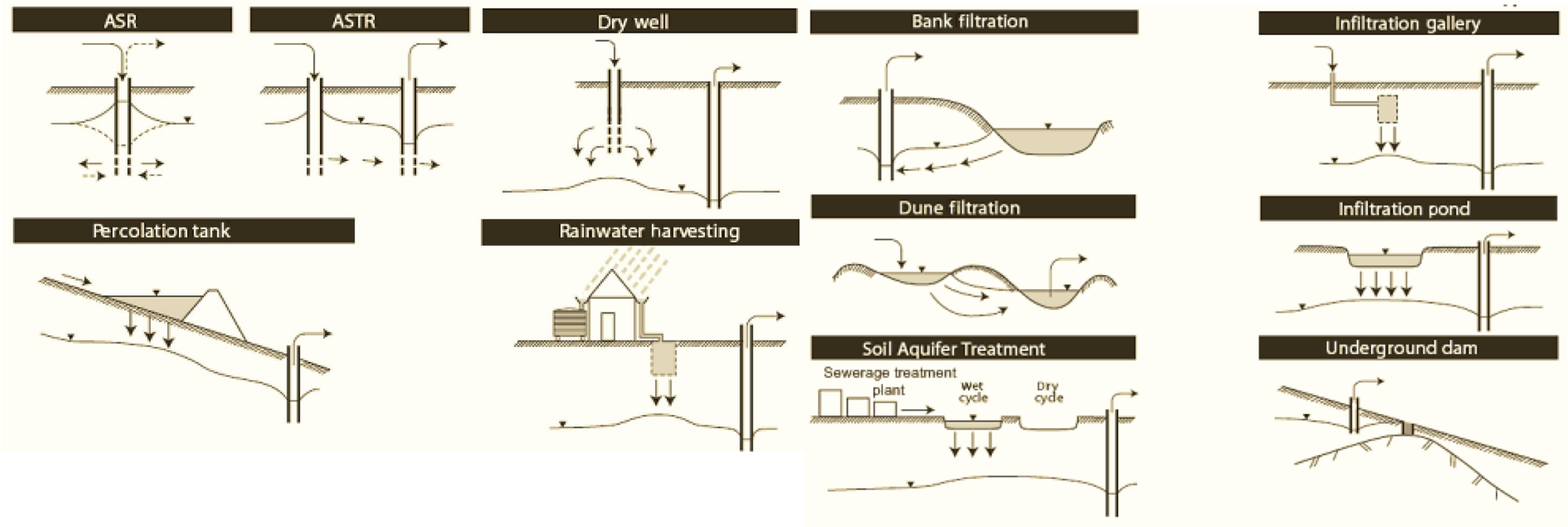

Da: AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGING HEALTH AND ENVIRONMENTAL RISKS (PHASE 2)
Managed Aquifer Recharge
(Natural Resource Management Ministerial Council + Environment Protection and Heritage Council +National Health and Medical Research Council 2009)

Are all MAR types to be assumed as NbS?

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Do MAR systems provide environmental benefits? Net biodiversity gain?

What do we mean by net biodiversity gain?

Supporting habitats and life

Supporting groundwater dependant-ecosystems

Supporting healty soils

MAR type	Engineered	Cost-effective	Biodiversity benefit
Infiltration basin (sw)	Medium	Yes	Direct
ASR/ASTR	Highly	Not always	Indirect
Induced Bank Filtration	Medium/Highly	Yes	Indirect/not always*
Infiltration gallery	Medium	Yes	Indirect
Dune filtration	Low	Yes	Direct
Soil Aquifer Treatment	Highly	Not always	To be evaluated
Underground dam	Highly	Not always	Indirect
Forested Infiltration Areas	Highly	Yes	Direct

* it may modify the river morphology

MAR and NbS

LIFE REWAT Infiltration Basin – Suvereto (Italy)

Up to 2 Mm^3/y infiltration capacity

REWAT sustainable water management in the lower Cornia Valley

Life

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ELSEVIER

Understanding and predicting physical clogging at managed aquifer recharge systems: A field-based modeling approach

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MAR and NbS

Amsterdan dune system (Netherlands)

85 ha using 40 infiltration channels and basins

Infiltration capacity: **55 Mm^3/year**

Objectives: provide drinking water, ecosystem maintenance, combat seawater intrusion

MAR and NbS

Forested Infiltration Areas

VENETO AGRICOLTURA

(Veneto, Italy)

NbS and aquifer recharge

NATURAL WATER RETENTION MEASURES

water-related NbS concept before NbS

Natural Water Retention Measures (NWRM) are multi-functional measures that aim to protect and manage water resources using natural means and processes, therefore building up Green Infrastructure, for example, by restoring ecosystems and changing land use.
NWRM have the potential to provide multiple benefits, including flood risk reduction, water quality improvement, groundwater recharge and habitat improvement.
As such, they can help achieve the goals of key EU policies such as the Water Framework Directive (WFD), the Floods Directive (FD) and Habitats and Birds Directive.

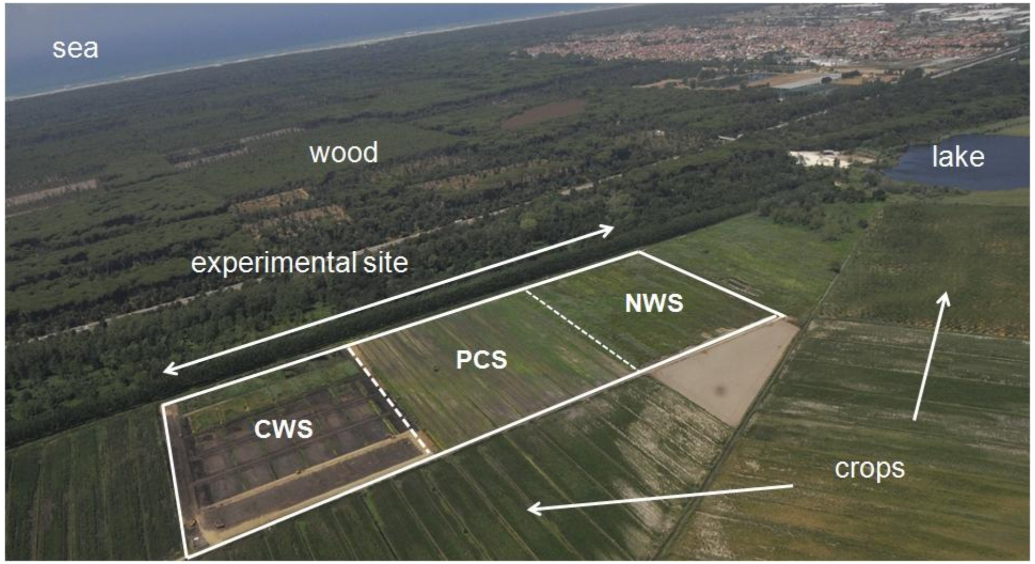
https://www.nwrm.eu/

Table 1. Illustrating the diversity of measures classified as NWRM[1]

Type	Class	Non-exhaustive list of examples
Direct modification in ecosystems	**Hydro-morphology (Rivers, Lakes, Aquifers, connected wetlands)**	Restoration and maintenance of rivers, lakes, aquifers and connected wetlands; Reconnection and restoration of floodplains and disconnected meanders, elimination of riverbank protection…
Change & adaptation in land-use & water management practice	**Agriculture**	Restoration and maintenance of meadows, pastures, buffer strips and shelter belts; soil conservation practices (crop rotation, intercropping, conservation tillage...), green cover, mulching…
	Forestry and Pastures	Afforestation of upstream catchments; targeted planting for "catching" precipitation; Continuous cover forestry; maintenance of riparian buffers; urban forests; Land-use conversion for water quality improvements…
	Urban development	Green roofs, rainwater harvesting, permeable paving, swales, soakaways, infiltration trenches, rain gardens, detention basins, retention ponds, urban channel restoration…

NWRM and NbS

Paludiculture/Constructed wetlands (Vecchiano – Italy)



NWS : Natural Wetland System

- Re-wetted area
- Spontaneous vegetation

CWS : Constructed Wetland System

- Engineered water flow
- Spontaneous vegetation (helophytes)

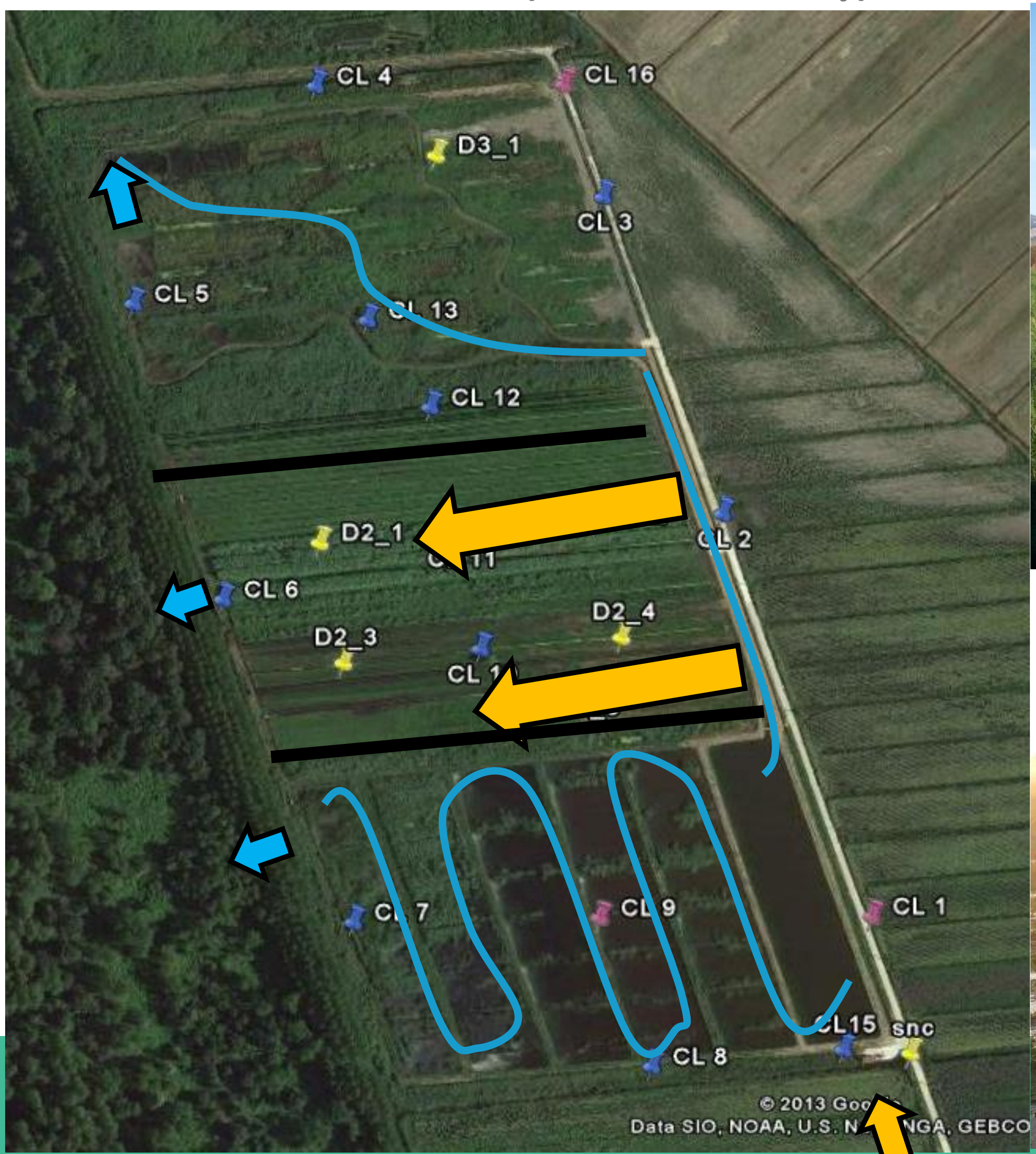
PCS : PaludiCulture System

- Grass and wood species watered with drainage water

Rural Sustainable Drainage Systems (RSuDS) https://assets.publishing.service.gov.uk/media/5a7b956b40f0b645ba3c541b/scho0612buwh-e-e.pdf

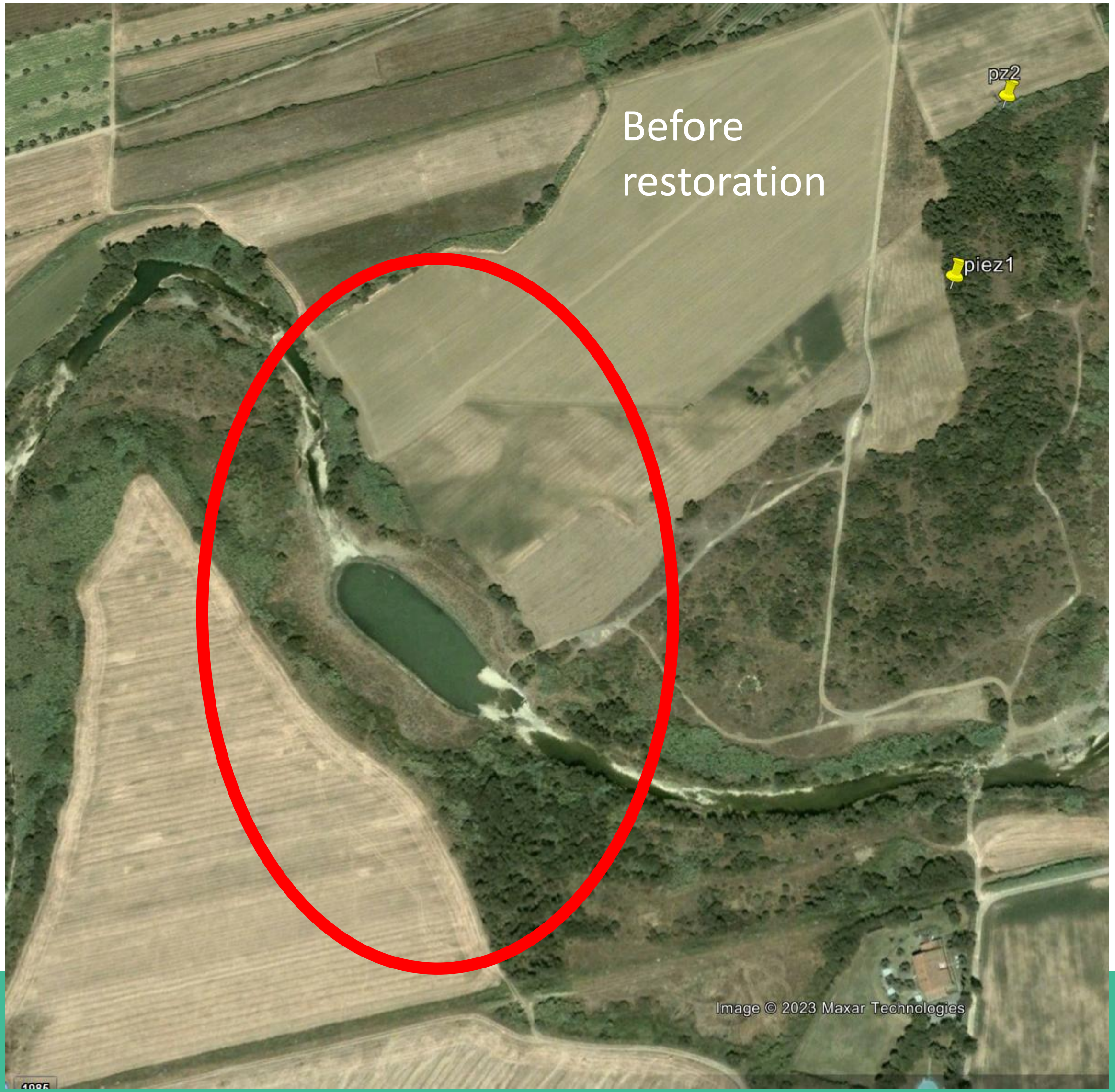
NWRM and NbS

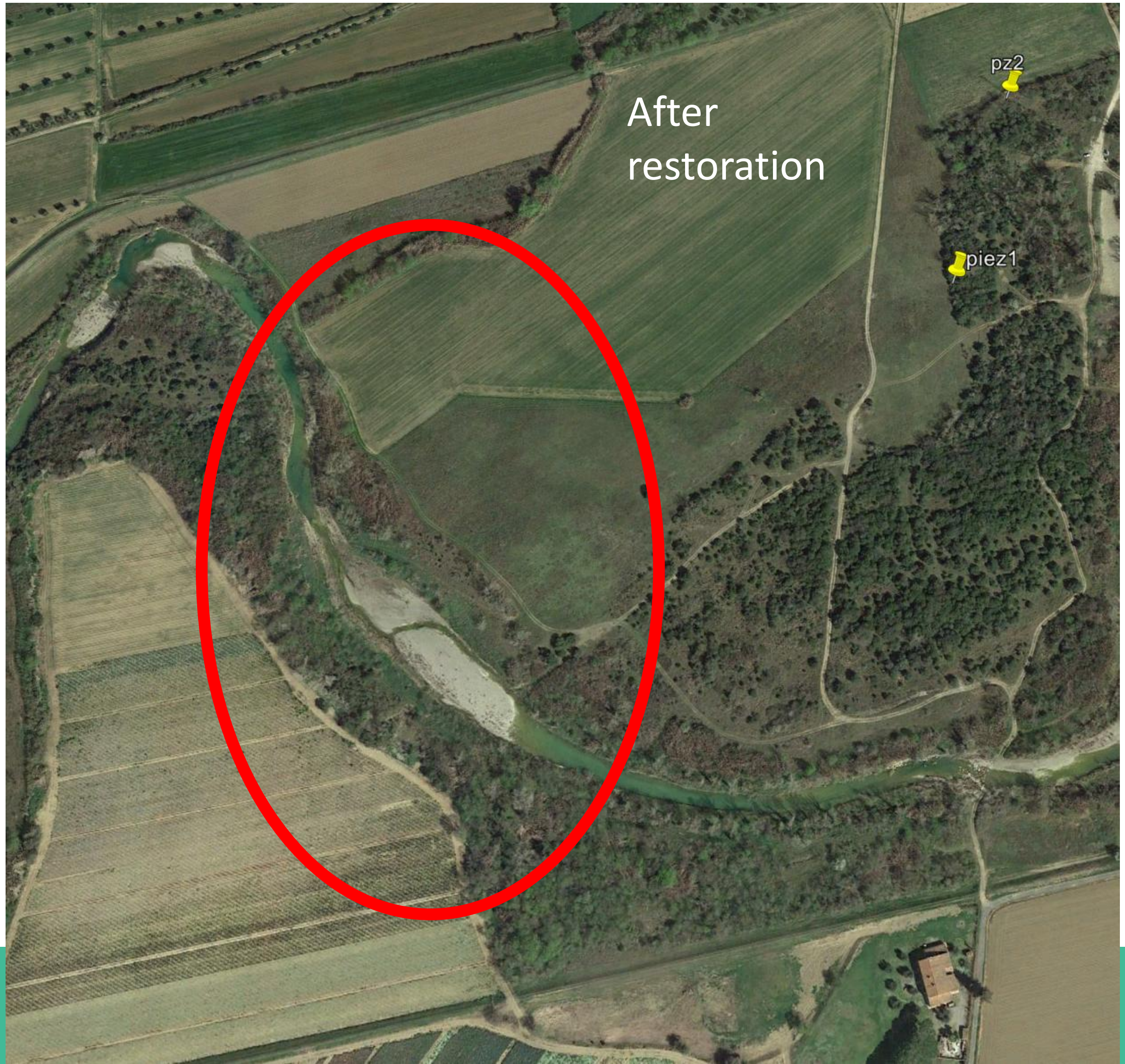
Paludiculture/Constructed wetlands (Vecchiano – Italy)



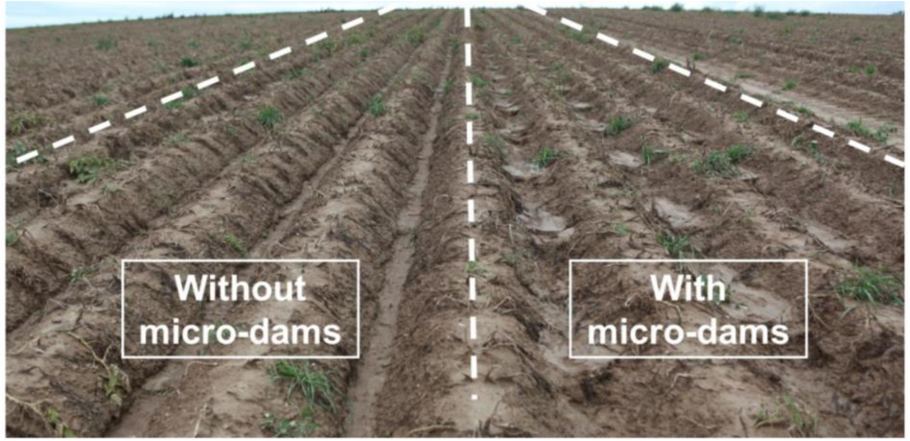
NWRM and NbS

River Cornia restoration - Italy





NWRM and NbS



In-furrow micro-dams

Olivier, C & Goffart, J.P. & Baets, Dirk & Xanthoulis, Dimitri & Fonder, Nat & Lognay, Georges & Barthélemy, J & Lebrun, Pierre. (2014). USE OF MICRO-DAMS IN POTATO FURROWS TO REDUCE EROSION AND RUNOFF AND MINIMISE SURFACE WATER CONTAMINATION THROUGH PESTICIDES. Communications in agricultural and applied biological sciences. 79. 513-24.c

https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_ws_nature-based-solutions-water-management_final-report_2022_en.pdf.pdf

AG-MAR???

- Increase infiltration
- Favour water storage in the soil

Minimum/no-tillage

Infiltration fields

Sustainable Drainage Systems (SuDS)

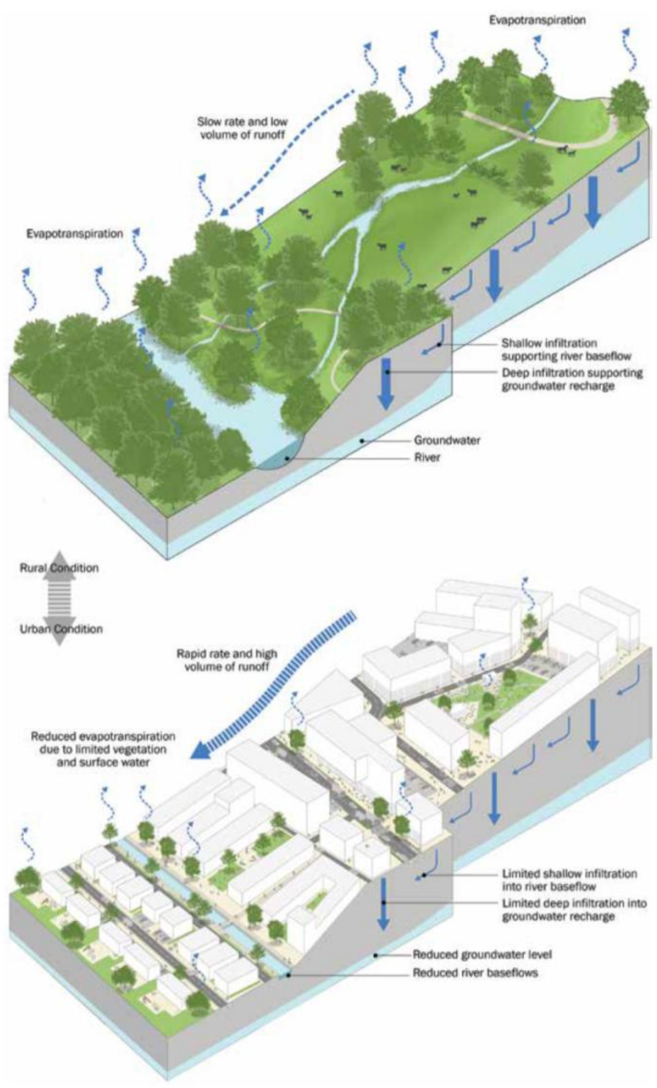
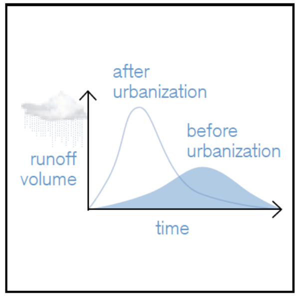


Figure 1.2 Impacts of urbanisation on a catchment



stormwater discharge before and after urbanization

WrGI/SuDS/LID

Infrastructures for rainfall management micking natural processes to perform hard engineering drainage processes

The SuDS Manual
Woods Ballard, B, Wilson, Udale-Clarke, H, Illman, S, Scott, T, Ashley, R, Kellagher, R
CIRIA 2015

+ more impervious surfaces=

+ runoff=

+++ flood
+++ water pollution
+++ erosion
+++ higher temperatures

Alteration of the hydrological cycle

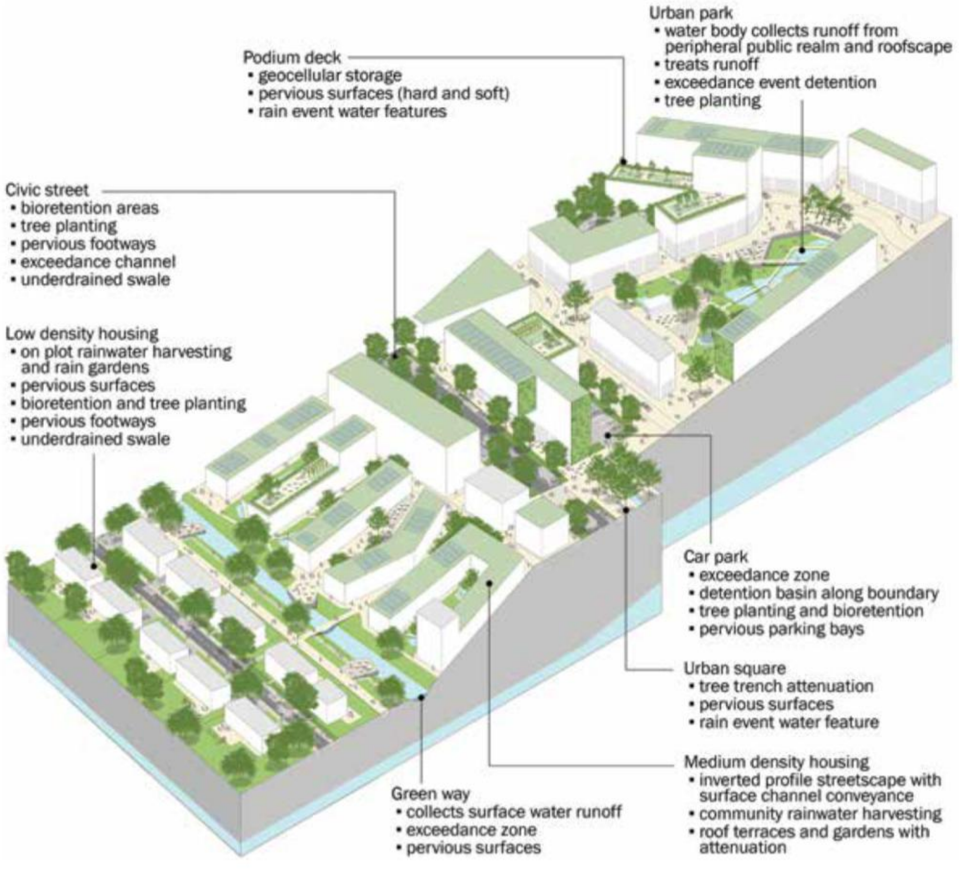


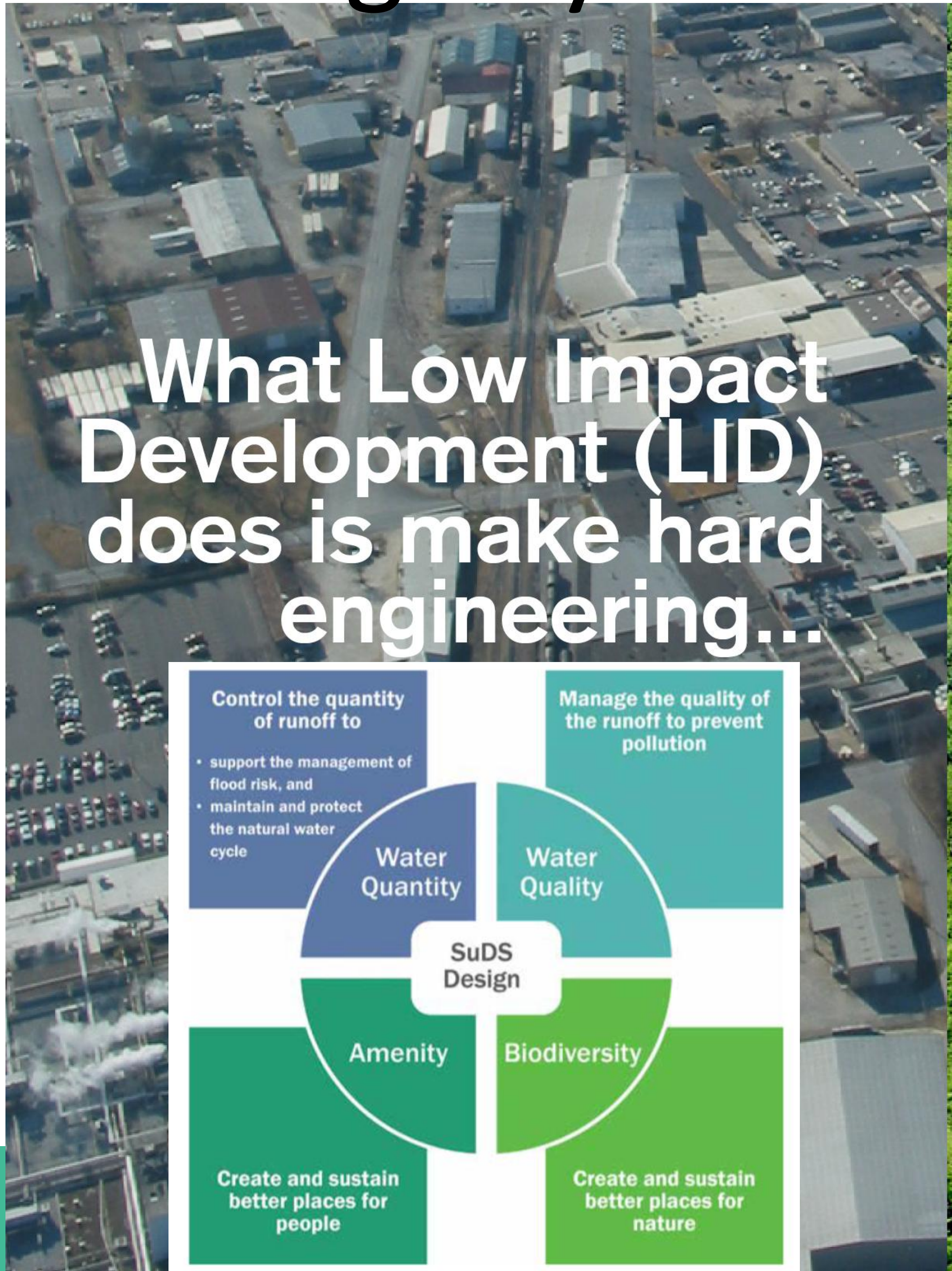
Figure 1.6 Examples of commonly used SuDS for different development types

Sustainable Drainage Systems (SuDS)

HARD ENGINEERING

Vs.

SOFT ENGINEERING



Low Impact Development
A design manual for urban areas
UACD, 2010

Sustainable Drainage Systems (SuDS)

Sustainable Drainage Systems (SuDS)

Approach SuDS/LID

SuDS design should be based on the following, as much as possible, in order to maximise benefits:

- use surface water runoff as a resource
- manage rainwater close to where it falls (at source)
- manage runoff on the surface (above ground)
- allow rainwater to soak into the ground (infiltration)
- promote evapotranspiration
- slow and store runoff to mimic natural runoff rates and volumes
- reduce contamination of runoff through pollution prevention and by controlling the runoff at source
- treat runoff to reduce the risk of urban contaminants causing environmental pollution.

Depending on the characteristics of the site and local requirements, these may be used in combination and to varying degrees.

SuDS/LID
Functions of components

Rainwater harvesting systems – components that capture rainwater and facilitate its use within the building or local environment.

Pervious surfacing systems – structural surfaces that allow water to penetrate, thus reducing the proportion of runoff that is conveyed to the drainage system, eg green roofs, pervious paving. Many of these systems also include some subsurface storage and treatment.

Infiltration systems – components that facilitate the infiltration of water into the ground. These often include temporary storage zones to accommodate runoff volumes before slow release to the soil.

Conveyance systems – components that convey flows to downstream storage systems. Where possible, these systems also provide flow and volume control and treatment, eg swales.

Storage systems – components that control the flows and, where possible, volumes of runoff being discharged from the site, by storing water and releasing it slowly (attenuation). These systems may also provide further treatment of the runoff, eg ponds, wetlands and detention basins.

Treatment systems – components that remove or facilitate the degradation of contaminants present in the runoff.

The SuDS Manual
Woods Ballard, B, Wilson, Udale-Clarke, H, Illman, S, Scott, T, Ashley, R, Kellagher, R
CIRIA 2015

8 CRITERIA FOR DESIGNING NbS

IUCN

IUCN Global Standard for Nature-based Solutions

A user-friendly framework for the verification, design and scaling up of NbS

This Standard aims to equip users with a robust framework for designing and verifying NbS that yield the outcomes desired, in solving one or several societal challenge(s).

Based on the feedback of actual and potential NbS users, it has been developed as a facilitative Standard, purposefully avoiding a rigid normative framing with fixed, definitive thresholds of what NbS ought to achieve.

Rather the Standard is designed to support users to apply, learn and continuously strengthen and improve the effectiveness, sustainability and adaptability of their NbS interventions.

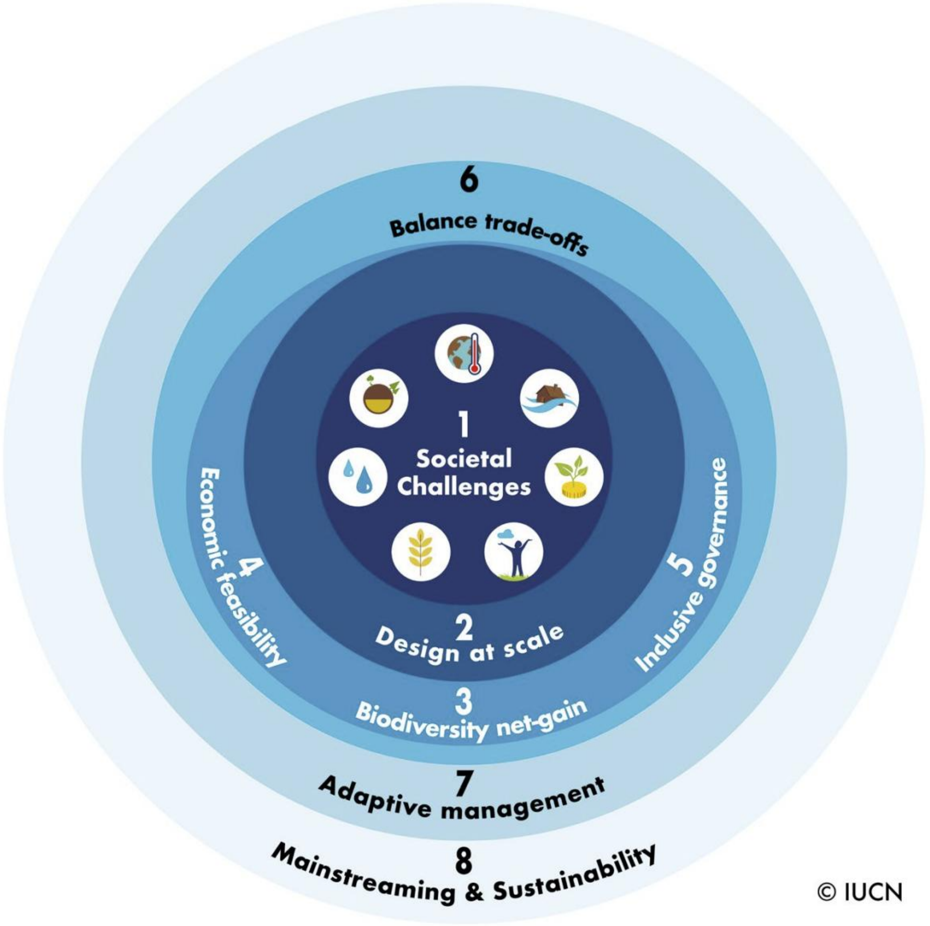


Figure 2 The eight Criteria that make up the IUCN Global Standard for NbS are all interconnected.

https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf

CO-DESIGN of NbS

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This criterion requires that NbS acknowledge, involve and respond to the concerns of a variety of stakeholders, especially rights holders.

Good governance arrangements are proven to not only reduce an intervention's sustainability risks, but also to enhance its social 'license to operate'.

Conversely inadequate governance provision for otherwise well-intended actions can adversely affect the legitimacy of benefit and cost sharing arrangements.

At a minimum, NbS must adhere to and align with the prevailing legal and regulatory provisions, being clear on where legal responsibilities and liabilities lie.

However, as often is the case with natural resources, basic compliance will need to be complemented with ancillary mechanisms that actively engage and empower local communities and other affected stakeholders.

https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf

Inclusive governance

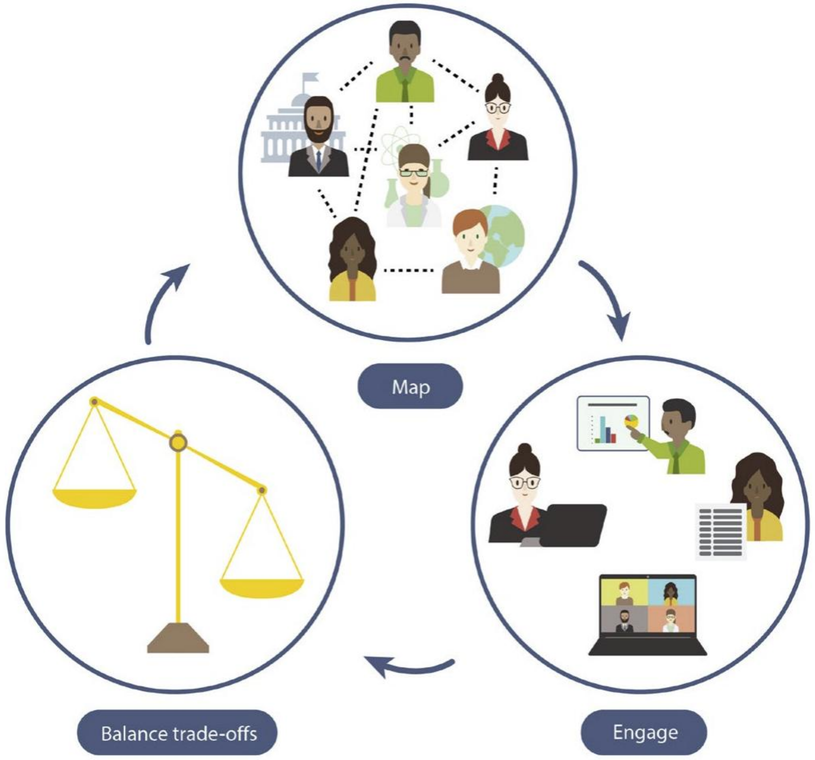

Figure 12 The immediate and long-term success of NbS depends on inclusive, transparent processes of engagement, management and leadership.© IUCN

FINAL REMARKS

Water-related NbSs address water management challenges providing environmental benefits (i.e. improving water quality and quantity) and providing biodiversity net gain.

We usually let Managed Aquifer Recharge fall into NbS domain.

But when including the **net biodiversity benefit**, this inclusion may not be so clear.

Need an effort in providing more evidences about the biodiversity benefit we gain by increasing recharge.

Natural water retention measures or **river restoration techniques** may qualify as relevant (landscape) means to increase groundwater recharge along with biodiversity gains.

SuDS should be carefully look at as a mean for recharge. While their aesthetic and residual flood risk reduction value is noteworthy – *what about infiltration of urban polluted water*?

Questions?